The measurement of physical activity and sedentary behaviour in older adults residing in care homes

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Abstract

Introduction: Evidence suggests engagement in physical activity (PA) is beneficial for older care home (CH) residents. However, few studies measure PA or sedentary behaviour; likely due to the unique challenges surrounding measurement of these behaviours in this population. Thus, the overarching aim of this thesis was to identify and evaluate an appropriate method of assessing PA and sedentary behaviour (i.e. PA behaviour) in CH residents.

Methods: Reviews were undertaken to**:** a) determine which method was best suited to assessing PA behaviour in a CH population and b) synthesise existing literature detailing accelerometer use in CH residents. Experimental work explored the impact of methodological decisions on the validity and reliability of estimates of PA behaviour in older adults, including CH residents. A phased, iterative approach was adopted to develop and refine an accelerometer data collection protocol for use with CH residents. The feasibility and acceptability of this protocol was then evaluated within the context of a cluster randomised control trial. Accelerometer data collected throughout this thesis was pooled and the levels and patterns of PA behaviour in CH residents were described.

Results: Accelerometers have potential application in a CH setting. The validity of energy expenditure estimates were better with a hip- compared to wrist-worn accelerometer. Classification agreement of PA behaviour was better for vector magnitude compared to vertical axis accelerometer counts. Wearing an accelerometer for eight hours on any four days was sufficient to achieve reliable estimates of PA behaviour. Compliance rates improved following the refinement of the accelerometer data collection protocol. CH residents spent the majority of their time sedentary and the little PA they did engage in was typically of low intensity.

Conclusions: Accelerometers can be used to collect valid and reliable PA behaviour data in older CH residents, though it appears that a tailored data collection protocol is key.

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List of Abbreviations

ADLs - Activities of Daily Living

AES - Apathy Evaluation Scale

AL - assisted living

APAFOP - Assessment of Physical Activity in Frail Older People

AUECR – Academic Unit of Elderly Care and Rehabilitation

BHFNC - British Heart Foundation National Centre

BI - Barthel Index

BIHR - Bradford Institute for Health Research

BMI - body mass index

CCI - Charlson Comorbidity Index

CH – care home

CMAI - Cohen-Mansfield Agitation Inventory

CMAI-SF - Cohen-Mansfield Agitation Inventory Short From

CMO - Chief Medical Officer

CO_2 - carbon dioxide

CPM - counts per minute

CQC - Care Quality Commission

cRCT - cluster randomised control trial

CRF – cardio-respiratory fitness

CRN - clinical research network

CSDD - Cornell Scale for Depression in Dementia

DLW - doubly labelled water

DO - direct observation

ECG - electrocardiogram

EE - energy expenditure

ENRICH - Enabling Research in Care Homes

FAC - Functional Ambulation Category

GDS - Geriatric Depression Scale

HADS - Hospital Anxiety and Depression Scale

Hz - Hertz

ICC - intraclass correlations

IQR - inter-quartile range

LASA - Longitudinal Ageing Study Amsterdam

LFE - low-frequency extension

LoA - limits of agreement

LTC - long-term care

MCA - Mental Capacity Act

MEMS - micro-electromechanical system

MET - multiples of resting energy expenditure

MMSE - Mini Mental State Examination

MOST - Measuring Older adults' Sedentary Time

MOST - Multiphase Optimisation Strategy

MRC - Medical Research Council

NC - nominated consultee

NHS - National Health Service

NICE - National Institute for Health and Care Excellence

NIHR - National Institute for Health Research

O_2 - oxygen

PA - physical activity

PAG - physical activity guidelines

PAMRC - Physical Activity and Mobility in Residential Care scale

PAQE - Physical Activity Questionnaire for the Elderly

PAS-LTC - Physical Activity Survey for Long-Term Care

PC - personal consultee

PV - predictive value

QOL - quality of life

RCT - randomised controlled trial

REACH - Research Exploring physical Activity in Care Homes

REC - Research Ethics Committee

RMR - resting metabolic rate

SD - standard deviation

SE - standard error

SF-12 - 12-item short-from health survey

SPPB - Short Physical Performance Battery

UK - United Kingdom

VA - vertical axis

VM - vector magnitude

VO_2 - oxygen uptake

WHO - World Health Organisation

WS - workstreams

Chapter 1 Overview and introduction to the thesis

1.1 Introduction to the research topic

Over the previous century there has been a shift in the demographics of the world's population (World Health Organisation (WHO), 2011). There has been a particular expansion of the 85 years and above age group (i.e. the oldest old) and this trend is likely to continue as longevity in later life improves (Age UK, 2013). In the United Kingdom (UK), the number of individuals belonging to this age group is expected to more than double between 2014 and 2034 to 3.2 million (Office for National Statistics, 2011).

Whilst population ageing should be celebrated as one of humanity's major achievements, the fact that increases in life expectancy are typically mirrored by extended periods of morbidity and disability cannot be overlooked (Prince et al., 2015a). Many disabling conditions, including cardiovascular diseases, musculoskeletal diseases and mental and neurological disorders, are age-related (Prince et al., 2015a; Christensen et al., 2009). Moreover, the incidence of multi-morbidity increases sharply with age (Kirchberger et al., 2012; Caughey et al., 2010). As a result, many older adults will experience complex and interacting health needs and will ultimately require some form of support in their later years (WHO, 2011). Although policy and service developments have emphasised alternatives to long-term care (LTC) (Rodrigues et al., 2012), recent estimates suggest that around one in four older people will spend some time in a care home in their last year of life (Forder and Fernandez, 2011). Evidently, the need for such care will persist (Harwood, 2004).

Residents of care homes are amongst the frailest individuals in the UK population, distinguishable from community-dwelling older adults of the same age because of their physical disability, multi-morbidity, dependency on others and cognitive impairment (Gordon et al., 2014). For these individuals, their dependency and functional impairments will likely compound health difficulties by directly affecting their physical and psychological health and reduce opportunities to participate in social activities. Social isolation in turn has a negative impact on mood and self-esteem which can further adversely affect physical health (National Institute for Health and Care Excellence (NICE), 2008). Furthermore, the increasing health requirements of this expanding client group places considerable burden on the UK National Health Service (NHS) (Gordon et al., 2014). Still, frailty may be considered a dynamic process and whilst it is likely that residents become frailer and are at higher risk of worsening disability, falls and admission to hospital, this deterioration is not immutable and there is scope to intervene (Clegg et al., 2013). Accordingly, it is important to explore factors which may help slow the progression in functional decline and also maintain or improve quality of life (QOL) in this population.

One factor known to have a positive impact on the ageing process and to contribute to the maintenance of health with rising age is physical activity (PA) (Myint and Welch, 2012). There is an established body of evidence concerning the health and social benefits of engaging in PA for older adults (Physical Activity Guidelines (PAG) Advisory Committee, 2018; Department of Health, 2011). Moreover, evidence from interventional studies supporting the implementation of PA as a preventative and therapeutic intervention for residents of care homes is emerging (Jansen et al., 2015; Crocker et al., 2013a). Specifically, engagement in PA has been shown to have favourable effects in terms of physical function (Crocker et al., 2013b; Weening-Dijksterhuis et al., 2011; Chin A Paw et al., 2008) and social engagement (Mendes de Leon, 2005). However, it is notable that many of the interventions implemented to date have been short-term and dependent on external resources (e.g. therapists). Moreover, those with complex needs were often excluded and gains tended not to be sustained (Crocker et al., 2013a).

In addition, there is growing evidence of the detrimental effect sedentary behaviour may have, independently of engagement in PA, on a number of parameters related to health (de Rezende et al., 2014), including cardiovascular risk (Same et al., 2015), physical function (Sardinha et al., 2015; Gennuso et al., 2013) and QOL (O'Neill and Dogra, 2016; Meneguci et al., 2015). With respect to care home residents specifically, engagement in high levels of sedentary behaviour may lead to increased incidence of pressure sores, contractures, cardiovascular deconditioning, urinary tract infections and loss of independence (Butler et al., 1998).

Given that observational research suggests older adults residing in care homes spend the majority of their time sedentary (Sackley et al., 2006), it may be surmised that a recommendation to reduce sedentary time would be well placed. This is supported by guidance for interpreting the UK PA guidelines which states that frail older adults should strive to engage in some PA every day and minimise the amount of time they spend being sedentary for extended periods (British Heart Foundation National Centre (BHFNC), 2012). Nevertheless, there are a lack of interventions aimed at increasing routine PA and reducing the time care home residents spend sedentary. In order to develop such interventions a thorough understanding of the levels and patterns of PA and sedentary behaviour in this population is needed. Yet to date, there has been limited research into the levels and patterns of PA and sedentary behaviour in older care home residents (Barber et al., 2015; Chin A Paw et al., 2006). This may be attributed to the fact that a consensus on the best method to assess PA and sedentary behaviour in older care home residents is yet to be reached.

1.2 Thesis aims and objectives

The overarching aim of this thesis is to identify an appropriate method of assessing PA and sedentary behaviour in older adults residing in care homes.

In order to achieve this aim, seven specific objectives are outlined:

i. To review a sample of PA and sedentary behaviour assessment methods (identified through a scoping review of the literature, as having potential application in a care home population) in order to determine which method is most appropriate for simultaneously assessing PA and sedentary behaviour in a care home population (**Chapter 2**).
ii. To synthesise current literature detailing accelerometer use in older adults residing in care homes in order to gauge what literature already exists and identify gaps in the knowledge base (**Chapter 3**).
iii. To review existing research investigating methodological issues associated with accelerometer use, with a specific focus on studies involving older adults (**Chapter 4**).
iv. To explore the impact of key methodological decisions on accelerometer-determined estimates of PA and sedentary behaviour in older care home residents (**Chapter 6**).
v. To explore the practical issues associated with using accelerometers to measure PA and sedentary behaviour in field-based research with older care home residents and develop a data collection protocol, which is both appropriate to the population and context-specific (**Chapter 7**).
vi. To evaluate the accelerometer data collection protocol developed in a larger, independent sample of care home residents within the context of a cluster randomised control trial (cRCT) (**Chapter 8**).
vii. To describe, through data collected throughout this thesis, the levels and patterns of PA and sedentary behaviour in older care home residents (**Chapter 9**).

1.3 Structure of the thesis

This thesis is comprised of ten chapters. Whilst each chapter represents a stand-alone piece of work, they do flow on from one another (Figure 1.1). This chapter (**Chapter 1**) provides an introduction to the research topic and outlines the overarching aim and specific objectives of the thesis. As this thesis was completed alongside a larger programme of research, an overview of this programme, along with details regarding my role in its delivery, are also provided.

Chapter 2 sets the context and provides the theoretical underpinning for this doctoral work. It is split into two sections. Part one defines and explains the concepts of ageing, PA and sedentary behaviour before going on to describe the importance of PA and the health consequences of sedentary behaviour in older adults, defined in this thesis as those aged over 65 years. Part two reviews a sample of PA and sedentary behaviour assessment methods, identified through a scoping review of the literature, as having potential application in a care home population.

Chapter 3 presents a systematic review, conducted to identify and synthesise existing literature detailing accelerometer use in older adults residing in care homes. The specific objectives of the review were to: report on the accelerometer data collection and processing methods utilised; identify which outcome(s) derived from accelerometers are most appropriate for describing PA and sedentary behaviour in older care home residents and finally to describe the PA and sedentary behaviour of older care home residents. The findings from this review informed the remaining studies presented within this thesis.

Chapter 4 reviews the existing literature regarding the key methodological decisions associated with the use of accelerometers in order to ascertain whether there is any empirical evidence to support particular decisions in older care home residents.

Chapter 5 provides an overview of the common methods and procedures employed in the original research studies undertaken by the researcher presented in Chapters 6 – 9.

Chapter 6 explores the impact of key methodological decisions on estimates of PA and sedentary behaviour in older adults (including those residing in a care home). The chapter is comprised of three separate studies, each with a different objective and distinct methodology. Briefly, ***Study 1*** explores the impact of three decisions on the criterion validity of estimates of energy expenditure (EE) in a population of community-dwelling older adults. The three decisions considered are: the filter used to process the raw acceleration data, the count value considered and accelerometer wear location. ***Study 2*** examines the impact of the count value considered and epoch length on the criterion validity of estimates of PA and sedentary time in care home residents. Finally, in ***Study 3*** a pragmatic approach is adopted in an effort to identify the optimal wear time criteria required to achieve reliable estimates of PA and sedentary behaviour in older care home residents.

Chapters 7 and 8 describe the process of using accelerometers with older care home residents in field-based research. Specifically, **Chapter 7** sought to explore the practical issues associated with using accelerometers in this population and ultimately adopt an iterative approach to the development of an accelerometer data collection protocol, which is both appropriate to the population and context-specific. The provisional protocol developed was then evaluated with a larger, independent sample of care home residents within the context of a cluster randomised control trial (cRCT) in **Chapter 8**.

It became apparent in Chapter 3 that few studies conducted with care home residents have reported estimates of time spent engaging in different intensities of PA and sedentary behaviour. Thus, the collection of accelerometer data in Chapters 6 – 8 offered an opportunity to address this notable gap in the literature. The data were pooled to form a larger dataset in **Chapter 9** with the intention of describing the accelerometer-determined levels and patterns of PA and sedentary behaviour in a large sample of care home residents.

Chapter 10 provides an overall discussion and critical reflection of the work presented in this thesis including: a summary of key findings; the implications of the key findings; challenges with conducting research in a care home setting; a review of the limitations of the research conducted and finally directions for future research.

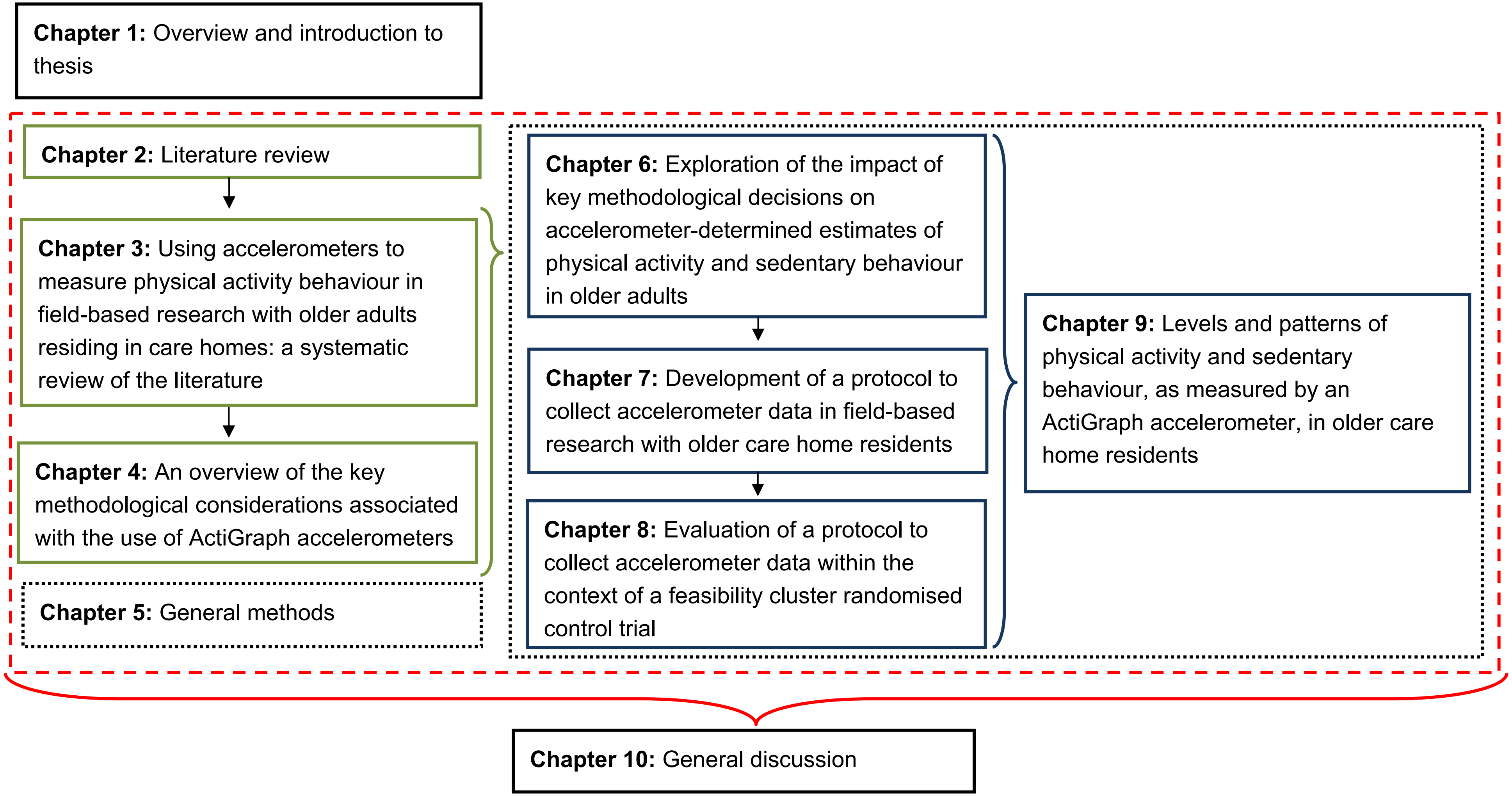


Figure 1.1 Overview of the structure of the thesis.

1.4 Role of the researcher

For the duration of the PhD, I, Jennifer Airlie, was employed as a research assistant and latterly as a research fellow within the Academic Unit of Elderly Care and Rehabilitation (AUECR), based at the Bradford Institute for Health Research (BIHR). I was part of the research team working on a five-year National Institute for Health Research (NIHR) funded research programme titled **R**esearch **E**xploring physical **A**ctivity in **C**are **H**omes (REACH). A brief overview of the REACH programme and more details regarding my role in its delivery are provided below in **section 1.5**.

As will become evident, I had a prominent role within the delivery of REACH and it was because of this, that I identified additional research questions which I felt were not being directly addressed as part of the existing programme of work. As a result, these questions formed the basis of this thesis. I formulated specific aims (outlined above in **section 1.2**) and associated objectives which allowed me to answer these questions. My role within the REACH research team offered a great opportunity as I was able to incorporate any additional data collection relating to the aims and objectives of this thesis to what was originally planned. Consequently, a large proportion of the data presented in the data collection chapters which follow (Chapters 6 - 9), was collected as part of the REACH programme. Again, it will be made clear in **section 1.5** which data collected as part of REACH are presented in each of the separate studies within this thesis.

1.5 Research Exploring Physical Activity in Care Homes (REACH): programme overview and my role

1.5.1 Programme overview

The overarching aim of REACH was to develop strategies to increase the time care home residents spend engaging in PA and reduce the time they spend sedentary with the ultimate intention of improving their physical and psychological health and social well-being. The REACH programme comprised five distinct, yet overlapping workstreams (WS) (Figure 1.2). Briefly, the aim of the first WS was to gain an understanding, through the use of ethnographic fieldwork and interviews with key stakeholders (i.e. residents, staff and relatives), of the contextual and organisational factors that influence residents' engagement in PA. WS 2 sought clarification around the appropriateness of a range of proposed outcome measures to assess PA, mobility, QOL and mood in care home residents. The purpose of WS 3 was to use knowledge gleaned from the ethnographic observations and interviews conducted in WS 1 to develop, through the process of intervention mapping, an intervention and associated implementation process which would encourage residents to engage in more PA and spend less time sedentary. Elements of the proposed intervention and implementation process were then refined and tested in WS 4 using an action research approach. The fifth and final WS of the REACH programme was a feasibility trial, designed to explore the practicality and acceptability of implementing a large-scale cRCT comparing the REACH intervention plus usual care to usual care alone in UK care homes.

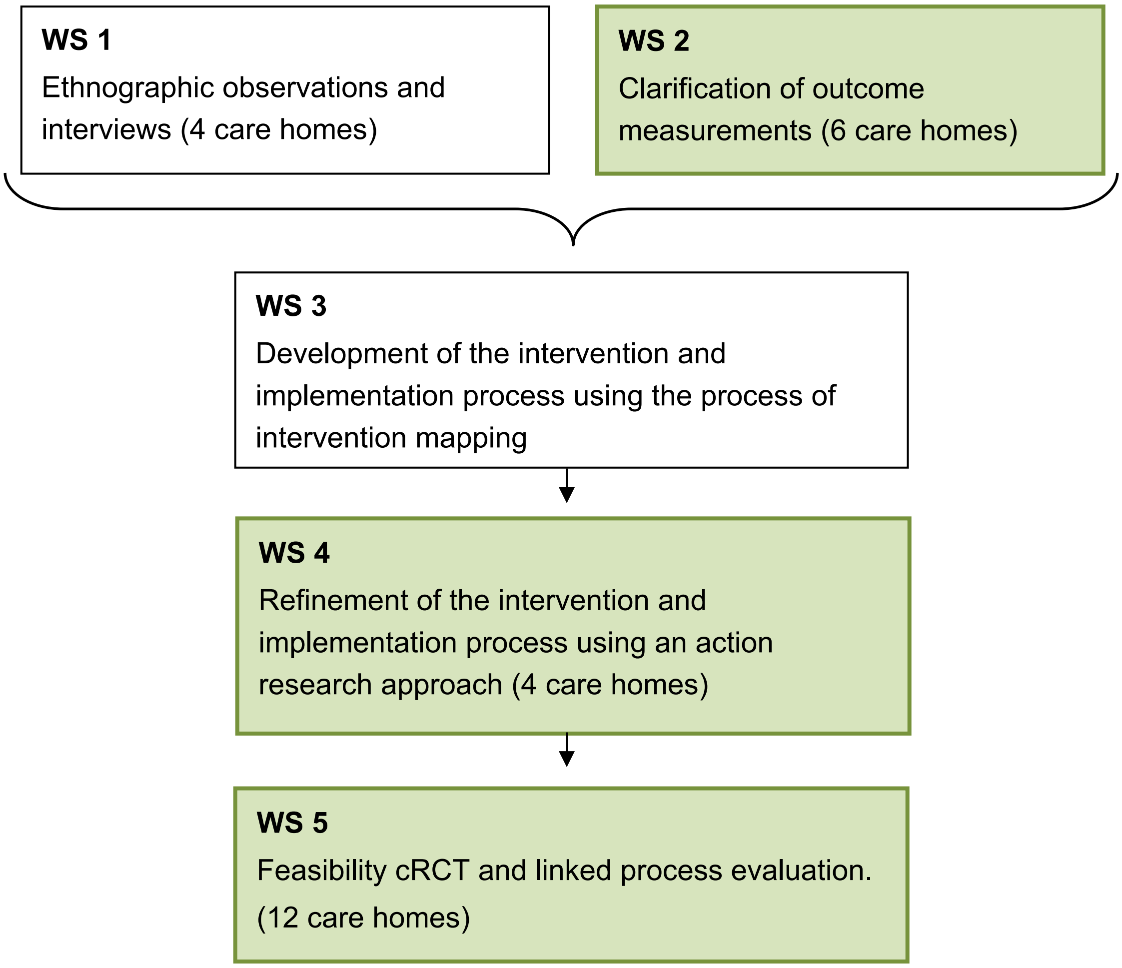


Figure 1.2 Overview of the REACH research programme. Data collected as part of WS 2, WS 4 and WS 5 (highlighted in green) are presented in this thesis.

1.5.2 My role

My role within the research team was to provide expertise in PA, exercise and measurement science. I was therefore integral to the delivery of each of the WSs outlined above. In addition to my consistent presence and input at researcher meetings for each of the five WSs, I also attended and actively contributed to meetings held with the Programme Management Group (PMG) and Programme Steering Group (PSG). I was heavily involved in putting together the ethics applications, for WS 2, WS 4 and WS 5 as I helped write the protocols and accompanying materials (i.e. participant information sheets, consent forms etc.). With the support of colleagues, I led the implementation of WS 2 and thus was responsible for the recruitment of residents; the collection and appropriate storage of data; data analysis and authoring a report detailing the work completed. As my role within the research team evolved during the PhD, I went on to lead the data collection pertaining to WS 4 and WS 5. This required me to train, co-ordinate and manage research assistants to ensure data was collected in an appropriate and timely manner. As part of this, I developed protocols and produced materials specific to the accelerometer data collection to supplement the researcher training and to support data collection (e.g. activity logs and “how to guides” for care home staff). With regards to the accelerometer data collection, I was solely responsible for ensuring these were initialised correctly; tracking the devices; downloading and processing the data and finally, the appropriate storage and subsequent transfer of the data.

Chapter 2 Literature Review

2.i. Preface

The literature reviewed below provides the context and theoretical underpinning for the thesis. The chapter is split into two sections. Section one defines and explains the concepts of ageing, PA and sedentary behaviour before going on to describe the importance of PA and the health consequences of sedentary behaviour in older adults, defined in this thesis as those aged over 65 years. Given the conceptualisation of sedentary behaviour as a distinct, albeit, related construct to PA, Section two reviews the literature regarding the measurement of PA and sedentary behaviour in older adults. Still, given the primary focus of this doctoral work is on the identification of an appropriate method to assess PA in a care home population, a more detailed review of PA measures is presented.

2.1 Section one: ageing and physical activity behaviour

2.1.1 Ageing

Our understanding of the aetiology of ageing is constantly evolving as research progresses and new information becomes available. Hence, numerous theories of ageing have been posited (Medvedev, 1990). Whilst a thorough discussion of the various theories of ageing is outside the scope of this thesis, based on the current evidence base, it may be surmised that an accumulation of molecular and cellular damage across the life course, subsequent to reduced investment in complex maintenance systems, is the primary mechanism underlying the ageing process (Figure 2.1, Kirkwood, 2005). As the molecular and cellular damage accumulates, there is a progressive loss of physiological integrity which eventually manifests as functional loss, an increased risk of chronic disease and ultimately results in death (Lara et al., 2013). Thus, ageing may be defined as “the progressive loss of function accompanied by decreasing fertility and increasing mortality with advancing age” (Kirkwood and Austad, 2000).

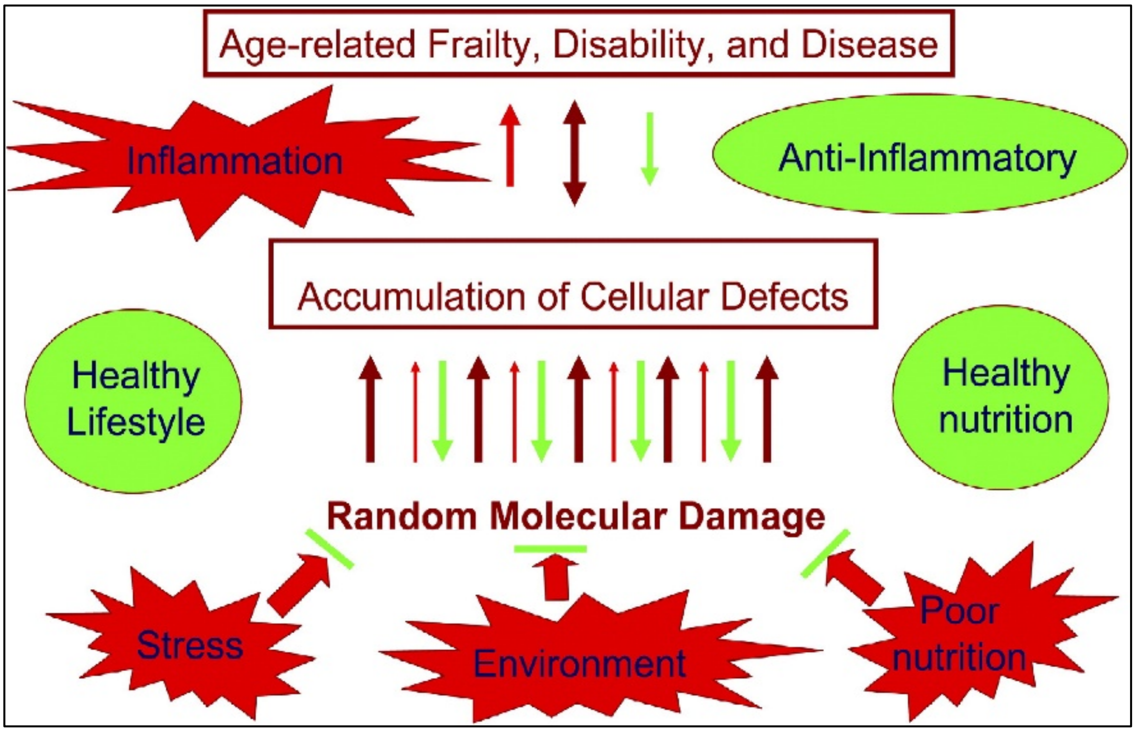


Figure 2.1 Damage and ageing (Kirkwood, 2005).

Whilst the notion that ageing is the result of an inevitable accumulation of cellular and molecular damage over time is becoming increasingly accepted, the exact amount of damage needed to see deleterious consequences (e.g. functional loss and disease) associated with ageing is unknown (Clegg et al., 2013). Moreover, it is notable that not everyone ages in the same way. There is great diversity in how the physical and psychological changes associated with ageing are characterised and experienced at an individual level (WHO, 2015). For example, some 70-year olds experience little deterioration in terms of their physical functioning and are free of chronic disease whereas others require considerable support to meet their basic needs due to substantial declines in their physiological capacity.

This heterogeneity may be attributed in part to the fact that the cellular and molecular damage associated with ageing is inherently stochastic in nature (Figure 2.1). It may also suggest some of the factors implicated in the ageing process are modifiable (Peel et al., 2005). There is an increasing body of evidence which suggests that modification of environmental factors such as diet, smoking and PA behaviour can have a positive impact on the ageing process and contribute to the maintenance of health with rising chronological age (Myint and Welch, 2012). The focus in this thesis will be on the influence of just one of these behavioural factors: physical activity behaviour.

2.1.2 Physical activity behaviour

Physical activity behaviour is an umbrella term which may be utilised to encompass two fundamental human behaviours: PA and sedentary behaviour. Whilst these two behaviours are related and likely impact upon each other in terms of their behavioural and biological effects, they are distinct constructs which need to be clearly defined (Tremblay et al., 2017; Hadgraft et al., 2017).

2.1.2.1 Physical activity

PA is a complex and multidimensional behaviour which involves skeletal muscle contraction and results in increased energy expenditure (EE) (Gabriel et al., 2012). It is an integral part of human behaviour that occurs throughout the day, for a variety of purposes (PAG Advisory Committee, 2018). Accordingly, PA is often categorised according to ‘type’ or the domain (i.e. the physical or social environment) in which it occurs (Caspersen et al., 1985). Four domains, namely leisure-time, occupational, domestic and transport, are commonly used within the literature (PAG Advisory Committee, 2018). Leisure-time PA refers to discretionary activities individuals choose to participate in during their free time therefore participation in sports, dancing and gardening are all relevant examples (Howley, 2001). In contrast, the PA which occurs in the other domains (i.e. occupational, domestic and transport) may be considered ‘incidental’ as they are activities individuals engage in whilst they are working (occupational), completing household tasks (domestic) or for the purpose of getting somewhere (transport) (Caspersen et al., 1985).

Irrespective of the domain in which it occurs, PA is typically described and quantified in terms of the following characteristics: frequency, duration and intensity (Gabriel et al., 2012). Frequency describes how often PA is done in a given time period and is often referred to as the number of sessions or bouts over a given time frame. (e.g. 3 sessions per week) (Strath et al., 2013). Duration, typically quantified in minutes or hours, is the length of time spent engaging in PA over a pre-specified time period. Duration can be used to quantify a single session (e.g. a 10-minute PA bout) or can be reported as an average amount across a pre-specified time-frame such as a day or a week (Gabriel et al., 2012). Intensity is defined as the level of exertion / effort required to perform a given PA; therefore it is directly related to the rate of EE (Strath et al., 2013). It is often expressed in absolute terms and quantified as multiples of resting energy expenditure (METs), with one MET reflecting an individual’s resting metabolic rate (RMR). Within the literature, one MET is generally assumed to be equivalent to an oxygen uptake (VO_2) of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ (Jette et al., 1990). Thus, the MET value of a given activity is typically calculated by dividing VO_2 (measured in $mL \cdot kg^{-1} \cdot min^{-1}$) by 3.5. For example, an activity (such as doing laundry) requiring an oxygen consumption of 7 $mL \cdot kg^{-1} \cdot min^{-1}$ is equal to 2 METs. The Compendium of Physical Activities (Ainsworth et al., 2011) provides a comprehensive list of PAs and their associated MET values. Thresholds based on MET values are commonly used to categorise the intensity of a given PA as light (1.5 – 2.9 METs), moderate (3.0 – 5.9 METs) or vigorous (≥ 6.0 METs) (Ainsworth et al., 2011).

Although the use of MET categories to describe PA intensity has become common-place within the literature it is not without limitations. Absolute intensity does not take into account an individual's physiologic capacity therefore the generalisability of the aforementioned MET thresholds, identified in a population of healthy adults, to other population groups is questionable (Kwan et al., 2004). Physiological changes which occur during the ageing process mean that older adults tend to experience declines in aerobic capacity (King and Lipsky, 2015). As a result, the perceived level of effort required to perform a given PA is likely higher in this group compared to their younger counterparts (Chodzko-Zajko et al., 2009). Consequently, the descriptors (i.e. light, moderate and vigorous) used to describe PA intensity may no longer be appropriate. Thus, many studies also opt to report on individuals' perception of the effort required to perform a given PA using standardised scales such as the Borg Scale (Borg, 1970). Alternatively, intensity can be expressed in relative terms such as percentage of maximal aerobic capacity or heart rate (HR) (PAG Advisory Committee, 2018).

In addition to an increase in EE, improvements in physical fitness generally result from engagement in PA, thus it is not uncommon for inferences about PA to be made based on measures of physical fitness (Blair et al., 2001). However, caution is needed when interpreting the literature as these terms are not synonymous. PA is behaviour whereas physical fitness is a "state" or outcome (Paterson et al., 2007). Specifically, the term physical fitness refers to a set of attributes individuals either have or develop which enable them to engage in PA (Caspersen et al., 1985). Such attributes include, but are not limited to, cardiorespiratory endurance, skeletal muscle strength and flexibility (Howley, 2001). It is also important to note that not all PA is a determinant of physical fitness (Paterson et al., 2007) and the type and dose of PA are critical in determining the improvement (if any) in physical fitness (Kokkinos and Myers, 2010). For many individuals, engagement in domestic PA such as ironing are unlikely to improve cardiorespiratory endurance (as an example), whereas engagement in purposive PA which is planned, structured and repetitive (i.e. exercise) will.

2.1.2.2 Benefits of physical activity in older adults

It is widely accepted that the regular participation in PA has beneficial effects on a range of outcomes related to health, irrespective of age (Department of Health, 2011). There is incontrovertible evidence that PA can reduce the risk, severity and progression of a myriad of chronic diseases including: cardiovascular disease, diabetes and osteoarthritis (PAG Advisory Committee, 2018). Further, many longitudinal studies have demonstrated that there is a dose-response relationship between PA and all-cause mortality (Lee et al., 2018a; Arem et al., 2015). A recent prospective cohort study conducted in older men (n = 1274, mean age: 78 ± 5 years) found that engagement in PA, defined as being of at least light intensity, was associated with decreased mortality (Jefferis et al., 2018).

This has important implications for older adults in particular given recent self-report data suggest few older adults (approximately 44%) adhere to the 2011 Chief Medical Officer's (CMO) PA guidelines which recommend that older adults should aim to engage in 150 minutes of moderate-vigorous (MV) PA per week accumulated in bouts of at least ten minutes to achieve health benefits (Health and Social Care Information Centre, 2017). Notably, objective data suggest adherence may be even lower. For example, accelerometer data collected in a subsample of approximately 400 older adults participating in the 2008 Health Survey for England suggested 5% of men and 0% of women adhered to this guideline (Health and Social Care Information Centre, 2009).

Still, in older adults, the maintenance of physical function with increasing age is arguably a greater concern than the prevention of disease and increased longevity as it ultimately helps to delay the onset of major disability, preserve independence and improve quality of life (Stessman et al., 2009; Vogel et al., 2009). Hence, a considerable amount of research in recent years has looked at the association between PA and functional outcomes. Indeed, several systematic reviews and meta-analyses have been conducted in an effort to synthesise the extensive literature base (Chase et al., 2017; Paterson and Warburton, 2010). As a result, there is now strong evidence that PA improves physical function and reduces the risk of age-related loss in function (PAG Advisory Committee, 2018).

Encouragingly, there is also a growing body of evidence which suggests that the beneficial effect of PA on physical function is also observed in older adults with chronic diseases and / or disabilities (Chodzko-Zajko et al., 2009). For example, Pahor and colleagues (2014) found that a structured MVPA intervention, compared with a health education intervention, significantly reduced major mobility disability (defined by loss of ability to walk 400 m), persistent mobility disability and the combined outcome of major mobility disability or death over a 2.6-year follow-up. Moreover, the Cochrane review conducted by colleagues within the AUECR suggests PA may have a beneficial effect on physical function in older adults residing in LTC facilities (Crocker et al., 2013a).

There is also evidence to suggest that regular participation in PA reduces the risk of falls and fall-related injuries requiring medical attention in older adults (PAG Advisory Committee, 2018). A recent meta-analysis of data from 15 studies including 3,636 participants aged between 53 and 83 years, provided evidence that exercise interventions had a beneficial effect on the prevention of fall-related fractures and the reduction of relevant risk factors for fall-related fractures (Zhao et al., 2017). Notably, the favourable effect of PA appears to extend to the 'oldest-old' (i.e. those aged ≥ 85 y), though there appears to be a threshold of PA below which benefits are not observed. For example, Iinattiniemi and colleagues found that in their sample of 512 older adults (mean age = 88 y ± 2.6 y) the risk of injury-causing falls was reduced in those who reported engaging in at least 60 minutes of PA such as gardening, swimming and cycling per week. However, in this sample, walking was not associated with a reduction in risk of injury from a fall. Indeed, even those who reported that they engaged in more than 140 minutes of walking per week experienced no significant reduction in risk of fall-related injury (Iinattiniemi et al., 2008).

There is growing recognition that the benefits of PA extend beyond physical health (Bauman et al., 2016; Chodzko-Zajko et al., 2009). Hence, research regarding the impact of PA on outcomes relating to psychological health in older adults is increasing (Penedo and Dahn, 2005). For example, Lee and Russell (2003) explored the relationship between PA and mental health outcomes both cross-sectionally (n = 10,063) and longitudinally (n = 6,472) in women aged ≥ 70 years participating in the Australian Longitudinal Study on Women's Health. The cross-sectional data demonstrated a positive association between PA and emotional well-being as measured by the Medical Outcomes Study Short Form (SF-36). The longitudinal data were also suggestive of a positive relationship as those women who maintained or adopted PA tended to have better outcomes (Lee and Russell, 2003). Similarly, in their prospective cohort study of 1,097 older adults (mean age = 70.3 y ± 5.6 y), Balboa-Castillo et al (2011) found that higher levels of leisure time PA were associated with better long-term health-related quality of life (QOL) as measured by the SF-36 questionnaire.

Several studies have specifically explored the association between PA and mood in older adults, including those with dementia (de Souto Barreto et al., 2015; Potter et al., 2011; Penedo and Dahn, 2005). Whilst there is some evidence to suggest PA has a positive impact on depression in older adults, other studies have reported no effect. In their sample of healthy, predominantly sedentary older adults (n = 30, mean age = 66.9 y ± 4.3 y), McLafferty et al (2004) found that a 24-week resistance training programme with weekly meetings was associated with improvements in mood as assessed by the Profile of Mood States tool. Reductions in the confusion, anger and tension subscales were also observed (McLafferty et al., 2004). Likewise, Teri et al (2003) reported that exercise training combined with teaching behavioural management techniques to care-givers improved physical health and depression as measured by the Cornell Depression in Dementia Scale in their sample of community-dwelling older adults (n = 153, mean age = 78 y). Encouragingly, improvements in depression were maintained after 24 months in those participants with high levels of depression at baseline. However, a large cluster randomised trial involving 891 older adults (mean age = 86.5 y, range = 65-107 y) in 78 care homes found that a moderate intensity exercise programme did not reduce depressive symptoms (Underwood et al., 2013). The authors suggest that alternative strategies may be required to manage depression in this frail population.

Emerging evidence suggests PA may also have a positive effect on cognition in older adults, though findings regarding the intensity of PA required for benefits are more disparate. For example, a large prospective study of older women (n = 18,766) found that self-reported, regular PA participation was associated with higher levels of cognitive function and less cognitive decline (Weuve et al., 2004). Notably, the favourable effects were not limited only to those who engaged in vigorous PA as cognitive performance was better in those women who walked at an ‘easy pace’ for 1.5 hour per week compared to those who walked less than 40 min per week (Weuve et al., 2004). Conversely, Kerr et al (2013) found that engagement in MVPA, but not lower intensity PA, was associated with better cognitive function in free-living older adults (n = 215, mean age: 83.4 y ± 6.6 y). Accordingly, the authors concluded by suggesting there may be a dose-response relationship between PA intensity and cognitive functioning in older adults. Encouragingly, the positive effect of PA on cognition appears to extend to those with mild cognitive impairment (Barber et al., 2012) and dementia (Groot et al., 2016). Indeed, based on data collected from 802 participants included in 18 randomised control trials (RCTs), the results from a recent meta-analysis suggest PA interventions positively influence cognition in older adults with dementia (Groot et al., 2016).

Evidently, there is ample evidence to suggest that engagement in PA is an important component of healthy ageing, defined here as the maintenance of functional ability that enables well-being in later life (Beard et al., 2016). What is less clear however, is whether the beneficial effects of PA are intensity-dependent. The prevailing approach in PA research has been to focus on leisure time MVPA therefore much of the evidence regarding the benefits typically attributed to ‘global PA’ is in fact just for MVPA. Nevertheless, research interest in light intensity PA is increasing and the body of evidence regarding the beneficial effects of light intensity PA is accumulating (Fuzeki et al., 2017; LaMonte et al., 2017). Notably, there is some evidence to suggest that in older adults the physical health benefits of engaging in light PA are comparable to those observed for MVPA and that in terms of psychological well-being, light intensity PA may actually confer greater benefits compared to MVPA (Buman et al., 2010). Encouragingly, the positive association between light intensity PA and various health parameters (e.g. waist circumference and insulin resistance) has also been observed in individuals with poor physical function (Loprinzi et al., 2015). The expanding knowledge base on the beneficial effects associated with light intensity PA has important implications given a considerable proportion of older adults, particularly those who are frail, fail to meet the MVPA recommendations.

2.1.2.3 Sedentary behaviour

The term sedentary, derived from the Latin verb “sedere” meaning “to sit”, is often used within the PA literature to describe individuals who do not engage in sufficient PA (i.e. do not meet PA recommendations) (Pate et al., 2008). However, contemporary researchers in the field refute this position and suggest that it would be more apt to describe the individuals in the aforementioned example as “inactive” rather than sedentary (Tremblay et al., 2017).

It has been postulated that sedentary behaviour is a distinct, albeit related construct to PA (Tremblay et al., 2010). This is supported by increasing amounts of experimental evidence suggesting there is a link between engagement in excessive amounts of sedentary behaviour and adverse health outcomes, independent of the amount of PA an individual engages in (Biswas et al., 2015). Moreover, it has been shown that PA and sedentary behaviour can co-exist as one behaviour does not simply displace the other (Tremblay et al., 2017; Ekelund et al., 2016; Dempsey et al., 2014). Indeed, as can be seen in Figure 2.2, it is possible for an individual to be categorised as “active” (i.e. meeting the CMO PA guidelines) but still spend the majority of their waking time sedentary. Alternatively, whilst some individuals may be categorised as being ‘inactive’ on the basis that they do not meet the PA recommendations, it is conceivable that they may engage in a large volume of low intensity PA through the completion of domestic tasks and spend little time sitting (Dempsey et al., 2014). In light of this evidence, there is a broad consensus that sedentary behaviour is best defined as "any waking behaviour characterized by an EE ≤1.5 METs, while in a sitting, reclining or lying posture" (Sedentary Behaviour Research Network (SBRN), 2012).

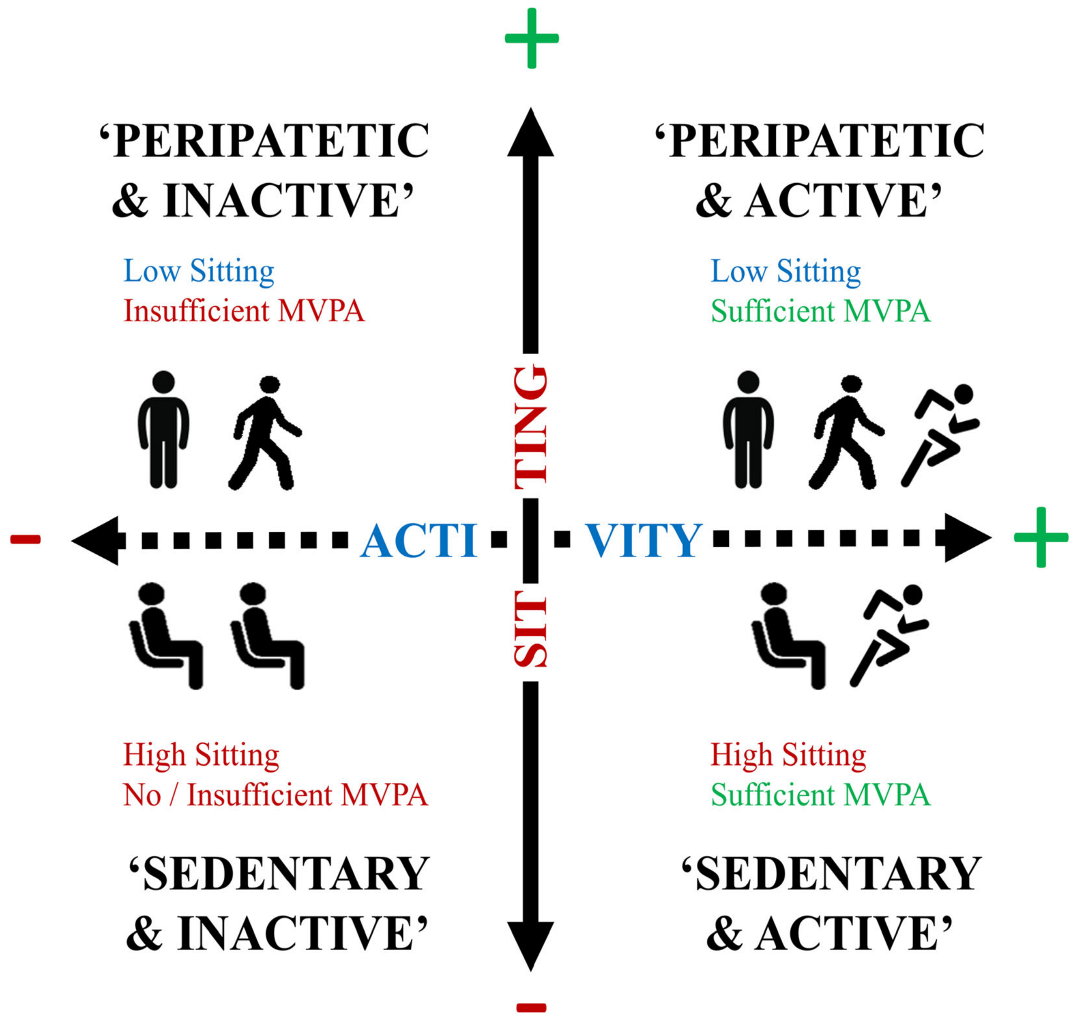


Figure 2.2 Continuum of time spent sitting (vertical line) and in MVPA (horizontal line) as two distinct classes of behaviour. Plus and minus signs indicate a healthier and riskier behaviour pattern respectively. Note, the term peripatetic means "to move around, and/or perambulate" and denotes not participating in MVPA, but sitting very little (Dempsey et al., 2014).

Sedentary behaviour, like PA, is an integral part of human behaviour which may be accumulated within the leisure, domestic, occupational and transport domains (Hadgraft et al., 2017). Watching television, computer use and driving a car are all pertinent examples of sedentary behaviours as they are typically done whilst sitting down and incur low EE.

Whilst sedentary behaviours are often conceptualised as being at one end of the EE continuum with vigorous PA at the other end (Figure 2.3), the frequency, duration and interruptions in prolonged bouts of sedentary behaviour should also be considered, particularly when attempting to quantify these behaviours given the EE associated with sedentary behaviours is fairly constant (Tremblay et al., 2010). Briefly, the frequency and duration dimensions are analogous to those associated with PA and interruptions refer to the number of breaks in sedentary time during a prolonged sedentary bout (Ainsworth et al., 2017).

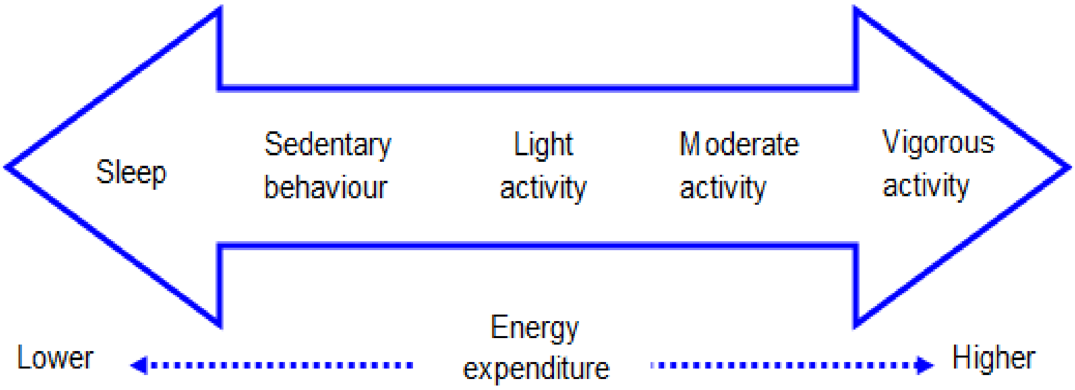


Figure 2.3 The continuum of human movement and energy expenditure (BHFNC for Physical Activity and Health, 2012)

2.1.2.4 Health consequences of sedentary behaviour in older adults

Compared to PA, less literature is available regarding the health consequences of sedentary behaviour. Nevertheless, in the last 15 years research interest in sedentary behaviour has increased rapidly such that there is an increasing body of experimental and epidemiological evidence which suggests that sedentary behaviour can have deleterious effects, independent of the amount of PA an individual engages in, on an array of health outcomes (Biswas et al., 2015; Grøntved and Hu, 2011; Tremblay et al., 2010).

In older adults, much of the research conducted to date looking at the relationship between sedentary behaviour and health outcomes has looked at either mortality or cardiovascular risk (Dogra et al., 2017; de Rezende et al., 2014). Indeed, several longitudinal studies have demonstrated that there is a graded, inverse relationship between all-cause mortality and total sedentary time in older adults (Pavey et al., 2015; Matthews et al., 2015). Similarly, those studies looking at the relationship between cardiovascular risk and sedentary behaviour have reported a positive association (Same et al., 2015; Stamatakis et al., 2012). However, it is important to recognise that the majority of studies conducted have been cross-sectional therefore it is not appropriate to infer causality.

Studies in older adults are increasingly looking at the association between sedentary behaviour and geriatric-relevant outcomes such as physical function, cognitive impairment and QOL (Copeland et al., 2017). With regards to physical function, the majority of studies conducted to date have reported an inverse relationship between physical function and total sedentary time (Rosenberg et al., 2016; Davis et al., 2014; Gennuso et al., 2013). Having said this, some studies, including that conducted by Bann et al (2015) which evaluated the associations between light intensity PA and sedentary time with body mass index (BMI) and grip strength in a large sample (n = 1,130) of older adults aged between 70 y and 89 y, have found no relationship between sedentary behaviour and physical function. In addition to total sedentary time, how the sedentary time is accumulated (i.e. the pattern) appears to be important, with studies demonstrating that “breaking up” prolonged periods of sedentary behaviour is associated with better physical functioning (Sardinha et al., 2015).

Research regarding the impact of sedentary behaviour on outcomes other than those relating to an individual’s physical health is more disparate (O’Neill and Dogra, 2016; Meneguci et al., 2015). In an attempt to provide a comprehensive perspective for future development of sedentary guidelines for middle-aged and older adults, O’Neil and Dogra (2016) assessed the association between a variety of sedentary activities and self-reported wellness outcomes in middle-aged (45 – 60 y, n = 8,161) and older adults (≥ 60 y, n = 9,128). The authors found that several sedentary activities were positively associated with wellness outcomes. Conversely, Meneguci et al (2015) investigated the relationship between sitting time and QOL in older adults aged ≥ 60 y (n = 3,206) and found that participants with the highest amount of sitting time presented the worst scores in the physical domain and social participation facet of both the WHOQOL-BREF questionnaire and the WHOQOL-OLD questionnaire. Evidently, further research is warranted to fully understand the impact of sedentary behaviour on QOL in older adults.

The evidence regarding the influence of sedentary behaviour on cognitive function in older adults is also equivocal (Copeland et al., 2017; Hamer and Stamatakis, 2014). For example, a number of studies have demonstrated that sedentary behaviour is negatively associated with cognitive function (Da Ronch et al., 2015; Kesse-Guyot et al., 2014), yet others suggest that sedentary activities such as reading or using a computer may actually be associated with better cognitive performance (Rosenberg et al., 2016; Nadel and Ulate, 2014). In their prospective study of sedentary behaviour, risk of depression and cognitive impairment in 6,359 older adults (mean age = 64.9 y ± 9.1 y), Hamer and Stamatakis (2014) found that television viewing was associated with poorer global cognitive function, whereas internet use was linked with higher global cognitive function. This led them to conclude that some, but not all sedentary behaviours have an adverse effect on psychological health.

On the whole, it appears there is now ample evidence to support the supposition that sedentary behaviour has an impact on a number of health outcomes in older adults. It is less clear however, whether the detrimental effects believed to be attributed to sedentary behaviour are independent of the amount of PA an individual engages in. Whilst many studies involving older adults, including those discussed above, have reported significant associations between sedentary behaviour and health outcomes after adjusting for MVPA, there is some evidence to suggest engagement in MVPA may attenuate the deleterious effects of high levels of sedentary behaviour (Ekelund et al., 2016; Chau et al., 2013). In their recent meta-analysis of data from more than one million men and women, Ekelund et al (2016) adopted a harmonised approach to directly compare mortality between people with different levels of sedentary time and PA. The findings suggest engagement in high levels of moderate intensity PA (i.e. 60-75 min per day) may eliminate the increased risk of mortality associated with high levels of sedentary time. Whilst the finding that participation in PA may 'undo' some of the negative effects of sedentary behaviour is encouraging, the relevancy of this to older adults, many of whom will engage in very little, if any, MVPA is questionable. Evidently, further work is required to elucidate the interactive and independent effects of sedentary time and PA on the health of older adults.

2.1.3 Ageing and physical activity behaviour: concluding remarks

PA is known to have a positive impact on the ageing process and contribute to the maintenance of health with rising chronological age. There is an established body of evidence concerning the health and social benefits of engaging in PA for older adults (i.e. those aged ≥ 65 y). In addition, there is growing evidence regarding the negative impact sedentary behaviour, independent of PA, may have on a number of health parameters in this population. Still, it is notable that few studies have included care home residents, with some purposively excluding this population (Foster et al., 2005). As a result, there is comparatively less empirical evidence regarding the effects of PA and sedentary behaviour specifically in this population.

Having said this, evidence from interventional studies that supports the implementation of PA as a preventative and therapeutic intervention for residents of care homes is emerging (Jansen et al., 2015; Crocker et al., 2013a). Nonetheless, it is important to acknowledge that most of these intervention studies were not designed to measure PA as a primary outcome measure and none considered sedentary behaviour. The focus has tended to be on examining the impact of the PA intervention on another outcome, typically physical function (Crocker et al., 2013a). Moreover, even in those studies that assessed PA, a variety of different methods were used. Additionally, few studies provide sufficient information regarding the psychometric properties of the assessment method used (Jansen et al., 2015).

Taken together the aforementioned points suggest a consensus on the most appropriate method of assessing PA and sedentary behaviour in this population remains elusive. This is problematic as the accurate measurement of these two behaviours is important to:

- examine dose-response relationships between PA and / or sedentary behaviour and outcomes of interest;
- identify and monitor levels and patterns of PA and / or sedentary behaviour;
- evaluate the effectiveness of interventions designed to modify these behaviours.

Thus, the focus of the next section is on the measurement of PA and sedentary behaviour in care home residents.

2.2 Section two: measurement of physical activity and sedentary behaviour in older adults

The complex and multidimensional nature of PA behaviour makes its measurement difficult. Still, a plethora of assessment methods, typically categorised as either indirect or direct, are available (Table 2.1). Indirect or subjective measures rely on individuals reporting on their PA / sedentary behaviour either in real time or more often, historically (e.g. in the previous week) (Ainsworth et al., 2015). The predominant indirect measures used to assess PA and sedentary behaviour are questionnaires as they are perceived to be easy to administer and are generally well-accepted by participants (Dishman et al., 2001). Direct or objective measures record and quantify either EE, movement or physiological variables such as HR (Trost and O'Neil, 2014). Such measures are generally considered more accurate than indirect measures as they are not reliant on participant recall. Thus, they are often used as criterion measures against which to validate indirect measures (Prince et al., 2008). Nonetheless, each method, irrespective of whether it is categorised as indirect or direct, has both merits and drawbacks associated with its use. For this reason, the choice of assessment method should be based on, among other factors, the primary construct (PA or sedentary behaviour) and dimension which is of interest, and the appropriateness of the measure to the population being studied (Ward et al., 2005).

As alluded to in the preface of this chapter, the primary construct of interest in this thesis is PA. Having said this, interest in sedentary behaviour has increased dramatically over recent years and considerable research effort has been directed towards advancing the science of sedentary behaviour measurement (Biddle and Bennie 2017). It seemed pertinent therefore to consider the measurement of sedentary behaviour too, particularly given observational research suggests care home residents (the population of interest in this thesis) spend a considerable amount of time “inactive” (Sackley et al., 2006).

Whilst the measurement of PA and sedentary behaviour is complex across all populations, quantifying PA and sedentary behaviour in older adults residing in care homes is likely to present unique challenges. Many of these challenges relate to the fact that, compared to community-dwelling older adults, older care home residents are likely to have diminished physiological capacity, multimorbidity and / or experience some degree of cognitive impairment (Gordon et al., 2014). For example, in light of the aforementioned attributes, care home residents may be sceptical of the value of measuring their PA and sedentary behaviour and thus, be less inclined to participate.

Similarly, if residents do agree to take part, researchers need to be mindful that compliance to data collection procedures may be affected and attrition may be higher than in other populations. In addition, (as discussed in more detail below) the accuracy of data collected, whether this be via indirect or direct methods, may also be compromised.

For example, whilst questionnaires are one of the most widely used assessment methods in PA and sedentary behaviour research, their accuracy for quantifying the intermittent, low intensity PA typical of a care home population is questionable for a number of reasons. First, many questionnaires focus on quantifying structured PA and would therefore fail to capture much of the PA residents engage in (Kowalski et al., 2012). Second, this kind of PA is inherently more difficult to recall accurately, particularly for individuals with cognitive or memory impairments (Hauer et al., 2011). Third, given the perception of PA intensity is influenced by age and physical fitness (amongst other factors); misinterpretation of questions is possible (Shephard, 2003; Rikli, 2000). For example a care home resident may consider an activity typically categorised as light as more demanding and thus report on it as moderate. Furthermore, the practice of assigning ‘standard’ MET values to determine PA intensity, whilst commonplace, is problematic in care home residents as an individual’s physiologic capacity is not accounted for (Ainsworth et al., 2000).

It may be surmised that the use of direct measures such as pedometers and accelerometers provide a better approach to quantifying PA and sedentary behaviour older care home residents. Having said this, as was the case with indirect measures, the type and intensity of PA care home residents typically engage in does complicate direct measurement. For example, pedometers would likely underestimate PA levels in a care home residents as the daily activities typical of the population (for example, ADLs) are not based on ambulatory movement (Tudor-Locke and Myers, 2001a). The prevalence of slower walking speeds and gait disturbances may also affect the accuracy of data collected (Martin et al., 2012). Furthermore, thresholds used to define different intensities of PA and sedentary behaviour in older adults tend to be based on absolute intensity and derived from healthy populations (Santos-Lozano et al., 2013; Copeland and Esliger, 2009). The applicability of these thresholds to care home residents is questionable given the relative effort require to perform a given PA is likely to be higher for this population (Ozemek et al., 2013; Miller et al., 2010). It is also important to recognise that familiarity and comprehension of the technology in these devices may affect residents’ willingness to wear these devices (Chase, 2013).

Moreover, visual impairments and / or poor manual dexterity due to conditions such as arthritis may affect residents ability to put these devices on properly.

Whilst it is apparent from the brief discussion above that there are specific challenges associated with the measurement of PA and sedentary behaviour in care home residents, identifying the optimal assessment method in this population is of upmost importance. Hence, the purpose of this section is to review assessment methods, identified through a scoping review of the literature, as having potential application in a care home population.

Table 2.1: Overview of methods commonly used to assess physical activity and sedentary behaviour*

	Indirect Methods		Direct Methods						
								Accelerometers	
	Questionnaires	Diaries / Logs	Direct Observation	Calorimetry	Doubly Labelled Water	Heart Rate Monitoring	Pedometers	EE devices	Posture devices
Physical Activity									
Type	✓	✓	✓	✗	✗	✗	✗	Maybe	✗
Frequency	✓	✓	✓	✗	✗	✓	✓	✓	✓
Duration	✓	✓	✓	✗	✗	✓	Maybe	✓	✓
Intensity	✓	✓	✓	✗	✗	✓	✗	✓	✗
Volume	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sedentary Behaviour									
Type	✓	✓	✓	✗	✗	✗	✗	Maybe	✗
Frequency	✓	✓	✓	✗	✗	✓	✗	✓	✓
Duration	✓	✓	✓	✗	✗	✓	✗	✓	✓
Interruptions	✓	✓	✓	✗	✗	✓	✗	✓	✓
Volume	✓	✓	✓	✗	✗	✓	✓	✓	✓

Practical Considerations									
Cost	Low	Low	High	High	High	Moderate	Low	Moderate	Moderate
Participant burden	Low	Moderate	Low	Moderate	Low	High (with individual calibration)	Low	Low	Low
Researcher burden	Low - Moderate	Moderate	High	High	High	High (with individual calibration)	Low	Moderate - High	Moderate - High

*Not always in accordance with the conceptual definition defined in **section 2.1.2.3**.

2.2.1 Indirect measures of physical activity in older adults

2.2.1.1 Physical Activity Survey for Long-Term Care

The Physical Activity Survey for Long-Term Care (PAS-LTC) was purposively developed to assess the PA levels of individuals residing in LTC facilities (Resnick and Galik, 2007). The measure consists of a list, compiled and reviewed by individuals working with LTC residents (e.g. geriatric nurse practitioner and nursing assistants), of PAs thought to be common to LTC residents. The PAs listed are grouped into seven categories: routine PA or exercise; personal-care activities; structured exercise; recreational activities; caretaking activities; repetitive activities and routine daily activities. The PAS-LTC requires a care assistant to document the amount of time the resident they are working with spends engaging in each of the listed activities (e.g. wandering or folding / unfolding linens such as clothes or napkins) over an eight-hour shift. A brief description of each PA is given to aid correct identification of an activity. The primary outcome of the PAS-LTC is the total amount of time spent in PA, though sub-totals for each PA category can also be derived.

The convergent validity and reliability of the PAS-LTC was considered as part of its development (n = 13 participants) (Resnick and Galik, 2007). A statistically significant relationship was observed between the PAS-LTC score (derived during evening and night shifts) and total activity counts recorded by the ActiGraph accelerometer. However, the relationship between the PAS-LTC completed during a day shift and accelerometer counts was not significant. Furthermore, there was not a statistically significant relationship between PAS-LTC score and functional impairment as indicated by the Barthel Index (BI) score. Thus, it may be inferred that there is limited support for the validity of the PAS-LTC. Resnick and Galik (2007) did provide preliminary evidence for the reliability of the PAS-LTC. Inter-rater reliability was deemed acceptable based on intraclass correlations (ICC) of 0.83, 0.87 and 0.94 being reported when two different nursing assistants completed the PAS-LTC simultaneously during the day, evening and night shifts respectively. Moreover, an intraclass correlation of 0.89 was reported when the total PAS-LTC score throughout the day was considered.

2.2.1.2 Assessment of Physical Activity in Frail Older People

The Assessment of Physical Activity in Frail Older People (APAFOP) is an interview-administered PA questionnaire that was purposely developed and tested for reliability in older people with and without cognitive impairment (Hauer et al., 2011). Respondents are asked to recall the activities they have engaged in during the previous 24 hours, with a focus on activities of daily living (ADLs) in an attempt to prevent floor effects previously identified as an issue with questionnaires (Tudor-Locke and Myers, 2001a). As well as considering PA in different domains, the APAFOP assesses the frequency, intensity, time and type of PA.

To ensure this information is captured, the APAFOP is highly structured and should be administered in a standardised way; hence the development of an interview manual (Werner, 2013). Briefly, the interviewer should begin with gathering some general background information about the interviewee and explain the interview process thoroughly. The interview manual suggests dividing the recall period into segments (i.e. specific time frames) and using typical recurring daily activities to help foster recall. All activities engaged in are classified by the interviewer as one of the following: walking, outdoor activity, indoor activity, sitting, or lying. The interviewer also documents the time spent engaging in them, probing the interviewee further if necessary. Next, the intensity of each activity can be rated using adjusted MET values (provided as part of the interview materials). In an attempt to avoid ceiling effects, sport activity is assessed and documented (as described above) in a separate table. Each item is scored by multiplying the time (in hours) spent in each item by the MET-intensity level assigned (Schuler et al., 2001). The total activity index is then defined as the sum of items scores.

In their development study, Hauer and colleagues considered the concurrent validity, test-retest reliability and sensitivity to change of the APAFOP. They reported good and excellent correlations with the Physical Activity Questionnaire for the Elderly (PAQE; (Voorrips et al., 1991) and the Physilog activity monitor (BioAGM, CH) respectively; an excellent test-retest reliability coefficient of 0.97 and presented evidence that the APAFOP was sensitive to change during a three-month intervention (Hauer et al., 2011). However, to date there are no examples in the peer-reviewed literature of the APAFOP being used in other studies.

A small feasibility assessment of the use of the APAFOP was undertaken by myself and a colleague during WS2 of the REACH programme. The APAFOP was trialled with two residents, purposively selected as they were deemed to have relatively strong capacity. Although the APAFOP was relatively straightforward to administer, consideration must be given to participant and researcher ‘burden’ as it took over an hour to complete. Moreover, the feasibility of administering the APAFOP and its validity in a population with high levels of cognitive impairment was questioned. Further, given that the range of activities undertaken by the residents was fairly limited in scope and the fact the many were associated with low EE, the sensitivity of the tool was poor. In light of these findings it may be inferred that the APAFOP is not an appropriate tool to measure PA in a care home population.

2.2.1.3 Physical Activity and Mobility in Residential Care Scale

The Physical Activity and Mobility in Residential Care scale (PAM-RC) was specifically developed to assess the mobility and PA levels of care home residents (Whitney et al, 2013). Based on activity levels over the previous week, a resident's key carer rates five domains: mobility (0 - 6); balance (0 - 4); walking frequency (0 - 4); wandering (0 - 3) and outdoor mobility (0 - 4). Higher scores indicate greater independence / engagement in more PA. The mobility and balance domains may be considered together as questions related to 'abilities' and may be referred to as the first subsection of the scale. Equally, walking frequency, wandering and outdoor mobility may be considered together as 'activity' questions and the second subsection of the scale.

To date, the PAM-RC has only been piloted in a small sample of residential care residents (n = 43, mean age = 84.2 y ± 8 y) but it has been reported that it has excellent test retest reliability (ICC = 0.98); internal consistency (Cronbach's α = 0.76) and good construct validity (Whitney et al., 2013). Specifically, time spent sitting / lying as assessed by the activPAL activity monitor (PAL Technologies Ltd, Glasgow, UK) was used as the primary criterion measure in light of questions surrounding the accuracy of step counts in individuals with slow walking speeds / reduced foot clearance. A strong, significant correlation (r = -0.72, $p < 0.01$) between this criterion measure and PAM-RC total score was reported (Whitney et al., unpublished). The construct validity of the PAM-RC was further supported by high correlations with measures of physical performance including, among others, gait (r = -0.85, $p < 0.01$), balance (r = 0.72, $p < 0.01$) and sit-to-stands (r = 0.65, $p < 0.01$) (Whitney et al., 2013). Unsurprisingly, when the ability and activity subsections of the scale were scored and analysed separately, stronger correlations were generally seen between the ability subsection score and physical function measures and similarly between the activity subsection score and outcomes derived from the activPAL activity monitor such as time spent standing and sitting / lying.

Accordingly, it may be surmised that the PAM-RC scale is a quick and easy scale for care home staff to complete and offers promise as a tool to accurately measure care home residents' PA (Whitney et al., 2013). However, further exploration of the validity and reliability of the scale in an independent sample of care home residents is warranted prior to recommending its use. Furthermore, the scale's sensitivity to change has not yet been explored; therefore it is unknown whether it is appropriate to use this measure to evaluate an intervention in a care home setting.

2.2.2 Direct measures of physical activity in older adults

2.2.2.1 Direct observation

Direct observation (DO) is best described as a procedure or process for generating data rather than as a single measure (McKenzie, 2010). Observational procedures can be flexible and permit the collection of important contextual information as well as details regarding the type, frequency and duration of PA behaviours (Warren et al., 2010; McKenzie, 2002). Estimates of PA EE can also be derived from DO by calculating the displacement of body mass and limb acceleration (Dishman et al., 2001). Thus, DO may be used as a process and / or outcome measure (McKenzie, 1991).

DO involves a trained individual (i.e. an “observer”), observing a participant over a pre-determined period of time and recording an instantaneous rating of PA that can be quantified and analysed (McKenzie, 2010, 1991). Whilst the instantaneous rating of PA recorded varies dependent on the research question, it is typically based on a pre-determined coding convention and recorded on either an electronic or paper coding form (Pate et al., 2010). Codes tend to correspond to the characteristics of PA (i.e. type, frequency, duration and intensity) (Pate et al., 2010). The use of a coding system is easier than attempting to write a detailed description of the PA behaviour observed and enables the observer to systematically classify the PA behaviours they have observed into distinct categories (McKenzie, 2010).

Despite being the first, and perhaps one of the most basic approaches to measuring PA, DO is considered by many as one of the ‘gold standards’ by which other PA measures can be compared (Vanhees et al., 2005). Nonetheless, the use of DO as a measure of PA behaviour in adults and older adults is limited and much of the evidence pertaining to the validity of DO is based on paediatric studies (McKenzie, 2002). Lyden et al (2014) did report that DO was a valid measure of time spent in various intensities of PA in young adults (n = 15, mean age: 25 y ± 4.8 y) based on ICC values of between 0.80 and 0.93 when compared to indirect calorimetry. Welch et al. (2016) built on this previous work and evaluated the validity (compared to indirect calorimetry) of DO to estimate EE in a population of older adults (n = 9, mean age: 71 y ± 6.9 y). Although the variability between the mean measured and estimated MET values derived from DO was low (50% of the activities estimated values were within 0.5 METs of the measured values), the low point estimates suggests improvements in accuracy are needed if DO is to be used as a measure of PA EE in older adults. Also of note is that Welch and colleagues found that 68.9% of sedentary activities were misclassified which could be problematic given the evidence of independent associations of sedentary and light intensity PA on health outcomes (Biswas et al., 2015). Nevertheless, DO remains an invaluable measure of PA because of the abundance of information it is able to provide relating the frequency, type and duration of PA (Strath et al., 2013).

Another important advantage associated with the use of DO is that the burden on participants is low compared to other methods commonly used to measure PA behaviour (McKenzie, 2010, 2002). Issues associated with self-report measures, such as reporting bias and issues with recall, are also eliminated (Taylor, 2014). Even so, there are potential weaknesses associated with the use of DO. DO is highly labour-intensive in terms of the length of the observation period and time taken to code and interpret observations; hence the burden on the observer is high (Taylor, 2014; McKenzie, 2002). Furthermore, it is imperative that the observer is objective and non-judgemental; therefore appropriate training is required which takes time and incurs a cost (McKenzie, 2010). In situations where more than one individual is conducting observations, regular inter-observer reliability testing is also required to ensure the accuracy of data acquisition (Pate et al., 2010). It is also possible that participants react to the presence of an observer and thus deviate from “normal” PA behaviours (McKenzie, 2002; LaPorte et al., 1985). Whilst conducting repeated observations of the same individual may minimise the potential effect of ‘reactivity’, consideration needs to be given to both the social acceptability and feasibility of repeatedly observing an individual over prolonged time periods (Dishman et al., 2001). Additionally, observations cannot be conducted in certain environments (e.g. in bathrooms) and it may not be appropriate to observe certain activities (e.g. self-care activities such as dressing) therefore the use of DO as a measure of habitual PA may be questioned (McKenzie, 2010).

2.2.2.2 Calorimetry

As noted in **section 2.1.2.1**, PA is often quantified in terms of EE. Liberation of energy from the body’s main fuels (i.e. carbohydrates and fats) results in oxygen (O_2) consumption, carbon dioxide (CO_2) and heat production. Thus, EE can be estimated by measuring any one of these (Hills et al., 2014).

The measurement of heat production directly is referred to as direct calorimetry (Leonard, 2010). During this process participants are enclosed in an insulated chamber (a calorimeter) so that changes in air temperature, subsequent to heat being produced and released from the participant, can be measured (Levine, 2005). Although direct calorimetry is considered an accurate, valid and reliable measure of EE it is not widely used due to a number of limitations (Ainslie et al., 2003). Namely, expense; the necessity for the researcher to have extensive expertise to maintain and run the calorimeters and the restrictions placed on the participant's movement (Leonard, 2010). Consequently, it is more common for a proxy measure of heat production, either O_2 consumption and / or CO_2 production, to be measured. This process is referred to as indirect calorimetry (Hills et al., 2014).

The most widely adopted approach to indirect calorimetry is the use of an 'open circuit system' (Strath et al., 2013). Open circuit systems involve the participant breathing in ambient air which has constant concentrations of O_2 and CO_2 and then collecting expired air so that it can be analysed to determine the quantities of O_2 and CO_2 (Levine, 2005). Technological advancements have resulted in the development of portable open circuit systems which comprise a mouth-piece or a mask which the participant breathes through (Shephard and Aoyagi, 2012). The mouth piece is connected to a one-way valve which ensures the expired air is collected (Ainslie et al., 2003).

As is the case with direct calorimetry, indirect calorimetry provides an accurate, valid and reliable measure of EE. However, when used in insolation this method does not provide any information on the context and type of PA engaged in (Ainslie et al., 2003). Furthermore, due to a number of practical issues (including cost, participant and researcher burden and measurement protocol) this method is not suitable for use in epidemiologic and interventional research (Haugen et al., 2007; Levine, 2005). In light of this, the main utility of indirect calorimetry is as a validation measure (Vanhees et al., 2005) and it has been used in this capacity in studies involving older adults (Colbert et al., 2011).

2.2.2.3 Doubly labelled water

The doubly labelled water (DLW) technique was originally developed by Lifson and colleagues in the1950s and is still considered by many as the gold standard measure of determining total EE in a free-living environment (LaPorte et al., 1985). The theoretical basis of this method is the differing rate of O_2 and hydrogen loss from body water (Lifson et al., 1955). Evidence suggests O_2 is eliminated from the body as both water and respiratory CO_2 whereas hydrogen is eliminated as water only (Lifson et al., 1955). The difference between these elimination rates is indicative of CO_2 production, from which EE can be calculated (Schoeller and Van Santen, 1982).

In practice, this method involves participants ingesting a known dose of water labelled with two stable isotopes: ^{2}H and ^{18}O (i.e. DLW) (Lifson et al., 1975). Samples of blood, saliva or urine are taken prior to the ingestion of the DLW and then regularly over the measurement period (typically between 7 and 21 days) so that the concentrations of the ^{2}H and ^{18}O isotopes can be measured and EE calculated (Levine, 2005). The initial validation of DLW in humans was conducted by Schoeller and Santen in 1982 following evidence that the technique was feasible in humans. They found the accuracy and precision of DLW comparable to the intake-balance technique for estimating EE and thus deemed DLW to be a simple and non-invasive technique to measure EE (Schoeller and Van Santen, 1982).

Since this first validation study, the DLW technique has been used to measure total EE in various settings and with a range of populations, including older adults (Shephard and Aoyagi, 2012; Manini et al., 2006; Elia et al., 2000). However, it must be noted that the calculations used to derive estimates of total EE which underpin the use of the DLW technique are based on several assumptions which may not always hold true (Bhutani et al., 2015). For example, the volume of body water and the natural abundance of both isotopes are assumed to be constant during the measurement period yet changes in factors such as diet, geographical location or health status can affect this (Bhutani et al., 2015). In considering older adults specifically, there is a chance they could be taking medications which could affect water retention (Rikli, 2000). Moreover, they are more likely to have medical conditions which affect renal function or the circulatory and / or the respiratory system which could mean the assumptions are not met (Rikli, 2000). Still, with the appropriate modifications (e.g. correcting for water flux) this technique can still be used to derive accurate estimates of total EE (Bhutani et al., 2015).

Although DLW is considered the criterion measure of total EE, it is only when combined with measurements of RMR and the thermic effect of food that it can be used to calculate PA EE (Starling et al., 1999). Moreover, the method does not provide any information relating to the frequency, intensity, type or duration of PA (Taylor, 2014). Additional limitations associated with the use of DLW include the inherent burden (for both researcher and participant) related to the repeated collection of samples and the cost allied to the specialist equipment and researcher expertise required (Ainslie et al., 2003). Despite these limitations, an estimated error of less than 8% (Levine, 2005), evidence of validity and reproducibility of this technique mean it has great utility as a criterion measure to validate other measures of EE (Hills et al., 2014; Shephard and Aoyagi, 2012).

2.2.2.4 Heart rate monitoring

Current HR monitors are typically configured as small wrist worn devices which act to receive signals wirelessly from electrodes secured to a chest strap (i.e. the transmitter) (Freedson and Miller, 2000). The design and relatively low cost of these devices, coupled with their capability to record continuously over a prolonged time period, makes HR monitoring a viable and attractive method to monitor the intensity, duration, and frequency of PA (Schrack et al., 2014; Hiilloskorpi et al., 2003). Indeed, a recent review suggests HR monitors are the most common direct physiological measure of PA used in free-living settings (Ainsworth et al., 2015).

The use of HR monitoring to measure PA is based on the assumption that a linear relationship exists between HR and VO_2, which reflects EE (Shephard and Aoyagi, 2012; Freedson and Miller, 2000). That is, the increase in EE subsequent to engagement in PA will result in a proportionate increase in HR. However, the utility of this method to measure PA is hampered by several issues. Firstly, there is considerable intra- and inter-individual variation in the relationship between HR and VO_2 (Leonard, 2003). This can be attributed to the fact that numerous factors, not just engagement in PA, affect HR (Keim et al., 2004). Such factors include the type of muscular contraction and the proportion of muscle mass utilised, cardiorespiratory fitness, age and emotional stress (Haskell and Kiernan, 2000). Secondly, the linear relationship between HR and VO_2 is not robust at lower HRs as the relative influence of these 'other' factors is greatest when individuals are engaging in sedentary behaviours or low intensity PA (Keim et al., 2004; Rutgers et al., 1997). It is also important to note that there is a delay in the HR response at the beginning or cessation of a bout of PA such that sporadic activities may be masked (Trost, 2007). Evidently, the use of HR monitoring to measure PA is not without issues and given the low intensity, sporadic PA customary to many older adults, it is likely to be particularly problematic in this population.

In an effort to overcome these limitations and improve the accuracy of the key PA outcomes derived from HR monitoring, some form of individual calibration is needed (Schrack et al., 2014; Spurr et al., 1988). Accordingly, many researchers use the "flex-HR" approach, originally develop by Spurr et al in 1988 (Dowd et al., 2018). With this approach, HR and VO_2 data are collected simultaneously whilst an individual performs a range of activities in order to produce an individualised HR-VO_2 curve (Spurr et al., 1988). Once an individual's HR-VO_2 curve has been produced, it becomes evident that it is only above a given intensity-threshold that the HR-VO_2 relationship is linear and at lower HRs the relationship is more variable (Spurr et al., 1988). Thus, the flex-HR method posits that when using HR to derive estimates of EE it is first necessary to determine an HR threshold (i.e. the flex-HR) to discriminate between "rest" and "activity" (Spurr et al., 1988). Then, if a given HR is above the flex-HR then the calibration curve is utilised to estimate EE (Leonard, 2003; Spurr et al., 1988). Conversely if the observed HR is below the flex-HR then an individual's RMR is used to estimate EE (Leonard, 2003; Spurr et al., 1988).

Since the initial validation study conducted by Spurr and colleagues in 1988, the flex-HR approach has been validated in various populations, including older adults (Ekelund et al., 2002; Morio et al., 1997; Livingstone et al., 1992). Morio et al (1997) compared estimates of daily EE derived from HR monitoring to daily EE measured by DLW in a sample of healthy older adults (n = 12, mean age = 71.1 y ± 2.7 y). The results of a Bland-Altman analysis showed that the daily EE estimates derived from the HR data were on average 4.7% ± 16.1% (limits of agreement = - 8.3% to 7.6%) higher compared to the measured daily EE. Still, the authors found that the daily EE estimate derived from HR monitoring was not significantly different to daily EE measured by DLW and therefore concluded that HR monitoring could be used to estimate EE in both sedentary and active individuals if the HR-VO_2 relationship is individually calibrated.

However, there are limitations. This method is reliant on the individual calibration between HR and VO_2 and this involves much resource (Keim et al., 2004). Moreover, it has been argued that the calibration protocols (e.g. the number and type of activities included) may have an impact on the accuracy of estimates of EE (Li et al., 1993). Also, it may be postulated that the assumption that one HR (i.e. the flex HR) is sufficient to distinguish between rest and engagement in PA is problematic (Freedson and Miller, 2000). Empirically, the flex-HR is defined as the average of the highest resting HR value and the lowest HR value during PA (Ainslie et al., 2003; Freedson and Miller, 2000). However, agreement that this is the most appropriate way of defining the flex-HR is lacking (Ekelund et al., 2002).

An alternative and less burdensome approach often employed when assessing PA via HR is to use HR indices that account for individual differences in resting HR. For example, one technique commonly employed is to determine the number of minutes an individual spends above a predetermined percentage of maximum HR or HR reserve

(Hiilloskorpi et al., 2003). Similarly, net HR, defined as activity HR minus resting HR, is another technique adopted to assess PA (Hiilloskorpi et al., 2003; Freedson and Miller, 2000). Still, in order to measure HR, the transmitter needs to be in direct contact with the skin which may cause discomfort to participants. With respect to older adults specifically, skin irritation and damage to the skin are concerns (Medical Research Council (MRC) Epidemiology Unit, no date). Having said this, Rutgers et al. (1997) demonstrated the feasibility of using HR monitoring in older adults. However, akin to other direct measures discussed (e.g. DLW and calorimetry) HR monitoring does not provide any information relating to the type of PA (MRC Epidemiology Unit, no date). Furthermore, although HR is indicative of the cardiorespiratory stress which accompanies PA and may provide a general picture of PA (Strath et al., 2013), several practical issues associated with its use limit its utility to assess habitual PA in older adults.

2.2.2.5 Pedometers

Pedometers are small, lightweight motion sensors designed to measure ambulatory activity (Haskell and Kiernan, 2000; Bassey et al., 1987). There are many different models of pedometers commercially available, yet the internal mechanism responsible for the functionality of the device is likely one of the following: horizontal spring-lever, magnetic reed proximity switch or a piezoelectric mechanism (Bassett et al., 2008).

As the name suggests, the horizontal spring lever mechanism is made up of a lever which moves in response to the vertical accelerations of the hip during walking (Crouter et al., 2003). The movement of this lever opens and closes an electrical circuit which results in registration of a step (if movement of lever is sufficient) (Bassett, 2012). Similarly, the magnetic reed proximity switch mechanism is comprised of a horizontal lever arm which moves in response to vertical accelerations. However, it is the creation of a magnetic field (a consequence of a magnet being attached to the lever) which results in a step being counted rather than the closing of an electric circuit (Schneider et al., 2004). The third mechanism commonly used in a pedometer, a piezoelectric accelerometer, records vertical accelerations instantaneously which permits the generation of a sinusoidal curve as vertical acceleration can be plotted against time (Schneider et al., 2004). From this curve, the point where the acceleration goes from positive to negative is used to count steps (Bassett, 2012; Crouter et al., 2003).

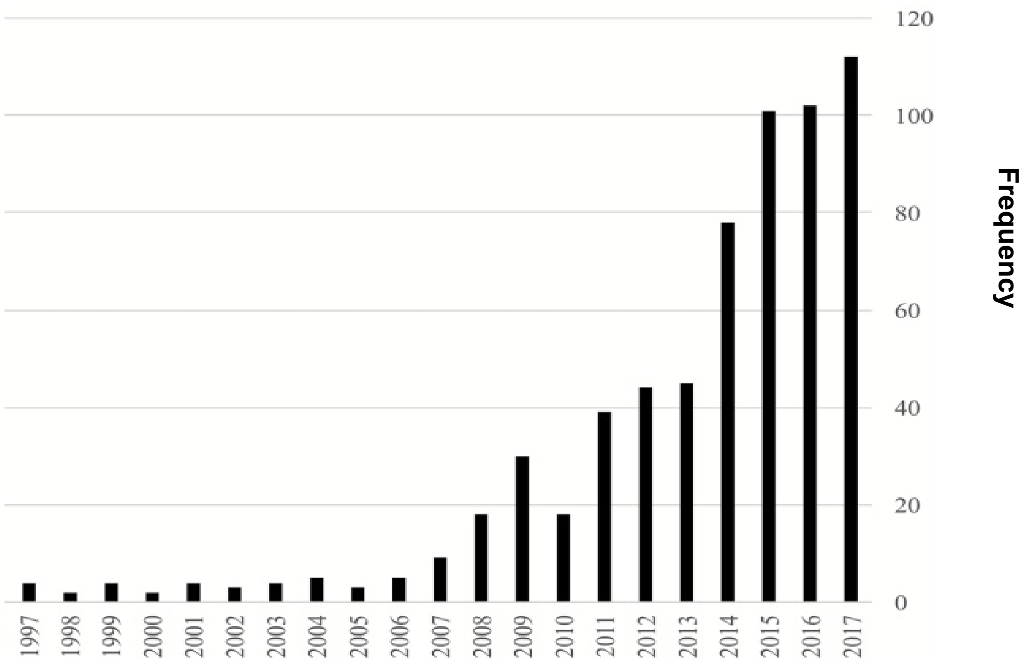
The primary data output from pedometers is steps accumulated; though it is possible to derive other outcomes if additional information is provided (Bassett et al., 2008). For example, distance walked may be determined if information on stride length is provided and EE can be estimated based on step count, stride length and weight (Tudor-Locke and Myers, 2001b; Freedson and Miller, 2000). However, the process of manipulating step data to derive estimates of distance walked or EE introduces possible error and there is limited evidence to support the validity of these metrics. As a result, it has been recommended that pedometers are only used to count steps (Crouter et al., 2003). Still, in terms of practicality, the use of pedometers to assess ambulatory activity in a free-living environment remains an appealing option given their low cost, unobtrusive nature and ease of use (Tudor-Locke and Myers, 2001b).

Having said this, their application as a measure of PA in older adults is limited for a number of reasons. Firstly, evidence on the validity of pedometers in this population is equivocal. Much of the early research suggested that the accuracy of pedometers was diminished at slower walking speeds characteristic of older adults, thus pedometers were not an appropriate tool for measuring PA in this population (Cyarto et al., 2004; Crouter et al., 2003). Despite reports of improvements in the accuracy in step counts as measured with a piezoelectric pedometer (Melanson et al., 2004), a study conducted by Martin et al. (2012) concluded that pedometers remain inaccurate at slower walking speeds, irrespective of the internal mechanism. Also, whilst it is not surprising given the purpose for which pedometers were designed (i.e. to detect vertical accelerations), the sensitivity of these monitors to record movement resulting from non-ambulatory PA is limited (Tudor-Locke et al., 2002). Given that the daily activities typical of many older adults are not based on ambulatory movement (for example, ADLs) it is probable that pedometers would underestimate PA levels in this population (Tudor-Locke and Myers, 2001a).

2.2.2.6 Accelerometers

Accelerometers are small, non-invasive motion sensors which directly measure the acceleration, defined as the change in velocity over time, of the body segment to which they are attached (LaPorte et al., 1985). Whilst accelerometers have been used to study human movement for over 40 years and their potential application in PA research was first recognised by Montoye in 1983, it is only in the last 20 years that they have become more accessible and have gained acceptance as an objective measure of PA (Bassett Jr et al., 2012). When applied to PA measurement, they provide objective information on the volume, frequency, intensity and duration of PA (Ainsworth et al., 2015; Westerterp, 2009). Estimates of EE and body posture can also be derived (Yang and Hsu, 2010). Hence, accelerometers have emerged as one of the most commonly used methods of assessing PA in a free-living environment (Bassett, 2012).

The feasibility of using accelerometers in older adults has consistently been demonstrated in population studies (Lohne-Seiler et al., 2014; Jefferis et al., 2014; Ortlieb et al., 2014). Figure 2.4 highlights the rapid increase in the number of research studies using accelerometers specifically in older adults.



Year of publication

Figure 2.4 Frequency of PubMed manuscripts with keywords “accelerometer” and “older adults” from 2000 to 2017 (adapted from Shiroma et al., 2018).

As a result of the increased popularity of accelerometers, there are now many accelerometry-based devices (both research- and consumer-grade), commercially available (Freedson et al., 2012; Welk et al., 2012). Whilst each individual monitor has its own technical specifications and features, all accelerometry-based activity monitors are made up of two major components:

i) a transducer (i.e. sensor) which samples the accelerations and
ii) a data acquisition element which filters, processes and stores the data either in units of acceleration due to gravity (g) or in a propriety format (i.e. activity count) (Chen et al., 2012).

The primary output from most accelerometers is an “activity count”, a dimensionless unit derived from the raw acceleration data through a multi-step process (Chen and Bassett, 2005). Briefly, the raw acceleration signals are filtered to remove any data not likely to reflect human movement before being converted into a digital series of numbers referred to as ‘raw counts’ (Chen and Bassett, 2005). These raw counts are then aggregated over a discrete time period (i.e. epoch) to produce the integrated signal referred to as an activity count (John and Freedson, 2012; Chen and Bassett, 2005). Whilst these activity counts provide an overall indication of movement, they are an arbitrary unit and therefore need to be translated into more “meaningful” information which describes an individual’s PA (Strath et al., 2013). This process is referred to as value calibration (Bassett Jr et al., 2012; Welk, 2005).

The process of value calibration involves collecting activity count and criterion data (typically EE) simultaneously whilst individuals perform a range of activities assumed to be ‘typical’ to the population of interest (Bassett Jr et al., 2012; Welk, 2005). Next, one of several different statistical approaches are used to determine the relationship between the activity count and criterion data (Bassett Jr et al., 2012). The most popular approach employed in the calibration studies conducted to date is linear regression, likely due to its simplicity (Matthews, 2005; Freedson et al., 1998; Montoye et al., 1983). Once a regression equation has been derived, activity counts can be used to estimate an individual’s EE and thresholds (i.e. cut-points) denoting different intensities of PA (i.e. light, moderate and vigorous) can be identified (Ward et al., 2005) (Figure 2.5).

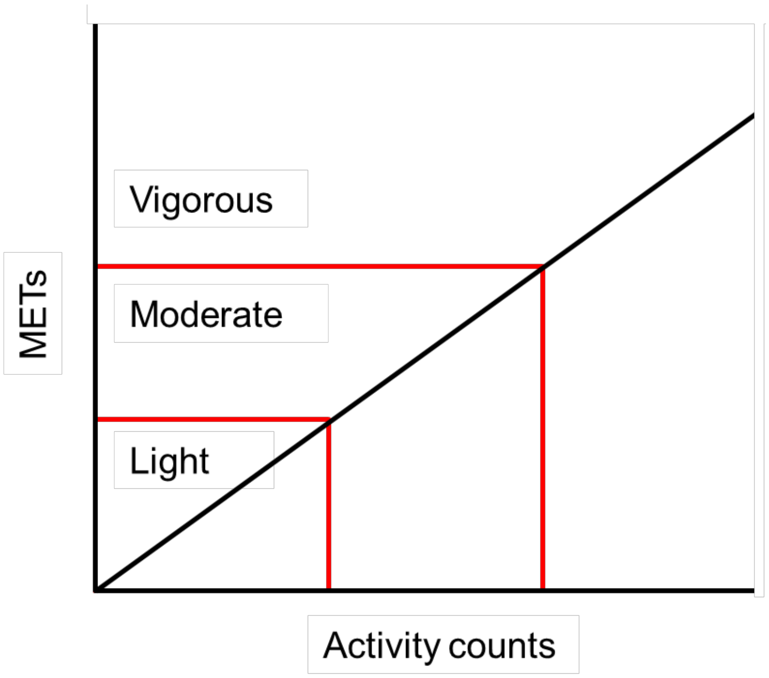


Figure 2.5 Concept behind the use of cut-points to convert activity counts into time spent in different intensities of PA.

Several calibration studies have been conducted with various different populations, including older adults (Copeland and Esliger, 2009; Freedson et al., 1998). The first calibration study conducted specifically with older adults was conducted by Copeland and colleagues in 2009. The authors reported a moderate linear relationship (r = 0.6) between activity counts recorded by a hip-worn accelerometer and EE in a population of healthy, active, older adults (n = 38, mean age: 69.7 y ± 3.5 y) (Figure 2.6). However, even in this active group of participants, the narrow range of walking speeds attained prevented the authors from developing an equation to estimate EE. Instead, a reference activity (walking at 3.2 km/h) was used to identify a single cut-point (≥ 1,041 counts per minute (cpm)) to discriminate moderate intensity PA. More recently, studies in older adults have established a range of cut-points for differing intensities of PA (light, moderate and vigorous) (Evenson et al., 2015; Zisko et al., 2015).

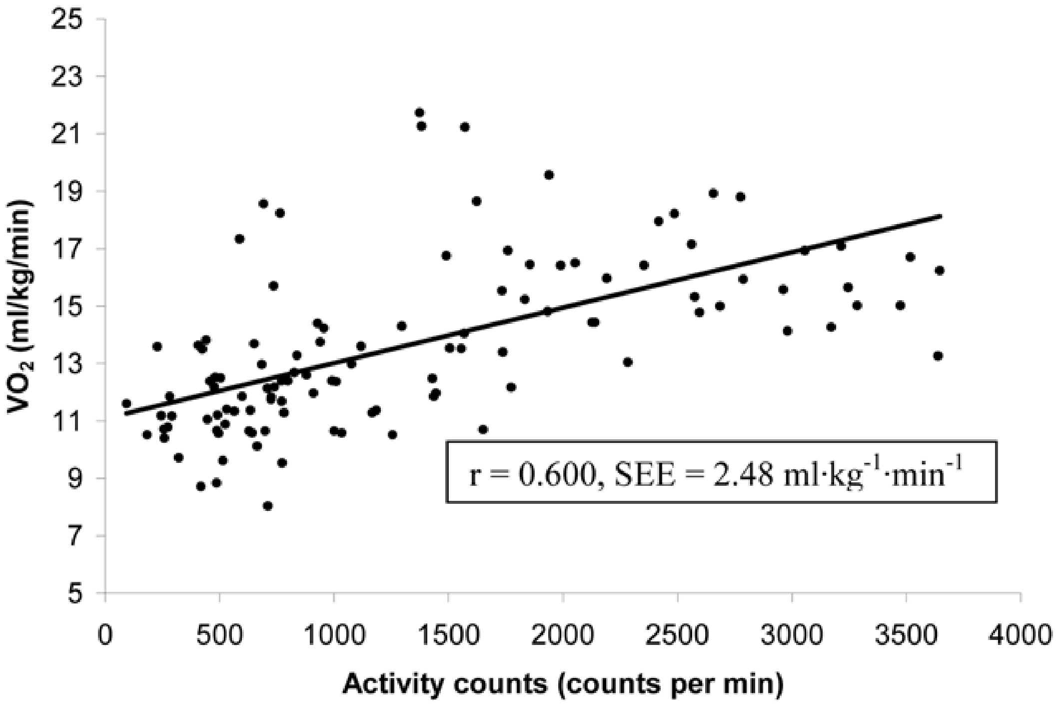


Figure 2.6 Example of a graph plotting the relationship between activity counts and oxygen consumption. (n = 38). SEE = standard error of the estimate. (Copeland et al., 2009)

Following calibration, it is important to establish the validity of the accelerometer data (Bassett Jr et al., 2012). The majority of calibration studies conducted with older adults also provide preliminary evidence with regards to the validity of estimates of EE and / or time spent in differing intensities of PA (Copeland and Esliger, 2009). However, few prediction equations and / or cut-points developed are cross-validated in independent samples. Knowing that movement patterns, mechanical efficiency and cardio-respiratory fitness (CRF) can vary considerably amongst older adults, it is possible that a given prediction and / or cut-point may produce valid estimates in one group of older adults but not in another (Strath et al., 2012; Bassett, 2012). For example, estimates of time spent in differing intensities of PA may be valid in a population of healthy community-dwelling older adults but not for older adults residing in care homes, many of whom have some kind of functional limitation (Gordon et al., 2014; Rothera et al., 2003). Evidently, the validity of PA estimates derived from accelerometers needs to be established in the population of interest.

In addition to activity counts, the majority of accelerometers currently available (e.g. ActiGraph wGT3X+) also provide end-users (typically researchers) with the raw acceleration data, recorded in units of acceleration due to gravity (g) (Sasaki et al., 2016). The ability of the newer accelerometers to output the raw acceleration data represents a major advantage over older models as it should, in theory, mean the data collected from different monitors is comparable (Welk et al., 2012). This data also offers considerable opportunity to improve the characterisation of PA as the detailed characteristics of the raw acceleration signals are preserved (Intille et al., 2012; Chen and Bassett, 2005). Nevertheless, the sheer volume of data necessitates consideration of logistical issues and brings about unique analytical challenges (Schrack et al., 2016; Troiano et al., 2014). Appropriate analytical techniques (e.g. machine-learning algorithms) capable of translating this output into a desirable PA outcome are being developed (Ellis et al., 2016; Lyden et al., 2014a). However, this area of research is in its infancy and at present there is limited evidence regarding the validity of these approaches in a free-living setting (Sasaki et al., 2016). As a result, despite the limitations of using regression-based cut-points to derive estimates of time spent in differing intensities of PA, many study outcomes continue to be based on these conventional methods of analysis (Montoye et al., 2018; Troiano et al., 2014).

As alluded to previously, accelerometers have emerged as the preferred method for measuring PA in a free-living setting and are increasingly being used with older adults (Bassett, 2012). Nevertheless, the use of these devices with older adults has challenges. Like pedometers, accelerometers provide little information about the type of activity engaged in and are unable to adequately capture all PA accurately (Strath et al., 2013). For example, an accelerometer worn on the hip is unable to capture static PA which involves upper body movements (Montoye et al., 1983; Matthews, 2005) (Murphy, 2009; Dale et al., 2002). Furthermore, accelerometers are unable to capture the additional energy cost associated with walking up an incline or carrying a heavy load (Shephard, 2017). Should such information be of interest then the use of additional assessments are needed alongside a hip-worn accelerometer. Whilst it is important to acknowledge the aforementioned limitations, the lack of standardisation in the data collection and processing methods is arguably the biggest challenge of all. Related to this, the interpretation and reporting of accelerometer data is incredibly inconsistent which makes comparability across studies difficult and precludes ‘pooling’ of data to form larger datasets, thus limiting the opportunities that such practice could potentially offer. Although the accessibility of raw acceleration data holds promise, the issues described will persist until the research community “catches up” with the technological advances and not only develops but consistently implements appropriate methods of utilising this raw acceleration data.

2.2.3 Indirect measures of sedentary behaviour in older adults

Much of the early research into sedentary behaviour relied on indirect measures and self-report questionnaires in particular because of the relatively low participant burden and ease of administration (Atkin et al., 2012; Pate et al., 2008). However, many of the questionnaires used were not developed specifically to measure sedentary behaviour. Rather, existing PA questionnaires were amended (if they did not already take account of sedentary behaviour) to include question(s) regarding sedentary behaviour (Dall et al., 2017).

In an attempt to improve estimates of sedentary behaviour and gain a better indication of the types of sedentary behaviours individuals typically engage in, efforts have been made to develop questionnaires which specifically measure sedentary behaviour (Dall et al., 2017). In their recent paper, Dall and colleagues used a structured search protocol in order to compile a list of 37 self-report tools which could be used to measure SB in adults and older adults. Still, there is dearth of evidence regarding the psychometric properties of these questionnaires, particularly in older adults (Visser and Koster, 2013; Gardiner et al., 2011). Whilst it is outside the scope of this thesis to review all of the sedentary behaviour questionnaires which have been used in studies involving older adults, two of the most widely used English language questionnaires developed specifically for measuring sedentary behaviour in older adults: the Measuring Older adults' Sedentary Time (MOST) questionnaire (Gardiner et al., 2011) and the Longitudinal Ageing Study Amsterdam (LASA) sedentary behaviour questionnaire (Visser and Koster, 2013) are discussed below.

The MOST questionnaire is a brief, seven-item interview-administered questionnaire which asks respondents to state how long they have spent engaging in sedentary activities such as TV or video watching (item 1), computer use (item 2) and reading (item 3) over the previous week. The items included were adopted from a previous questionnaire developed by Salmon et al (2003) for use in population-based studies.

Gardiner et al examined the validity, reliability and sensitivity to change of the MOST questionnaire within the context of a sedentary behaviour intervention with a sample of non-working older adults ($n = 48$, mean age = 73 y ± 8 y). Although the MOST questionnaire did provide an overall estimate of sedentary time and some insight into the types of sedentary behaviours older adults may engage in, the authors concluded that the validity was less than ideal. Whilst the correlation between total sedentary time derived from the MOST questionnaire and an accelerometer was modest (ρ [95% CI] = 0.30 [0.02 – 0.54]), the Bland-Altman analysis suggested the agreement between the estimates of total sedentary time derived from the two measures was poor (mean difference = 3.6 $h \cdot d^{-1}$, limits of agreement (LoA) = mean difference ± 3.82 h) (Gardiner et al., 2011). Similar to the MOST questionnaire, the LASA sedentary behaviour questionnaire was developed specifically for use with older adults (Visser and Koster, 2013). It is a self-administered questionnaire which asks respondents to state how long, on average, over a 24-hour day, they spend engaging in ten pre-specified sedentary activities. This is done for a typical week- and weekend-day. The total time spent sedentary is derived by adding up the time spent engaging in each of the sedentary activities. In cases where more than four items are not completed the total score is deemed invalid.

The authors reported a modest correlation between estimates of sedentary time derived from an accelerometer and estimates derived from all ten items on the questionnaire (r = 0.35, $p < 0.05$). A stronger association with accelerometer-derived sedentary time was found when estimates were based on the six individual items which correlated best with the accelerometer estimate (r = 0.46, $p < 0.05$). Whilst the correlation was higher when estimates were based on six items, the Bland-Altman analysis revealed that the estimates of total sedentary time were underestimated (compared to estimates derived from accelerometer data). The mean difference was 2.1 hours, with LoA of -7.40 hours – 3.25 hours (Visser and Koster, 2013).

It may be inferred, based on the studies discussed, that there is little evidence to support the validity of estimates of total sedentary time derived from either the MOST questionnaire or the LASA sedentary behaviour questionnaire. Although it is widely acknowledged that the temporal pattern of sedentary behaviour makes it a difficult construct to measure (Kang and Rowe, 2015, Tremblay et al., 2010) it could be argued that the items included and the recall period (i.e. over the previous week) make the MOST questionnaire and the LASA sedentary behaviour questionnaires particularly susceptible to misreporting. For example, it is possible that respondents spend time watching television and doing hobbies (Items 1 and 6 on the MOST questionnaire and items 4 and 5 on the LASA sedentary behaviour questionnaire) and, despite instructions to only report the ‘main activity’, there is a chance that respondents may double report their sedentary time. By the same token, the habitual nature of sedentary behaviour makes recalling the time spent in specific sedentary pursuits over the previous week difficult therefore it is possible respondents will underreport their sedentary time (Hart et al., 2011a). It is also important to recognise that both of these questionnaires were developed for specific samples of community dwelling older adults therefore the items included may not sufficiently capture the sedentary behaviours typical of other populations (Tremblay et al., 2010).

Nevertheless, both questionnaires do provide useful information of the types of sedentary behaviours respondents engage in which could be used to inform the development of interventions (Dall et al., 2017). Moreover, their low cost and ease of administration mean questionnaires will remain a popular measurement tool to provide summary information on sedentary behaviours in large population-based studies (Ainsworth et al., 2017). It may be surmised that, at present, questionnaires may be best utilised as an adjunct measure for use alongside a more accurate measure of sedentary behaviour and that further work is required to develop accurate questionnaires to measure sedentary behaviour in older adults (Wullems et al., 2016; Kang and Rowe, 2015) .

2.2.4 Direct measures of sedentary behaviour in older adults: accelerometers

Although several different direct measures have been used to measure PA in older adults (**section 2.2.2**), only a few of these have potential application as a measure of sedentary behaviour (Tremblay et al., 2010). At present, accelerometry-based activity monitors are regarded as the direct measure of choice in light of their practicality and capability to provide information on both the volume and patterns of sedentary behaviour (i.e. duration of prolonged sedentary bouts, breaks in sedentary time) (Kang and Rowe, 2015; Rosenberger, 2012). However, it is important to acknowledge that the methods employed to process and subsequently interpret the data measured differs among accelerometery-based devices as this has important implications in terms of the measurement of sedentary behaviour (Kang and Rowe, 2015; Gibbs et al., 2015). For example, the ActiGraph monitors are often referred to as EE devices in the field of sedentary behaviour research as they quantify sedentary behaviour based on a lack of movement and low EE (Granat, 2012). Specifically, a cut-point approach (previously described in **section 0**) is typically employed such that if the number of activity counts produced is below a pre-defined threshold (typically < 100 cpm) it will be categorised as sedentary (Marshall and Merchant, 2013). Conversely, monitors such as the activPAL are referred to as posture classification devices as they quantify sedentary behaviour by postural allocation (Wullems et al., 2016). Specifically, these monitors use information about thigh acceleration and inclination to determine body position via the use of proprietary algorithms (Granat 2012). Time spent sedentary (i.e. sitting or lying) can subsequently be derived (Kang and Rowe, 2015; Granat, 2012).

Much of the early research into sedentary behaviour employed EE devices such as the ActiGraph (Rosenberger, 2012). However, caution is warranted when interpreting findings from studies which have employed EE devices as the cut-points used are somewhat arbitrary (Matthews, 2005). For example, although the cut-point of < 100 cpm is widely used to denote sedentary time (Hansen et al., 2012; Matthews et al., 2008) it was not empirically derived and there is some debate as to whether different cut-points should be used in different populations dependent on factors such as sex, age and body composition (Aguilar-Farias et al., 2014; Crouter et al., 2013; Kozey-Keadle et al., 2011). Furthermore, the cut-point approach does not take into account the postural element of sedentary behaviour (Marshall and Merchant, 2013). As a result, some light intensity PA (for example standing) may be misclassified as sedentary behaviour and vice versa (Kim et al., 2015). Given accumulating evidence suggests that breaking prolonged periods of sedentary time by engaging in light intensity activities such as standing can incur health benefits (Sardinha et al., 2015; Healy et al., 2008; Hamilton et al., 2004), the inability to distinguish posture represents a major limitation. This limitation is particularly pertinent in populations such as older adults who spend the majority of their time either sedentary or engaging in low intensity PA (Harvey et al., 2013).

It is therefore unsurprising that the use of posture classification devices (particularly the activPAL) in sedentary behaviour research has increased dramatically in recent years (Edwardson et al., 2017). As a result, there is a growing body of evidence which suggests that these devices not only produce valid estimates of sedentary behaviour in a range of populations (including older adults with functional impairments) but are in fact more accurate than EE devices, despite not being able to directly measure EE (Kim et al., 2015; Kozey-Keadle et al., 2011; Taraldsen et al., 2011; Grant et al., 2006). Accordingly, it has been suggested that posture-based devices are used in studies where sedentary behaviour in the primary outcome of interest (Kang and Rowe, 2015).

Still, there are concerns regarding the practicality and acceptability of these devices, particularly in frail older adults Indeed, during detailed programme development work conducted by colleagues from the AUECR prior to the start of REACH, care home staff expressed concerns about the method of attachment to the leg of the activPAL. They were particularly worried about irritation and damage to the skin of participants. Moreover, many studies conducted in the area of health research seek to fully understand PA behaviour; therefore accurate assessment of both sedentary behaviour and PA is required (Troiano et al., 2012). Thus, the conceptualisation of sedentary behaviour as part of a continuum of PA behaviours (Figure 2.3) will likely prevail in a research setting (Kang and Rowe, 2015).

2.2.5 Measurement of physical activity and sedentary behaviour: concluding remarks

A key finding of this review was that a plethora of assessment methods capable of measuring PA and sedentary behaviour in older care home residents do exist. However, advantages and disadvantages are associated with each and at present, evidence supporting the superiority of one method over another in this population is lacking. However, based on this review, the use of a direct method would appear to be preferable as they overcome many of the limitations associated with self-report questionnaires (e.g. issues with recall) and are generally considered more accurate.

Of the direct methods considered, accelerometers emerge as the most promising measure of PA behaviour in older care home residents. Specifically, the use of an EE device such as the ActiGraph would appear to provide the best approach to quantify PA. The ability of these accelerometers to provide information not only on the total volume of PA (which is typically low in this population), but also on the frequency, duration, intensity and pattern of PA is an important advantage over other methods. This capability means accelerometers provide an opportunity to define the dose-response relationship between the different characteristics of PA and the associated health benefits; further understand the potential impact of the pattern of PA and ultimately identify modifiable targets for intervention and / or advise on appropriate recommendations for this population (Shiroma et al., 2018).

In addition, whilst EE devices such as the ActiGraph do not assess posture well, no single measure is adequately able to capture both components (EE and posture) of sedentary behaviour (Edwardson et al., 2017). Moreover, it may be surmised that care home residents are unlikely to spend much time standing stationary therefore periods of no movement are likely to reflect seated or reclining positions. Thus, misclassification of light intensity activity is likely to be minimal. It would appear therefore, that the use of an EE device also represents a pragmatic option to the measurement of sedentary behaviour in a care home population, particularly when the primary outcome of interest is PA. However, the use of accelerometers in field-based research is not as established as other methods (e.g. self-report questionnaires) and at present the application of accelerometers (either EE or posture classification devices) in care home setting remains largely unknown.

Hence, the purpose of the following chapter is to synthesise the existing literature detailing accelerometer use to measure PA and sedentary behaviour in field-based research with older care home residents.

Chapter 3 Using accelerometers to measure physical activity and sedentary behaviour in field-based research with older adults residing in care homes: a systematic review of the literature

3.1 Chapter overview

This chapter presents a systematic literature review exploring the use of accelerometers to measure PA and sedentary behaviour in field-based research with older adults residing in care homes. A narrative account of the findings is provided, key findings are summarised and directions for future research are considered.

3.2 Context and rationale for review

There is now ample evidence that engagement in PA has beneficial effects on a range of outcomes related to health in older adults, including those residing in LTC facilities (**section 2.1.2.2**, **Chapter 2**). Hence, the growing interest in the promotion of PA, evidenced by the increasing amount of interventional research being conducted in LTC settings (Jansen et al., 2015; Crocker et al., 2013a), is not surprising. Nevertheless, few studies to date have actually measured PA, instead choosing to focus on examining the effect of PA on another outcome, typically physical function. This is highlighted in the Cochrane review on physical rehabilitation for older adults in LTC, conducted by colleagues within the AUECR, as only seven (10%) of the 67 trials included in the review actually measured PA (Crocker et al., 2013a). This is problematic as understanding the levels and patterns of the PA of care home residents is critical to optimise interventions and advise on appropriate recommendations to improve care in this population. Hence, the identification of appropriate method of assessing PA in older care home residents is an important research priority.

More recently, awareness of the negative impact sedentary behaviour may have on a number of health parameters in older adults has increased (**section 2.1.2.4**, **Chapter 2).** This research has resulted in a shift in the emphasis of the PA guidelines away from simply encouraging MVPA to now suggesting that all older adults should minimise the amount of time they spend being sedentary for extended periods and engage in some PA every day (BHFNC, 2012). These guidelines are more pragmatic for care home residents given observational research suggests they spend the majority of their time sedentary (Sackley et al., 2006). Further, a specific recommendation to reduce time spent sedentary would appear to be particularly prudent for a care home population given many are likely to be frail and thus more vulnerable to the adverse outcomes associated with sedentary behaviour (Manini et al., 2015; Clegg et al., 2013). However, to date, no studies have focused specifically on reducing sedentary behaviour in older care home residents. In order to develop such interventions a thorough understanding of the levels and patterns of sedentary behaviour in this population is needed. Yet, as is the case with PA, there has been limited research into the levels and patterns of sedentary behaviour in older care home residents (Barber et al., 2015; Chin A Paw et al., 2006). This may be attributed to the fact that a true consensus regarding the definition of sedentary behaviour has only recently emerged, therefore an appropriate method of assessing sedentary behaviour in this population is yet to be established (Tremblay et al., 2017).

In the previous chapter, accelerometers were judged to be the most promising method for simultaneously assessing both PA and sedentary behaviour in a care home population. However, the use of accelerometers in field-based research is not as established as other methods (e.g. self-report questionnaires) and at present it is unclear to what extent these monitors are being used in care home settings.

In a previous systematic review of the use of accelerometers for PA monitoring in different groups of older adults, just six of the 134 studies reviewed included older adults residing in a LTC facility (Taraldsen et al., 2012). However, interest in promoting PA and reducing sedentary behaviour in frail older adults, including those residing in LTC facilities, has increased markedly since this review was conducted in 2012 and accelerometers are now more accessible. It was therefore deemed important to conduct a systematic review to gauge what literature already exists and identify gaps in the knowledge base.

3.3 Aim

The primary aim of this review was to synthesise the existing literature detailing accelerometer use in field-based research with older care home residents.

The specific objectives of the systematic review were to:

a) Identify field-based research studies which have employed an accelerometer to measure PA and / or sedentary behaviour in an older care home population.
b) Report on the accelerometer data collection and processing methods utilised.
c) Identify which outcome(s) derived from accelerometers are most appropriate for describing PA behaviour in older care home residents.
d) Describe the PA behaviour of older care home residents.

3.4 Methods

3.4.1 Study inclusion and exclusion criteria

A robust literature search was conducted to identify all research studies (irrespective of study design) which had used an accelerometer to measure PA and /or sedentary behaviour in older adults residing in care homes. Inclusion criteria for studies are described in Table 3.1.

Table 3.1 Inclusion criteria for studies to be considered

1	Report primary data
2	Be a peer-reviewed full-text article (conference abstracts were excluded)
3	Include older adults (≥ 65 years of age) who reside in a care home*
4	Use an accelerometer to measure PA or sedentary behaviour (i.e. report on the level of PA and/ or sedentary behaviour)
5	Full text available in English

*A care home was defined based on the following characteristics: provides overnight accommodation and communal living facilities for long-term care; provides nursing or personal care and provides for people with illness, disability or dependence (Crocker et al., 2013a).

3.4.2 Study identification

3.4.2.1 Electronic search

A comprehensive search strategy (**Appendix B**) was developed with guidance from an information specialist. This search strategy, with appropriate adaptations, was used to search the following databases (n = 7) in October 2017: MEDLINE, EMBASE, Sport discus, *the Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (CINAHL),* PsyINFO and Physiotherapy Evidence Database (PEDro). In light of recent technological advancements in terms of accelerometers and the increased interest in the PA and sedentary behaviour of older adults residing in care homes, this search focused on studies published since 2012.

An initial screening of identified titles and abstracts, guided by the inclusion criteria (Table 3.1), was conducted to identify potentially relevant papers. Studies that did not meet the inclusion criteria were excluded. The full texts of those studies deemed potentially relevant were reviewed by the researcher (JA) and a final decision was made about the studies eligibility for inclusion.

3.4.2.2 Searching other sources

Colleagues within the AUECR are currently updating the Cochrane review of physical rehabilitation for older adults in LTC (Crocker et al., 2013a), a seminal piece of work in the area of care home research. As per the original review, studies included in the update will be either a randomised controlled trial (RCT) or cRCT that evaluated physical rehabilitation programmes for older people in care homes.

After discussing this review with members of the review team it became apparent that there was considerable overlap in both the search terms and the inclusion criteria for this review. Thus, the titles and abstracts of those articles meeting the inclusion criteria for the update of the Cochrane review were also screened to assess their eligibility for inclusion in this review based on the criteria detailed in Table 3.1.

3.4.3 Data extraction and synthesis

For all studies meeting the inclusion criteria two standardised forms were created to guide data extraction. First, in order to describe the studies in sufficient detail, the following data were extracted: author, year of publication, country of study, study aim(s); study design; LTC setting; sample information (inclusion / exclusion criteria, % eligible, sample size, analysis sample); participant characteristics (% female, age) and the key outcomes assessed.

As stated in the inclusion / exclusion criteria, in this review the term 'care home' refers to all facilities which provide overnight accommodation and communal living facilities together with nursing or personal care for people with illness, disability or dependence. Thus, the term encompasses residential homes, nursing homes and assisted living (AL) facilities. Given the provision of care and services provided differs across these facilities (Luff et al., 2015) it was deemed important to extract information on the setting in which the studies were primarily conducted.

It was also considered important to acknowledge any differences in the accelerometer data collection and processing methods when interpreting and synthesising findings as these may have an effect on the outcomes derived from the accelerometer data (Mâsse et al., 2005). Thus, the following data relating to the accelerometer data collection and processing were extracted: accelerometer brand and model; accelerometer wear location; monitoring period; criteria for valid data and the outcomes derived from the accelerometer data.

Where data were collected from the same participants at different time points (for example, pre and post an intervention), only baseline data were extracted. A narrative approach was used to synthesise the extracted data.

3.5 Results

3.5.1 Study Identification

A total of 5,444 references were identified though the database search conducted. An additional 51 articles were identified through searching other sources (i.e. the Cochrane review) (Figure 3.1). After the removal of duplicates, 3,675 references were screened and the full text of 45 articles deemed potentially relevant based on the title and abstract were reviewed. Of these, 27 articles were excluded (reasons provided in Figure 3.1). Thus, 18 studies employing an accelerometer to measure PA and / or sedentary behaviour in older adults residing in a care home were included in the synthesis.

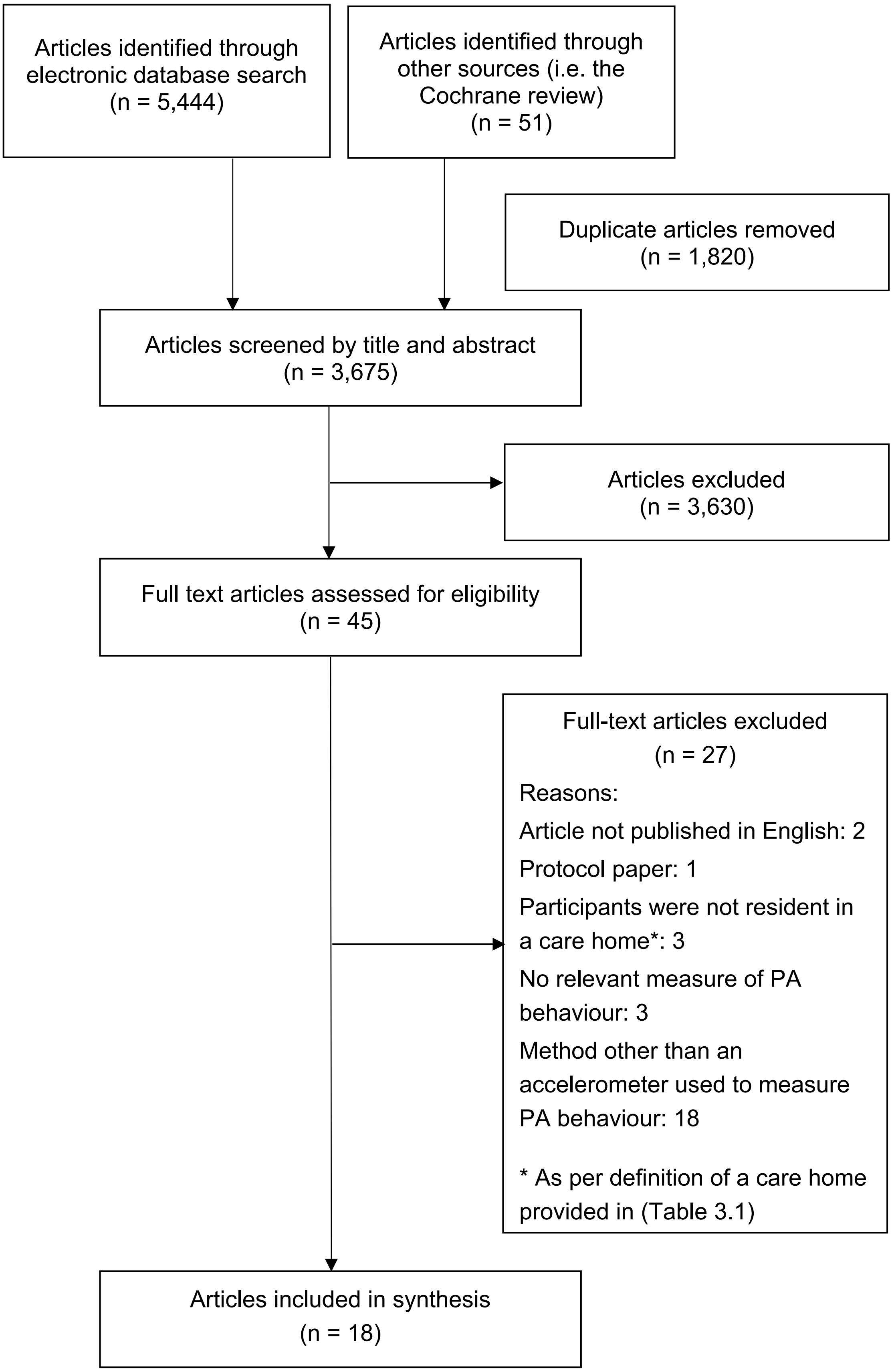


Figure 3.1 Flow diagram detailing the study selection process.

3.5.2 Overview of included studies

Characteristics of the included studies are detailed in Table 3.2. The number of relevant articles published was higher in 2017 compared to previous years. Seven of the included studies were published in 2017, three in 2016, five in 2015, one in 2014 and two in 2013. This likely reflects the evolution in technology and increased interest in PA and ageing research. The studies conducted were predominately cross-sectional (n = 12), with only four of the included studies reporting on an RCT. With regards to the other two studies, one was described as a quasi-experimental longitudinal study and the other as a pilot study.

Five of the included studies were conducted in the United States (USA), two each in the UK, Belgium and Australia and then one in Canada, Chile, Japan, Netherlands and Portugal. Two studies did not report on the country they were conducted in (Table 3.2). Seven studies were undertaken in a nursing home and four were undertaken in residential homes, with one study being conducted in both a nursing and a residential home. Six studies were undertaken in AL facilities (Table 3.2).

All of the studies except Park et al (2017) and Galik et al (2015) stated some eligibility / inclusion criteria (Table 3.2). A minimum age limit was one of the most consistent criteria reported with studies requiring participants to be aged ≥ 65 y (n = 8), ≥ 60 y (n = 2) or ≥ 55 y (n = 3). Some studies also stated that only those residents with an expected length of stay of ≥ 6 months (n = 2) or ≥ 12 months (n = 1) were included.

Notably, the majority of studies (n = 11) stated inclusion and / or exclusion criteria based on participants' mobility. The ability to stand and mobilise independently with or without a walking aid was a requirement of eight studies. A further two studies stated regular wheelchair use as an exclusion criteria. A variety of other health criteria were also reasons for exclusion. Six studies excluded participants who were acutely unwell or in receipt of palliative / hospice care. Five studies identified a variety of specific diseases / conditions as reasons for exclusion, including obesity (n = 1), acute neurological impairments such as stroke (n = 1), severe musculoskeletal impairment (n = 1), chronic obstructive pulmonary disease with dyspnoea (n = 1); any terminal disease (n =1), decompensated metabolic illness (n = 1), asthma (n =1), behavioural issues or physical limitations which would make data collection difficult (n = 3). One study ruled out participants if they were deemed not to be medically fit to exercise.

A number of the studies also either included or excluded participants based on their cognitive function (Table 3.2). Six studies purposively included those residents with dementia or cognitive impairment. Conversely, a total of ten studies excluded participants based on their cognitive function. Four studies excluded participants based on a dementia diagnosis or severe cognitive impairment; four studies stated in their inclusion criteria that participants needed to be able to understand instructions or able to provide written informed consent and a further two studies required participants to attain a minimum score on a cognitive impairment test (e.g. Mini Mental State Examination [MMSE]).

The sample size (i.e. those that met the studies' specific inclusion criteria) of included studies ranged from ten participants to 307 participants (Table 3.2). Five studies included more than 100 participants. Eight studies included less than 50 participants and two of these studies were particularly small with less than 20 participants. In addition to reporting the overall sample size, fifteen studies explicitly reported on the number of participants whose data contributed to the estimates of PA behaviour derived (i.e. the PA sample size in Table 3.2). In eight of these studies the PA sample size was smaller than the study sample size reported. The difference between the study sample size and PA sample size ranged from one to 81.

The participant data collected (beyond the basic demographic information such as gender and age recorded in Table 3.2) varied considerably across the studies considered. As a result, it was difficult to summarise the characteristics of participants and ultimately posed challenges in terms of making direct comparisons across studies. All but one study did report on the gender of included participants. A considerable proportion of participants in the studies considered were women (lowest proportion reported was 64% female), with one study exclusively including female participants. The mean age of participants in all of the included studies was above 80 years. This was unsurprising given that the majority of studies (n = 12) stated a minimum age limit of at least 55 years as a criterion for inclusion.

In addition to PA behaviour, other outcomes commonly assessed were: physical function or mobility (n = 13), one or more components of physical fitness (n = 3), cognitive performance (n = 7), mood (n = 8), agitation (n = 5), apathy (n = 3) and quality of life (n = 2). All of the unique outcomes addressed, along with the specific outcome measures used in each of the studies, are listed in Table 3.2.

Table 3.2 Characteristics of included studies (n = 18).

Study	Study aims	Study design	Participants	Key Outcomes
1. Mouton et al (2017)*	To examine the effects of a giant (4×3 m) exercising board game intervention on ambulatory physical activity (PA) and a broader array of physical and psychological outcomes among nursing home residents.	Quasi-experimental longitudinal study	**Country:** Belgium **Setting:** Nursing homes (selected according to similarities in terms of number of beds (> 90), services (e.g. nursing care, physical therapy, social and physical activities) and their environment (n = 2) **% Eligible:** 35% **Sample size:** n = 21 Two groups of participants: 1. Intervention group: n = 10 2. Control group: n = 11 **Analysis sample:** n = 21 Intervention group: n = 10 Control group: n = 11 **% female:** 67% Intervention group: 60% Control group: 73% **Age:** Range = 79 y - 91 y Intervention group: Mean = 82.5 y ± 6.3 y	**PA behaviour:** steps$\cdot$day^{-1} and EE (kcal$\cdot$day^{-1}) **Physical function:** Tinetti test; Short Physical Performance Battery (SPPB); the Timed Up and Go Test (TUGT) **Physical fitness:** Muscular isometric strength **Cognitive status:** MMSE **QOL**: EQ5D **Motivation for PA:** Behavioural Regulation in Exercise Questionnaire-2 (BREQ-2) French version

			Control group: Mean = 89.3 y ± 3.1 y **Inclusion criteria**: Aged ≥ 65 y; able to provide informed consent and understand the questionnaires (MMSE score > 18 out of 30); be able to walk and stand, including with technical assistance (assessed by the physiotherapist in the nursing home). **Exclusion criteria:** Not reported **PA sample size:** n = 21 Intervention group: n = 10 Control group: n = 11	
2. Taylor et al (2017)*	To investigate the effect of exergames on the mobility of LTC residents with and without cognitive impairment	Two-arm cRCT	**Country**: Not reported **Setting:** Low-level dependency LTC facilities‡ (n = 9) in one city **% Eligible:** 42% **Sample size:** n = 65 Two groups of participants: 1. Intervention group: n = 29 2. Control group: n = 36 **Analysis sample:** n = 58 Intervention group: n = 26 Control group: n = 32 **% female:** 74%	**PA behaviour:** % of time spent upright (i.e. in ambulation or standing) **Physical function / Mobility:** de Morton Mobility Index (DEMMI); TUGT **Cognitive status**: abbreviated mental test score

			Intervention group = 77% Control group = 72% **Age:** Intervention group: Median = 86.8 y Control group: Median = 85.8 y **Inclusion criteria:** Aged ≥ 65 y, could mobilise independently with or without a walking aid and who were able to understand study instructions **Exclusion criteria:** Acutely unwell, had a visual impairment such that they could not see a large television screen **PA sample:** n = 30 Intervention group: n = 8 Control group n = 22	
3. Park et al (2017)	To use latent profile analyses to identify classes of older participants based on physical health, physical function, light physical activity (PA) moderate-to-vigorous PA, and sedentary behaviour,	Cross-sectional	**Country:** England **Setting:** AL facilities (n = 13) **% Eligible:** not reported **Sample size:** n = 101 **Analysis sample size:** n = 85 **% female:** 68.2% **Age:** Mean = 77.5 y ± 8.2 y, Range = 65 y – 99 y	**PA behaviour:** time spent engaging in sedentary behaviour, light PA and moderate PA **Body composition**: height, weight and BMI **Lung function**: hand-held spirometer **Physical function / mobility**: grip strength; TUGT

	and then examine differences in mental health between these classes		**Inclusion criteria:** None reported **Exclusion criteria:** Requiring a scooter or wheelchair for daily activities **PA sample:** n = 85	**Subjective physical and mental health:** 12-item short-from health survey (SF-12) **Anxiety and Depression**: Hospital Anxiety and Depression Scale (HADS) **Fatigue:** Multiple Fatigue Index (MFI-20) **QOL**: Dartmouth CO-OP Chart
4. Leung et al (2017)	To determine the prevalence of sedentary behaviour and its association with physical, cognitive, and psychosocial status among older adults residing in assisted living	Cross-sectional	**Country:** Canada **Setting:** AL sites with publicly funded units in the Fraser Health Authority region of greater Vancouver (n = 13) **% Eligible:** 93% **Sample size:** n = 148 **Analysis sample size:** n = 114 **% female:** 85% **Age:** Mean = 86.7 y ± 7.5 y **Inclusion criteria:** Aged ≥ 65 y, could read and understand simple directions in English and did not regularly use a wheelchair to move about **Exclusion criteria:** None reported **PA sample**: n = 114	**<u>PA behaviour</u>:** time spent engaging in sedentary behaviour, light PA and moderate PA; average number of sedentary bouts (≥ 1 consecutive minutes) per day and the average duration of the sedentary bouts **Physical function / mobility**: TUGT and SPPB **Cognitive status**: Montreal Cognitive Assessment (MoCHA) **Mood:** Short Geriatric Depression Scale (GDS) **Falls:** Modified Fall Efficacy Scale (MFES)

5. Marmeleira et al (2017)	To examine physical activity (PA) behaviour and physical fitness of institutionalized older adults with cognitive impairment and to investigate their interrelations.	Cross-sectional	**Country:** Portugal **Setting:** Nursing homes (n = 4) **% Eligible:** not reported **Sample size**: n = 70 Two groups of participants: 1. Cognitive impairment (CI) group: n = 48, 2. Without cognitive impairment (WCI) group: n = 22 **Analysis sample size**: as above **% females:** 67% CI group = 72.9% WCI group = 54.5% **Age:** Range = 65 y – 106 y CI group: Mean = 83.9 y ± 7.7 y WCI group: Mean = 82.2 y ± 8.8 y **Inclusion criteria:** Living in a nursing home, aged ≥ 65 y, capable of walking without the assistance of another person **Exclusion criteria:** none **PA sample size:** n = 38 CI group: n = 29 WCI group: n = 9	**PA behaviour:** Time spent engaging in sedentary behaviours, light PA and moderate PA; pattern of hourly mean PA, accelerometer cpm, steps·day^{-1} **Physical fitness**: Senior Fitness Test Battery **Balance:** Functional reach test and Berg balance test **Simple reaction time**: Deary-Liewald Reaction Time Task

6. Moyle et al (2017)	To objectively measure over a 24-h period the daytime and night-time levels of physical activity (PA) and sleep patterns of older people with dementia living in LTC facilities.	Cross-sectional	**Country**: Australia **Setting:** LTC facilities in south-east Queensland (n = 28) **Sample size:** n = 415 **Analysis sample size:** n = 192 **% female**: 74% **Age:** Mean age: 85.5 y ± 7.7 y **Inclusion criteria:** Documented diagnosis of dementia, aged ≥ 60 y **Exclusion criteria:** none **PA sample size:** n = 192	**PA behaviour:** Step count (n); total EE (kJ); METs; time spent in PA (i.e. MET > 1.5), lying down and awake **Sleep**: time spent asleep overall, in light sleep, in deep sleep and in very deep sleep **Cognitive status:** Rowland Universal Dementia Assessment Scale (RUDAS) **Agitation**: Cohen-Mansfield Agitation Inventory Short From (CMAI-SF)
7. Bucknix et al (2017)	To assess the relationship between results obtained with the pebble trackers (in step 2) and subjects' clinical characteristics, linked to physical frailty	Cross-sectional	**Country:** Belgium **Setting:** Nursing home (n = 1) **Sample size:** n = 27 **Analysis sample:** n = 27 **% female:** 75% **Age:** Mean = 86.7 y ± 7.8 y **Inclusion criteria:** Aged ≥ 65 y, able to stand and walk, able to provide written informed consent **Exclusion criteria:** Disorientated; occasional and temporal dysfunction **PA sample size:** n = 27	**PA behaviour:** steps·day^{-1}

8. Klinedinst et al (2016)	The purposes of this study were to [1] establish feasibility of the Volunteering-in-Place (VIP) Program based on treatment fidelity (design, treatment, delivery, enactment); and [2] evaluate preliminary efficacy via improvement in psychological health and decreased sedentary activity at 3 and 6 months.	Single-site pre-test/post-test pilot study	**Country:** Not reported **Setting:** AL facility **% Eligible:** 92% **Sample size:** n = 10 **Analysis sample size:** n = 10 **% female:** 80% **Age**: Mean = 88.1 y ± 9.8 y **Inclusion criteria:** Live in the AL setting, aged ≥ 65 y and score ≥ two on the three-item recall of the Mini-Cog. **Exclusion criteria**: Unable to pass the evaluation sign to consent **PA sample size:** n = 9	**PA behaviour:** steps·day^{-1} (FitBit); time spent engaging in PA (Yale Physical Activity Survey) **Depressive symptoms**: Patient Health Questionnaire-9 (PHQ-9) **Sense of usefulness**: single item Likert scale **Purpose in life**: 10-item scale derived from the Ryff's Scales of Psychological Well-Being **Psychological resilience**: Dispositional Resilience Scale II-Short Form **Life satisfaction**: AL Resident Life Satisfaction Tool
9. Corcoran et al (2016)	To describe levels of physical activity among older adults residing at assisted care facilities and their association with physical function	Cross-sectional	**Country:** USA **Setting:** Assisted care facilities within the greater Boston area (n = 20) **Sample size:** n = 146 **Analysis sample size:** n = 65 **% female:** 86% (n = 56) **Age:** Mean = 83.4 y ± 8 y, Range: 65 y - 99 y	**PA behaviour:** Time spent engaging in sedentary behaviours, light PA, lifestyle PA and MVPA; steps·day^{-1} **Physical function / Mobility:** SPPB; 400m walk time and maximum handgrip strength

			Inclusion criteria: Aged ≥ 65 y, were medically fit to exercise **Exclusion criteria:** Severe obesity (BMI ≥ 35 kg/m^2), severe cognitive impairment (6-CIT score >14); intention to move out of the facility within the next 12 months. 'Active' residents (i.e. those engaging in ≥ 125 minutes / week of MVPA (questionnaire) were also excluded **PA sample size:** n = 65	
10. van Alphen et al (2016)†	To objectively assess the physical activity (PA) levels of community dwelling and institutionalized ambulatory patients with dementia, and to compare with the PA levels of cognitive healthy older adults.	Cross-sectional	**Country:** Netherlands **Setting:** Nursing homes (n = 13) **% Eligible:** not reported **Sample size:** n = 83 **% female:** 80% **Age:** Mean = 83 y ± 7.6 y **Analysis sample size:** n = 83 **Inclusion criteria:** Diagnosis of dementia, ambulatory (with or without walking aid), ActiGraph data for ≥ 6 d, 24-h day **Exclusion criteria:** No dementia diagnosis documented in medical records; missing or insufficient accelerometer data **PA sample size:** n = 83	**PA behaviour:** Total volume of PA (counts·day^{-1}), time spent sedentary and in specific zones of activity counts with ranges of 100 cpm

11. Friedmann et al (2015)	Evaluate the effectiveness of the Pet AL (PAL) intervention to support physical, behavioural, and emotional function in AL residents with cognitive impairment	RCT	**Country:** USA **Setting:** AL facilities (n = 7) **Sample size:** n = 40 **Analysis sample size:** **% female**: 72.5% **Age:** Mean = 80.7 y ± 9.1 y, Range: 56 y – 95 y **Inclusion criteria**: Mild to moderate cognitive impairment (MMSE score > 8 and < 23), aged ≥ 55 y, anticipated length of stay in the AL facility of ≥ 6 months, English speaking, and with either prior experience with or interest in interacting with a dog **Exclusion criteria:** Known allergies to or fear of dogs, a physical illness like asthma that is exacerbated in the presence of a dog, or receiving hospice care **PA sample size:** n = 40	**PA behaviour:** PA EE ($kcal{\cdot}day^{-1}$) and time spent in MVPA **Physical function:** BI **Emotion function**: 7-Item Apathy Evaluation Scale (AES) **Mood:** Cornell Scale for Depression in Dementia (CSDD) **Behavioural function:** Cohen-Mansfield Agitation Inventory (CMAI)
12. Resnick and Galik (2015)	To describe and compare clinical outcomes of residents with moderate to severe cognitive impairment	Cross-sectional	**Country:** USA **Setting:** Residential Care Facilities (RCF) and Nursing Homes (NH) **% Eligible:** 46%	**PA behaviour:** Total volume of PA ($counts{\cdot}day^{-1}$), time in moderate PA and PA EE ($kcal{\cdot}day^{-1}$) **Physical function**: BI **Agitation**: CMAI

	living in residential care facilities (RCFs) and nursing homes (NHs)		**Sample size:** n = 199 Two groups of participants: 1. RCF group: n = 96 2. NH group: n = 10 **Analysis sample size:** n = 199 RCF group: n = 96 NH group: n = 10 **% female**: 74% RCF group: 71% NH group: 77% **Age:** Range = 83 y - 85 y RCF group: Mean = 85.6 y ± 7.2 y NH group: Mean = 83.8 y ± 10 y **Inclusion criteria:** Aged ≥ 55 y, MMSE score ≤ 15 (indicative of moderate-severe cognitive impairment) **Exclusion criteria:** Enrolled in hospice or receiving skilled rehabilitation services **PA sample size:** not explicitly reported	**Mood:** CSDD **Apathy:** AES
13. Pakozdi et al (2015)†	To assess total Energy Expenditure (EE) in healthy Chilean institutionalised and	Cross-sectional	**Country:** Chile **Setting:** Nursing home (n = not reported) **% Eligible:** not reported **Sample size**: n = 27	**PA behaviour:** The PA level (PAL) (calculated as the ratio of total EE/ resting EE) and PA EE ($kcal \cdot day^{-1}$) **Physical function**: TUGT

	community-dwelling individuals		**Analysis sample size:** n = 26 **% female:** 85% **Age:** Mean = 82 y ± 4.6 y **Inclusion criteria:** Aged ≥ 65 y; non-smoking; able to climb the first steps of stairs without a break; no hospitalisation within three months prior to the study and the absence of the following: [1]severe organ failure, [2]any terminal diseases, [3]decompensated metabolic illnesses; [4]use medications that could interfere with EE; [5]chronic obstructive pulmonary disease with dyspnoea; [6]involuntary weight loss of > 2 kg in the last three months, [7]physical handicaps that might interfere with body composition measurements; [8]acute medical treatment. **Exclusion criteria:** none explicitly reported **PA sample size:** n = 26	**Body composition:** Double X-ray Absorptiometry (DEXA) **Cognitive status:** MMSE **Nutrition:** Mini Nutritional Assessment (MNA) **Anthropometric measurements:** height, weight, calf and mid-arm circumference
14. Galik et al (2015)	To test the impact of The Function Focused Care Intervention for the Cognitively Impaired	6-month cRCT	**Country:** USA **Setting:** AL facilities (n = 4) **% Eligible:** 88% **Sample size**: n = 96	**PA behaviour:** Total volume of PA (counts·day^{-1}) and PA EE (kcal·day^{-1}) and PAS-LTC **Physical function**: BI

	(FFC-CI) on function, physical activity (PA), behaviour and falls.		Two groups of participants: 1. Intervention group: n = 48 2. Control group: n = 48 **Analysis sample size:** n = 96 Intervention group: n = 48 Control group: n = 48 **% female:** 71% Intervention group = 69% Control group = 73% **Age:** Mean = 84 y ± 7.1 y Intervention group: Mean = 83 y ± 7 y Control group: Mean = 84 y ± 7 y **Inclusion criteria:** Aged ≥ 55 y, lived in the AL at the time of recruitment; a MMSE score of ≤ 15; anticipated length of stay of ≥ 6 months **Exclusion criteria:** hospice, non-communicable **PA sample size:** not explicitly reported	**Anxiety / Agitation:** CMAI-SF **Depression:** CSDD **Apathy:** AES
15. Barber et al (2015)	To describe, using accelerometers, the habitual levels and daily and weekly patterns of physical activity (PA) and	Cross-sectional	**Country:** UK **Setting:** Care homes (n = 5) **% Eligible:** 51% **Sample size**: n = 33	**PA behaviour:** Total volume of PA (activity counts·day^{-1}), activity cpm, PA EE (kcal·day^{-1}), time spent engaging in sedentary behaviours, low PA, light PA and MVPA

	sedentary behaviours in older care home residents. The study also aimed to examine personal factors related to PA and sedentary behaviour		**Analysis sample size**: n = 28 **% female:** 64% **Age:** Mean = 82.6 y ± 9.2 y **Inclusion criteria:** None explicitly reported **Exclusion criteria:** Serve dementia, severe psychological disorder, acutely unwell or receiving palliative care. **PA sample size:** n = 28	**Physical function / Mobility:** BI and Functional Ambulation Category (FAC) **Cognitive status:** MMSE
16. Galik et al (2014)	To test the impact of the Function Focused Care intervention for the Cognitively Impaired (FFC-CI) on nursing home residents with dementia and the nursing assistants who care for them.	6-month cRCT	**Country:** USA **Setting:** Nursing homes (n = 4) **% Eligible:** 62% **Sample size:** n = 103 **Analysis sample size:** not explicitly reported **% female**: 77% **Age**: Mean = 83.7 y ± 9.9 y **Inclusion criteria:** Aged ≥ 55 y, MMSE score ≤ 15 (indicative of moderate-severe cognitive impairment); an anticipated length of stay of ≥ 6 months **Exclusion criteria**: none reported **PA sample size:** not explicitly reported	**PA behaviour:** Total volume of PA (counts·day^{-1}) and PA EE (kcal·day^{-1}) and the PAS-LTC **Physical function**: Tinetti scale and BI **Behaviour**: CMAI-SF **Mood:** CSDD **Apathy**: AES

17. Reid et al (2013)	To determine the feasibility of using the activPAL3™ activity monitor, and, to describe the activity patterns of residential aged care residents	Cross-sectional	**Country:** Australia **Setting**: Aged care facilities within 100km of the Gold Coast, Queensland (n = 11) **% Eligible:** 84% **Sample size:** n = 41 **Analysis sample:** n = 31 **% female:** 64.5% **Age:** 84.2 y **Inclusion criteria:** Ambulatory, ≥ 60 y, no cognitive impairment **Exclusion criteria:** dementia, non-ambulatory, pacemaker, end-stage palliative or terminal, behavioural problems that would endanger the researcher or medical conditions which would make data collection difficult (e.g. severe dementia, uncommunicable deafness) **PA sample size:** n = 31	**PA:** Time spent in differing postures (i.e. sitting and lying) and time spent stepping **Body composition**: BMI **Physical function/ Mobility:** SPPB **Cognitive status:** MMSE **Mood:** GDS
18.Ikezoe et al (2013)	Investigate the relationship between daytime physical activity patterns and physical fitness in elderly women	Cross-sectional	**Country:** Japan **Setting:** Nursing home (n = 1) **% Eligible:** not reported **Sample size**: n = 19 **Analysis sample size**: n = 19 **% female:** 100%	**PA behaviour:** Time spent in differing postures (i.e. upright (walking and standing), sitting and lying) and steps·day^{-1} **Physical function / Mobility**: maximal walking test and TUGT

			Age: Mean = 83.8 y ± 8 y **Inclusion criteria:** Able to ambulate independently or with an assistive device, no unstable condition, no dementia **Exclusion criteria**: Physical dysfunctions that may influence outcome measures, such as acute neurological impairment (acute stroke, Parkinson's, paresis of the lower limbs), severe musculoskeletal impairment and severe cognitive impairment. **PA sample size:** n = 19	**Physical fitness:** Muscular strength (hand-held dynamometer); balance test (One-Legged Stance Test (OLST); postural sway, stepping test; flexibility test

Note: PA sample size = the number of participants who had valid PA data; the outcome underlined = the primary outcome measure.

* Identified through additional sources; † Data from participants recruited from LTC facilities only

‡ Low-level dependency residents are those who need assistance with most instrumental ADLs and some ADLs but usually can ambulate and feed themselves.

3.5.3 Accelerometer data collection and processing methods

The key results from each of the studies, alongside details about the accelerometer data collection and processing methods used, are provided in Table 3.3.

The majority of studies (n = 15) utilised a research-grade accelerometer. Of these, ten used an ActiGraph monitor. Other research-grade accelerometers utilised were: Dynaport MoveMonitor, Sensewear Armband, Actiwatch, Actiheart and activPAL. Two studies utilised consumer devices (Pebble+ and FitBit Flex) and one study used a bespoke device.

Most of the studies employing an ActiGraph accelerometer (n = 8), necessitated participants to wear the device on the hip. Mouton et al and Friedmann et al however, opted for a different wear location; asking their participants to wear the accelerometer on the ankle and chest respectively. The bespoke device used in the study conducted by Ikezoe et al was also worn on the hip. Other wear locations included the wrist, arm, thigh and participant’s shoe. Two studies did not explicitly report on accelerometer wear location.

All of the studies provided some information regarding the accelerometer monitoring period; however, the level of detail varied (Table 3.3). In accordance with much of the literature measuring habitual PA behaviour, six studies employed a seven-day monitoring period. Still, other monitoring periods were employed. Corcoran and colleagues asked their participants to wear the accelerometer over ten days whereas two of the more recent studies opted for a shorter, three-day monitoring period. Six studies took a different approach and choose to monitor the PA behaviour of their participants over a single day. As well as the length of the monitoring period, most studies reported whether participants were asked to wear the accelerometer continuously (i.e. 24-h a day) (n = 8) or during waking hours only (n = 8). The remaining two studies did not report on this.

3.5.4 Physical Activity behaviour outcomes

As a consequence of the variation in the aims of the studies included (Table 3.2) and the accelerometer used, several different PA behaviour outcomes were reported on (Figure 3.2). A synopsis of the key findings will be presented for each of the PA outcomes separately below.

3.2.1.1 Activity counts

Five studies reported on the total activity counts per day (counts·day^{-1}) as a proxy measure of the total volume of PA performed (Table 3.3). In four of these studies participants wore an ActiGraph accelerometer on the hip. In these studies, the mean counts·day^{-1} reported varied considerably and ranged between 18,810 counts·day^{-1} (standard error (SE) = 3,007 counts·day^{-1}) (Galik et al., 2014) and 113,477 counts·day^{-1} (SE = 16,633 counts·day^{-1}) (Barber et al., 2015). Participants in the other study wore an ActiWatch accelerometer on their dominant wrist. The mean counts·day^{-1} reported in this study were 169,000 counts·day^{-1} (SE = 14,426 counts·day^{-1}) (van Alphen et al., 2016).

Two studies reported on activity counts per minute (cpm) as a global measure of PA (Table 3.3). Estimates from both studies were similar (80 cpm [SD = 39 cpm] and 150 cpm [SD = 123 cpm]). Whilst controversial, a threshold of < 100 cpm is often used to define sedentary behaviour in studies involving older adults (Jefferis et al., 2015; Sartini et al., 2015). Based on this definition, the findings reported by Corcoran et al and Barber et al suggest older adults residing in care homes are predominately sedentary.

3.2.1.2 Physical activity and sedentary time

Five studies, all of which necessitated participants to wear a hip-worn ActiGraph accelerometer during all waking hours, reported estimates of time spent engaging in different intensities of PA and sedentary behaviour (Table 3.3). Four studies reported estimates as a daily average and one as a weekly average. Still, the findings were similar. Older adults residing in care homes spent a considerable amount of their time (between 8 h 32 min [SD = 1 h 46 min] and 10 h 54 min [SD not available] daily) sedentary. Moreover, the little PA they did engage in was predominately of low intensity. For example, Marmeleria and colleagues reported that the participants in their study with cognitive impairment spent an average of 1 h 30 min (SD = 48) engaging in total PA, yet the mean daily time spent engaging in MVPA was 1 min (SD = 1 min). Similar estimates of MVPA were reported across studies (range between 1 min and 10 min [SD = 14 min]), with many studies also stating that this equated to less than 1% of waking time.

3.2.1.3 Physical Activity Energy Expenditure (PA EE)

The PA outcome most often reported on was PA EE (n = 8, Figure 3.2). Six studies employed the ActiGraph accelerometer; one study used the Sensewear Armband and one study used the Actiheart monitor (Table 3.3). Seven of the eight studies reported on PA EE in terms of number of calories expended in a day (kcal·day^{-1}). Thus, to enable direct comparison with the results from these studies, the data reported by Moyle et al 2017 was also converted to kcal.day^{-1} (from kilo-Joules (kJ) expended per day). In general, PA EE estimates derived from the ActiGraph accelerometers were lower (between 21 kcal·day^{-1} [SE = 3.2 kcal·day^{-1}] and 115 kcal·day^{-1} [SE = 17 kcal·day^{-1}]) than those derived from either the Actiheart (171 kcal·day^{-1} [Range = 127 kcal·day^{-1} - 374 kcal·day^{-1}]) or Sensewear Armband (850 kcal [SD = 220 kcal). Mouton et al.'s study was the exception to this (Mean PA EE =1753 kcal.day^{-1} [Range = 1639 kcal·day^{-1} -1877 kcal·day^{-1}]).

3.2.1.4 Steps

In seven studies the number of steps participants accumulated per day (steps·day^{-1}) was reported (Table 3.3). Three of these studies employed an ActiGraph monitor, two of which asked participants to wear the accelerometer on their hip while the other required participants to wear the accelerometer on the ankle. One study used the Sensewear Armband, two used a consumer-grade device and one used a bespoke device. The mean number of steps·day^{-1} did vary across studies and ranged from 308 ± 803 steps (Moyle et al., 2017) to 3,387 ± 731 steps·day^{-1} (Mouton et al., 2017). Perhaps unsurprisingly, the highest estimate was reported in a study which opted for the ankle as the chosen wear location whereas the lowest estimate was derived from the SenseWear Armband, worn over the triceps of the participant's non-dominant arm.

3.2.1.5 Time spent in different postures

Compared to the other PA metrics, fewer studies (n = 4) reported on the time participants spent in different postures (i.e. standing, sitting and lying). Two studies reported on the time participants spent upright (walking and standing), sitting and lying down. In contrast, the other studies tended to report on either the time spent upright or time spent sitting and / or lying down (Moyle et al., 2017). Nonetheless, it can be inferred that older adults residing in care homes spend the majority of their time either sitting or lying and their time standing or walking is limited. For example, the participants in the study conducted by Reid et al (2013) spent a median (inter-quartile range [IQR]) of 12 h 24 min (1 h 42 min) either sitting or lying down. Similarly, Ikezoe et al (2013) reported that the participants in their study spent approximately 75% of the monitoring period (i.e. between 10:00 and 16:00) either sitting or lying down. These findings are in accordance with Taylor et al who reported that their participants spent approximately 15% of their waking day standing or in ambulation (Table 3.3).

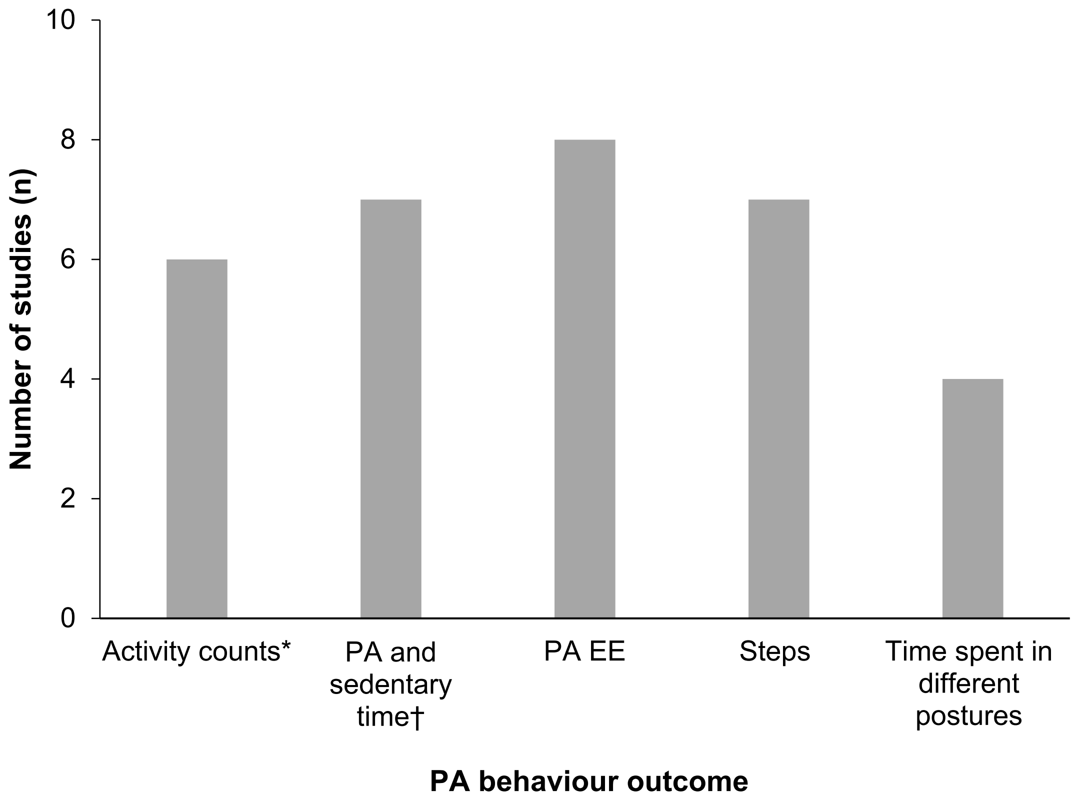


Figure 3.2 The PA behaviour outcomes reported on in the included studies (n = 18). *studies reported on counts·day^{-1} and / or counts·minute^{-1}, † Five studies reported on PA and sedentary time, one study reported on MVPA time only and one study reported on sedentary time only.

Table 3.3 Key accelerometer data collection and processing methods and PA behaviour data

Study	Accelerometer brand (model)	Accelerometer wear location	Monitoring Period	Criteria for valid data	PA behaviour data
1. Mouton et al (2017)*	ActiGraph (GT3X+)	Ankle, above the right malleolus (secured by an elastic strap)	Waking hours, 3 consecutive days (research assistant put the monitor on and took it off each day)	A valid day = non-missing counts for < 80% of the measurement day	**Activity counts:** n/r **Physical activity and sedentary time:** n/r **PA EE:** Control group: Mean = 1,658 kcal·day^{-1} (Range = 1,569 kcal·day^{-1} – 1,794 kcal·day^{-1}) Intervention group: Mean = 1,753 kcal·day^{-1} (Range = 1,639 kcal·day^{-1} – 1,877 kcal·day^{-1}) **Steps:** Control group: Mean ± SD = 3,387 steps·day^{-1} ± 731 steps·day^{-1} Intervention group: Mean ± SD = 2,921 steps·day^{-1} ± 1,352 steps·day^{-1} **Posture:** n/a
2. Taylor et al (2017)*	Dynaport MoveMonitor	Not reported (designed to be positioned on the lower back, height of the second lumbar vertebra)	10:00 – 20:00, 3 days	Not reported	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** n/a **Steps:** n/a **Posture**: Percentage time spent standing or in ambulation:

					Control group: Median = 15.04% (Q1:9.55%; Q3: 20.41%) Intervention group: Median = 13.8% (Q1: 9.25%; Q3: 20.09%)
3. Park et al (2017)	ActiGraph (GT3X+ and WGT3X-BT)	Right hip	Waking hours (07:00 -22:30)	≥ 10 hours ≥ 3 days, including 1 weekend day	**Activity counts**: n/a **Physical activity and sedentary time**: Mean ± SD daily time spent: Sedentary = 512 min ± 106 min Light PA = 201min ± 72 min MVPA = 10 min ± 10 min **PA EE:** n/a **Steps:** n/a **Posture**: n/a
4. Leung et al (2017)	ActiGraph (GT1M)	Waist	Waking hours, 7 consecutive days	≥ 8 hours ≥ 3 days	**Activity counts**: n/a **Physical activity and sedentary time**: Mean percentage time spent: Sedentary = 86.9% (10.9 h) Light PA = 12.9% (1.6 h) MVPA: 0.1% (1 min) Average number of sedentary bouts per day = 51.5 Average sedentary bout duration = 13 min **PA EE:** n/a **Steps:** n/a **Posture**: n/a

5. Marmeleira et al (2017)	ActiGraph (GT1M)	Hip	Waking hours, 7 consecutive days	≥ 8 hours ≥ 3 days	**Activity counts**: CI group: Mean ± SD = 60.1 cpm ± 28 cpm WCI group: Mean ± SD = 84.7 cpm ± 29.6 cpm **Physical activity and sedentary time**: CI group: Mean ± SD daily time spent: Sedentary = 604 min ± 80 min (87% of wear time [WT]) Light PA = 89 min ± 48 min Moderate PA = 1 min ± 1 min Total PA = 90 min ± 48 min WCI group: Mean ± SD daily time spent: Sedentary = 601 min ± 61 min (84% of WT) Light PA = 115 min ± 47 min Moderate PA = 2 min ± 1 min Total PA = 117 min ± 47 min **PA EE:** n/r **Steps:** CI group: Mean = 760 $steps \cdot day^{-1}$ (Range = 367 $steps \cdot day^{-1}$ – 1,164 $steps \cdot day^{-1}$) WCI group: Mean = 1,453 $steps \cdot day^{-1}$ (Range = 953 $steps \cdot day^{-1}$– 2,579 $steps \cdot day^{-1}$) **Posture**: n/a

6. Moyle et al (2017)	Sensewear Armband	Upper non-dominant arm over triceps muscle	Wore continuously for 24 hours	≥ 21 hours data	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** Over 24-h: Mean ± SD = 6,595 kJ ± 1,436 kJ Between the hours of 8 a.m. and 7:59 p.m.: Mean ± SD = 3557 kJ ± 921 kJ **Steps:** Over 24-h: Mean(± SD = 308 steps ± 803 steps Between the hours of 8 a.m. and 7:59 p.m.: Mean ± SD = 240 steps ± 647 steps **Posture**: Mean ± SD time spent: Lying = 2.0 h ± 2.3h (15% waking hours) Light PA = 1.8 h ± 1.8 h
7. Bucknix et al (2017)	(Pebble+)	Attached to residents' shoe	Hours per day not reported, 7 days	Not reported	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** n/a **Steps:** 1,678 steps·day^{-1} ± 1,621 steps·day^{-1} (Median (IQR) = 1,300 steps·day^{-1} (450 steps·day^{-1} - 2141 steps·day^{-1}). **Posture**: n/a

8. Klinedinst et al (2016)	Fitbit (Flex)	Not reported	24 hours, 1 day	Not reported	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** n/a **Steps:** Mean ± SD = 2392 steps·day^{-1} ± 3047 steps·day^{-1} **Posture**: n/a
9. Corcoran et al (2016)	ActiGraph (GT3XE)	Right hip	Waking hours, 10 days	≥ 10 hours ≥ 3 days	**Activity counts**: Mean ± SD daily cpm = 80.2 ± 39.4, Range = 26.5 - 184.7 **Physical activity and sedentary time**: Minutes <u>per week</u> spent engaging in: Inactivity: Mean ± SD = 4,657 min ± 805 min (Range = 3,415 min- 7,653 min) Low PA: Mean ± SD = 894 min ± 360 min (Range = 312 min - 1741 min) Lifestyle PA: Mean ± SD = 112 min ± 83 min (Range = 17 min – 343 min) MVPA: Mean ± SD = 11 min ± 16 min (Range = 1 min - 105 min) **PA EE:** n/r **Steps:** Mean ± SD = 1,346 steps·day^{-1} ± 1,110 steps·day^{-1} (Range: 0 – 4,300 steps·day^{-1}) **Posture**: n/a

10. Van Alphen et al (2016)[†]	ActiWatch	Dominant wrist	24-hours a day, 7-day monitoring period	24-hours a day, ≥ 6 days	**Activity counts**: Mean ± SD = 169,000 counts·day^{-1} ± 133,000 counts·day^{-1} **Physical activity and sedentary time**: Time per day spent sedentary: Mean ± SD = 17.3 h ± 3.2 h (72%) **PA EE:** n/a **Steps:** n/a **Posture**: n/a
11. Friedmann et al (2015)	ActiGraph (not reported)	Chest	24-hour wear, 1 day	Not reported	**Activity counts**: n/r **Physical activity and sedentary time**: n/a **PA EE:** Mean (SE) = 108 kcal·day^{-1} (10 kcal·day^{-1}), Range = 21 kcal·day^{-1} - 268 kcal·day^{-1} **Steps:** n/r **Posture**: n/a
12. Resnick and Galik (2015)	ActiGraph (not reported)	Hip	24-hour wear, 1 day	Not reported	**Activity counts**: RCF group: Mean ± SD = 36,152 counts·day^{-1} ± 25,525 counts·day^{-1} NH group: Mean ± SD = 19,610 counts·day^{-1} ± 21,418 counts·day^{-1} **Physical activity and sedentary time**: Time spent in moderate PA: RCF group: Mean ± SD = 2 min ± 3 min NH group: Mean ± SD = 1min ± 2 min

					PA EE: RCF group: Mean ± SD = 47 kcal·day^{-1} ± 38 kcal·day^{-1} NH group: Mean ± SD = 25 kcal·day^{-1}± 29 kcal·day^{-1} **Steps:** n/r **Posture**: n/a
13. Pakozdi et al (2015)[†]	Actiheart	Anterior chest	at least 72 hours	Not reported	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** Median = 171 kcal·day^{-1} (Range =127 kcal·day^{-1} – 374 kcal·day^{-1}) **Steps:** n/a **Posture**: n/a
14. Galik et al (2015)	ActiGraph (not reported)	Hip	24 hours wear, 1 day	Not reported	**Activity counts**: Control group: Mean ± SD = 37,667 counts·day^{-1} ± 4390 counts·day^{-1} Intervention group: Mean ± SD = 34,998 counts·day^{-1} ± 3961 counts·day^{-1} **Physical activity and sedentary time**: n/a **PA EE:** Control group: Mean ± SD = 51 kcal·day^{-1} ± 7 kcal·day^{-1} Intervention group: Mean ± SD = 44 kcal·day^{-1} ± 6 kcal·day^{-1} **Steps:** n/r **Posture**: n/a

15. Barber et al (2015)	ActiGraph (GT3X)	Hip	Waking hours, 7 consecutive days	≥ 10 hours ≥ 5 days	**Activity counts**: Mean ± SD = 113,477 counts·day^{-1} ± 88,012 counts·day^{-1} (Range = 9,914 counts·day^{-1} - 343,007 counts·day^{-1}) Mean ± SD = 150 cpm ± 123 cpm (Range = 29 cpm – 533 cpm) **Physical activity and sedentary time**: Time per day spent: Sedentary: Mean ± SD = 10 h 7 min ± 2h 11 min (79% of waking time) (Range = 5 h 12 min to 13 h 6 min, 45 to 97% of waking time) Low PA: Mean ± SD = 1 h 45 min ± 57 min (Range = 16 min to 4 h and 42 min, 14% of waking time). Light PA: Mean ± SD = 42 min ± 38 min (Range = 30s to 2 h 19 min, 6% of waking time) MVPA: Mean ± SD = 10 min ± 14 min (Range = 30 s to 53 min, 1% of waking time) **PA EE:** Mean ± SD = 115 kcal·day^{-1} ± 92 kcal·day^{-1} (Range = 8 kcal·day^{-1} - 372 kcal·day^{-1}) **Steps:** n/r **Posture**: n/a
16. Galik et al (2014)	ActiGraph (not reported)	Hip	24 hours wear, 1 day	Not reported	**Activity counts**: Control group: Mean (SE) = 18,810 counts·day^{-1} (3007 counts·day^{-1}) Intervention group: Mean (SE) = 20309 counts·day^{-1} (3340 counts·day^{-1})

					Physical activity and sedentary time: n/r **PA EE:** Control group: Mean (SE) = 21 kcal·day^{-1} (3.2 kcal·day^{-1}) Intervention group: Mean (SE) = 28 kcal·day^{-1} (5 kcal·day^{-1}) **Steps:** n/r **Posture**: n/a
17. Reid et al (2013)	activPal (n/a)	Right anterior mid-line of the right thigh	24-hours, 7 day	≥ 1 valid day Where a valid day defined as such if wear time comprised ≥ 80% of waking time <u>or</u> if waking time was not reported, ≥ 10h was used to define a valid day.	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** n/a **Steps:** n/a **Posture**: Median (IQR) time spent: Sitting / lying = 12 h .24 min (1 h 42 min) (73% of this time was accumulated in unbroken bouts of ≥ 30 min), Standing = 1 h 54 min (1 h 18 min), Stepping = 21min (37 min)

18. Ikezoe et al (2013)	Bespoke monitor (Activity Monitoring and Evaluation System)	Waist (iliac crest)	10:00 – 16:00, 1 day	Not reported	**Activity counts**: n/a **Physical activity and sedentary time**: n/a **PA EE:** n/a **Steps:** Mean ± SD = 2005 $steps{\cdot}day^{-1}$ ± 1998 $steps{\cdot}day^{-1}$ **Posture**: Mean ± SD time (percentage wear time) spent: Walking = 1 h 6 min ± 31 min (18.3% ± 8.6%), Standing = 26 min ± 23 min (7.3% ± 6.4%), Sitting = 3 h 25 min ± 1 h 12 min (56.9% ± 19.8%), Lying = 1 h 3 min ± 1 h 8 min (17.4% ± 18.7%)

Note: n/a = not applicable; n/r = not reported

* Identified through other sources; † Data from participants recruited from LTC facilities only

3.6 Discussion

3.6.1 Summary of main results

This review was conducted in order to synthesise existing literature detailing accelerometer use in older adults residing in care homes in order to gauge what literature already exists and identify gaps in the knowledge base. The identification of 18 studies which used an accelerometer to measure PA and / or sedentary behaviour in older adults residing in care homes, a population often neglected in research terms (Shepherd et al., 2015; Zermansky et al., 2007), suggests there is a growing recognition of the potential application of these monitors within this population. Still, there was considerable variation in the data collection and processing methods employed across the studies reviewed and several different outcomes were reported on. Thus, whilst the studies reviewed suggest that older adults residing in care homes engage in very little PA and spend the majority of their time sedentary, it seems premature to draw definitive conclusions regarding the profile of PA behaviour of care home residents.

3.6.2 Accelerometer data collection and processing methods

There was considerable variation in the accelerometer data collection and processing methods employed across the studies reviewed. It is noteworthy that, even across studies which reported on the same outcome, the accelerometer data collection and processing methods were inconsistent. For example, whilst estimates of PA EE were generally very low, with six of the eight studies measuring this variable reporting a mean PA EE less than 175 kcal$\cdot$day^{-1}, the other two studies reported estimates of 1,658 kcal.day^{-1} (Range = 1,569 – 1,794 kcal$\cdot$day^{-1}) and 850 kcal (SD = 220 kcal) respectively. This difference may, in part, be attributed to accelerometer wear location (discussed in more detail in **Chapter 4**). In the six studies which reported similar estimates of PA EE the accelerometer was worn near the participants centre of mass (i.e. the hip or chest) whereas in the two studies reporting the higher estimates, participant's wore the accelerometer on their ankle and upper arm. This example confirms that the decisions made regarding the collection and processing of accelerometer data can have an impact on the outcomes derived (Mâsse et al., 2005). It is therefore important that these differences are acknowledged when interpreting, synthesising or comparing findings across studies.

3.6.3 Physical activity behaviour outcomes

As demonstrated in earlier work, agreement on which of the outcomes derived from accelerometers is the most appropriate for assessing PA behaviour in older adults has not been reached (Gorman et al., 2014; Taraldsen et al., 2012). It was therefore unsurprising that a range of different outcomes were reported on in the reviewed literature, with many studies opting to present more than one outcome. For example, Marmeleria and colleagues reported on three outcomes: activity cpm, PA and sedentary time and steps$\cdot$day^{-1}. Whilst this made it challenging to synthesise results, each of the outcomes reflect a different aspect of PA behaviour. For this reason, it may be surmised that collating the findings from various different outcomes is important for furthering understanding of the whole profile of PA behaviour.

As was the case in a previous review of PA monitoring by use of accelerometers in older adults conducted by Taraldsen and colleagues in 2012, PA EE was the outcome most commonly reported on across the studies included in this review. Although this is unsurprising given that the quantification of EE is the basic construct underlying the assessment of PA with accelerometers (Butte et al., 2012), it could be argued that other outcomes may be more informative in this population given much of their total PA tends to be accumulated through engagement in activities such as ADLs which do not have a high energy cost (Ainsworth et al., 2011). Indeed, the PA EE of participants across the studies reviewed here, and by Taraldsen et al, was generally very low.

In addition to PA EE, quantification of PA in terms of steps$\cdot$day^{-1} was commonly reported. This was interesting, as although steps$\cdot$day^{-1} is an outcome which is easy to understand, enjoys universal interpretation and thus enables cross-study comparisons, the relevance of this outcome to older care home residents is questionable (**section 2.2.2.5**, **Chapter 2**). Furthermore, researchers in the field are often interested in the intensity, frequency and duration of PA over the course of a pre-defined time frame and as an outcome, steps$\cdot$day^{-1} does not provide any of this information **(section 2.2.2.5**, **Chapter 2**). Similarly, activity counts, whilst useful for providing an overall impression of the volume of PA, provide very little information about the intensity of PA older adults may participant in (Bassett Jr et al., 2012; Ward et al., 2005). Thus, of the outcomes reported on in the reviewed literature, it could be argued that estimates of time spent engaging in differing intensities of PA and sedentary behaviour are most informative in a care home population, especially given it is generally agreed that there is a graded relationship between PA / sedentary behaviour and health (Dogra et al., 2017).

3.6.4 Profile of physical activity behaviour

The 18 studies reviewed provide some insight into the profile of PA behaviour of older adults residing in care homes. However, it is important to recognise that a ‘formal’ quality assessment of the studies reviewed was not conducted. Whilst the concept of ‘quality’ in research is difficult to define, it relates to the methodological conduct and reporting of results (Harrison et al., 2017). Several ‘formal’ tools (e.g. Cochrane Risk of Bias Tool, (Higgins et al., 2011)) have been developed to ensure these key aspects of quality are considered in a standardised way. Given none of these were used, caution is required when interpreting the findings of the current study.

In addition, it is important that the findings are considered in light of the factors discussed below.

3.6.4.1 Care setting

Whilst the term ‘care home’ is clearly defined in this review it is important to recognise that the context within these facilities is likely to vary considerably dependent on a number of factors (Luff et al., 2015; Froggatt et al., 2009). According to Froggatt and colleagues, such factors include: the needs of the residents; the size of the facility; the resources available both internally (e.g. access to trained staff) and externally (e.g. access to primary care); and the ‘location’ of the facility in the wider health and social care economy. Given the care home context is likely to have an impact on the profile of PA behaviour of residents, caution is required when making direct comparisons across studies.

3.6.4.2 Participant representativeness

It was unclear whether the participants whose data contributed to the derivation of PA behaviour estimates (i.e. the PA sample) were representative of the wider population residing in care homes. This is particularly problematic in terms of being able to comment on the generalisability of results as the sample sizes of the included studies were generally small (44%, n = 8) of studies included less than 50 participants and two of these studies were particularly small with less than 20 participants). It is noteworthy that in studies which did report on the number of eligible residents within a facility (n = 9), five studies excluded more than 25% of the residents. Further, in eight of the fifteen studies which explicitly reported on the PA sample size, the number of participants who ultimately provided accelerometer data was smaller than the study sample size reported. This level of participant attribution may suggest that the PA sample is unlikely to be representative of care home residents. However, it is difficult to say this with certainty given the heterogeneity within this population is marked and the inclusion / exclusion criteria employed differed across the studies reviewed.

3.6.4.3 Participant variation

Previous research suggests older adults residing in nursing homes are typically frailer than those in living in other LTC settings (i.e. residential care homes or assisted-living facilities) (Gordon et al., 2014; Rothera et al., 2003). It was therefore hypothesised that the PA behaviour profile of residents would vary according to the LTC setting. However, a comparison across the reviewed studies revealed that although there was variation in PA outcomes between samples, there was no clear distinction between different LTC settings. Nevertheless, many of the studies reported large standard deviations or a wide range around their average estimates of PA outcomes which is indicative of a large amount of variation even within studies. This suggests that the characteristics of participants are likely to influence their PA behaviour; therefore it is important to interpret study findings within the context of the study population (Whitney, 2018).

3.6.5 Potential biases in the review process

Whilst a comprehensive search, based on input from an information specialist was carried out, only studies published in English and after 2012 were included. This may have led to potential bias regarding the studies that have been reviewed and reported. However, given the use of accelerometers in PA and ageing research is still relatively new, the potential for bias was judged to be low.

Bias may also have been introduced as only one ‘reviewer’ (JA) assessed studies for eligibility and extracted the data. However, strategies were employed in an effort to reduce this bias. Specifically, eligibility criteria were identified before the screening process and a standardised form was used to guide data extraction. Accordingly, the bias in the review process was deemed to be low.

3.7 Conclusions

This systematic review is the first to focus specifically on the use of accelerometers in field-based research with older adults residing in care homes. Whilst all of the included studies met the inclusion criteria and used an accelerometer to measure the levels of PA and / or sedentary behaviour of care home residents, the lack of uniformity across the studies posed a significant challenge when it came to comparing and synthesising findings. As a result, drawing definitive conclusions regarding the profile of PA behaviour in this population was problematic. Still, the studies reviewed did provide some insight. Irrespective of the outcome reported on, the persistent finding was that care home residents engage in very little PA and spend the majority of their time sedentary.

This review also highlighted some of the weakness in current research practices and perhaps more importantly, where the knowledge gaps are within this growing area of research. Indeed, a major finding of this review was the methodological inconsistencies across studies. Future studies employing accelerometers should be transparent and provide details on the methodological decisions made and the rationale for these decisions. Transparency on data collection and processing procedures utilised, coupled with a consensus on the best outcome derived from the accelerometer data would aid the interpretation of results and facilitate comparisons across studies.

An increasing body of evidence suggests that how PA and sedentary behaviours are accumulated may have different effects on health outcomes (Sardinha et al., 2015; Healy et al., 2008); yet the studies reviewed provided little information about the patterns of PA and sedentary behaviour in this population. This represents a significant gap in our knowledge. Additional research examining the patterns of PA behaviour in older adults residing care homes is required. Further work to advance our understanding of the levels of habitual PA and sedentary behaviour in this population is also warranted given many of the studies conducted to date have included small sample sizes and / or have employed short monitoring periods (i.e. < seven days).

Chapter 4 An overview of the key methodological considerations associated with the use of ActiGraph accelerometers

4.i Preface

Given the proliferation in the number of accelerometers commercially available, a notable finding from the systematic review presented in the previous chapter was that over half of the studies reviewed employed an ActiGraph accelerometer. This finding, considered alongside existing knowledge of accelerometers (**Chapter 2, sections 0** and **2.2.4**) and data collected by colleagues from the AUECR (**Appendix A**), suggests the ActiGraph accelerometer may be the most appropriate monitor to assess habitual PA in older care home residents.

Moreover, whilst evidence regarding the validity of other monitors is increasing, there is comparatively more published literature regarding the validity of the ActiGraph accelerometers in older adults. It is also important to acknowledge that the ActiGraph remains the most commonly used device in field-based research (Wijndaele et al., 2015) as being able to compare the results of this doctoral work with existing literature is an important consideration. Thus, the decision was made to focus on investigating the use of the ActiGraph accelerometer with older care home residents in the remaining studies presented within this thesis. The term accelerometer is therefore used to refer to these monitors going forward unless otherwise stated.

4.1 Introduction

As the systematic review conducted in the previous chapter demonstrates, the use of accelerometers (the ActiGraph in particular) to objectively measure PA and sedentary behaviour in older adults residing in care homes is increasing. Nevertheless, a key finding from this review was the methodological inconsistencies across the included studies. Whilst this might have been anticipated given several decisions pertaining to the data collection and processing methods need to be made, the lack of consensus makes it difficult for researchers opting to use accelerometers to make the “correct” decisions (Migueles et al., 2017; Trost et al., 2005). This is problematic as reports in the literature suggest these decisions can have a large impact on the outcomes derived from the accelerometer data (Mâsse et al., 2005).

Best practice recommendations have been published regarding accelerometer use (Matthews et al., 2012; Ward et al., 2005). However, as technology is constantly evolving and the use of accelerometers in field-based research continues to increase, there is a need to update the current knowledge base. Moreover, much of the evidence informing these recommendations was derived from studies with younger adults. Thus, whilst these offer a valuable resource, some of these recommendations may not be applicable to older adults residing in care homes.

Accordingly, the aim of the current chapter was to provide an overview of the key methodological decisions which require consideration when using an ActiGraph accelerometer in field-based research with older care home residents.

4.2 Methods

Care home residents have traditionally been regarded as a group that is hard to reach (Shepherd et al., 2015; Zermansky et al., 2007). Moreover, the use of accelerometers to measure PA and sedentary behaviour in care home residents is relatively new (seven of the 18 studies included in the review presented in **Chapter 3** were published in 2017). It seemed reasonable to assume therefore, that there would be a paucity of measurement-specific research involving care home residents. Thus, a search of the literature was conducted to identify studies investigating methodological issues associated with accelerometer use, with an emphasis on studies involving older adults.

The focus of the current chapter was on nine key methodological decisions related to the use of ActiGraph accelerometers. Namely:

- What model (uniaxial or triaxial) of accelerometer should be used?
- Where on the body should the accelerometer by worn?
- What sampling frequency should be used?
- What filter should be used?
- What epoch length should be used?
- How should non-wear time be identified?
- How long should the monitoring period be?
- What minimum wear time criteria should be used?
- Which cut-points should be used? (Cain et al., 2013b; Cliff et al., 2009)

Each decision is categorised under the following headings: pre-data collection and data processing and described in more detail below.

4.3 Pre-data collection decisions

4.3.1 Model (uniaxial or triaixal)

Rapid technological advancements have resulted in the release of several generations of ActiGraph monitors (Migueles et al., 2017). Whilst the primary functionality (i.e. to filter and process the measured acceleration data to generate an output which can be utilised by an end-user) is consistent across all generations, some features have evolved (Sievänen and Kujala, 2017). The most discernible difference between the different generation monitors is the number of planes in which acceleration is measured. The earlier generation ActiGraph accelerometers such as the GT1M, are described as uniaxial as they measure acceleration in the vertical plane only (Murphy, 2009). Conversely, many of the accelerometers currently available (e.g. GT3X, GT3X+ and wGT3X-BT) are triaxial, measuring acceleration in three orthogonal planes (vertical, medio-lateral and anterior-posterior) (John and Freedson, 2012). The triaxial accelerometers also produce a composite vector magnitude (VM) value of the three axes (ActiGraph Corporation, 2016).

Theoretically, triaxial accelerometers should provide better estimates of the PA behaviour typical of older adults as they have the capability to capture a wider range of movement (Sasaki et al., 2016). However the issue has received limited attention in this age group and many studies continue to use uniaxial monitors (Gorman et al., 2014). Keadle et al. (2014) compared estimates of PA and sedentary behaviour derived from vertical axis (VA) and VM counts in a large sample of older women (n = 7,650, mean age: 71 y ± 5 y) and reported that the estimates were substantially different. However, as the authors did not compare the estimates derived to a criterion measure it is not possible to make inferences regarding which estimate was most valid. Caution is required when comparing the findings from studies employing different models and direct comparison of results should be avoided in instances where studies have not specified which count value they have used.

4.3.2 Wear location

By design accelerometers can be attached to various body sites including the hip, wrist, thigh and ankle (Ward et al., 2005). Given accelerometers measure the acceleration of the body segment to which they are attached, wear location is a vital decision (LaMunion et al., 2017). To date, the hip has been the most commonly used wear location in studies involving older adults (Migueles et al., 2017). This is likely due to the fact that many studies continue to employ uniaxial accelerometers and / or favour analytic approaches such as linear regression to derive PA outcomes. Accordingly, the hip represent the most logical placement to capture habitual PA given the dominance of activities such as walking which result in vertical displacement (Matthews, 2005).

However, the use of hip-worn accelerometers is not without limitations. It is widely acknowledged that a hip-worn accelerometer is unable to adequately capture all PA, particularly static PA which involves upper body movements (Montoye et al., 1983; Matthews, 2005). This may be particularly problematic in populations such as older care home residents given a high proportion of the PA they engage in is likely to be done whilst seated and predominantly involve upper body movements (for example ADLs such as dressing) (Schrack et al., 2016). It may be that a wrist-worn accelerometer is better able to capture such movements; however, the issue of wear location has received little attention in older adults.

A recent study by Kamada and colleagues compared data collected simultaneously from both a hip- and wrist-worn accelerometer in a group of 94 community dwelling older women (mean age = 71.9 ± 6.0 y) in a free-living environment. Whilst it is unsurprising given that the magnitude and pattern of the accelerometer signal will vary according to the location of the accelerometer (LaMunion et al., 2017), the authors found that the activity counts recorded by the hip- and wrist-worn accelerometers were markedly different. As an example, the VM count per day recorded by the wrist-worn accelerometer were approximately four times higher than those recorded by the hip-worn monitor (Kamada et al., 2016). Evidently, the use of cut-points derived from hip data is inappropriate. Alternative methods of data analysis such as machine learning techniques are being developed, however there has been little validation work conducted in older adults (Ellingson et al., 2017; Ellis et al., 2016). As a result, guidance on how to interpret the data from wrist-worn accelerometers in a meaningful way in older adults is, at present, limited.

Another issue often associated with the use of hip-worn accelerometers is compliance (Corcoran et al., 2016; Troiano et al., 2008). Emerging evidence from large epidemiological studies suggests compliance may be improved when an accelerometer is worn on the wrist compared to the hip (Troiano et al., 2014). However, this has not yet been demonstrated in older care home residents thus warrants further investigation.

4.3.3 Sampling frequency

The sample frequency refers to the number of samples (accelerations) recorded per second and varies across accelerometers, dependent on the technical specifications of the specific monitor (Sasaki et al., 2016). The newer generation accelerometers (e.g. GT3X, GT3X+ and wGT3x-BT models) allow the end-user to choose from a range of sampling frequencies when initialising the monitor (ActiGraph Corporation, 2013).

Whilst no research has explored the impact of sampling frequency on accelerometer data in older adults specifically, there is evidence to suggest it can distort the acceleration signal and subsequently have an effect on activity counts recorded (Brønd and Arvidsson, 2016). In a sample of university students, Brønd and Arvidsson (2016) reported differences of + 90 counts per minute (cpm), + 180 cpm, +103 cpm and + 1,601 cpm for a slow walk, a fast walk, a slow run and a fast run respectively when a sampling frequency of 40 Hertz (Hz) was compared to 30 Hz. Additionally, when sampling frequencies in multiples of 30 Hz (i.e. 60 Hz and 90 Hz) were used, cpm estimates were similar to those recorded at 30 Hz. Conversely when one of a selection of alternative sampling frequencies (for example, 40 Hz, 50 Hz and 100 Hz) were used, the cpm estimates were higher. Based on these results, researchers need to be aware of the sampling frequency used when interpreting accelerometer data and making comparisons across studies as the random error introduced may lead to incorrect conclusions.

4.3.4 Monitoring period

Participant compliance in wearing an accelerometer is central to obtaining valid data (Ridgers and Fairclough, 2011; Ward et al., 2005). Thus, efforts should be made to minimise the perceived burden of the monitoring protocol on individuals whilst also ensuring the monitoring period is long enough to make inferences about an individual's habitual PA (Ridgers and Fairclough, 2011).

Participants are typically asked to wear an accelerometer during all waking hours over a seven-day period (Matthews et al., 2012; Ward et al., 2005); yet compliance to this protocol, particularly in older adults, is variable. A recent study reported that 19% of older care home residents approached to wear an accelerometer declined and cited not wishing to wear the accelerometer for so many days as their reason for doing so (Barber et al., 2015). Furthermore, reports of individuals forgetting to put the accelerometer back on after removing it for reasons such as showering (many of the monitors are not water-proof); discomfort and sleeping are not uncommon (Huberty et al., 2015; Troiano et al., 2014).

Recent large-scale epidemiological studies have employed a 24-hour monitoring protocol and have reported improved wear compliance (Tudor-Locke et al., 2015; Troiano et al., 2014). However, these studies tend to have used a wrist-worn monitor therefore it is difficult to ascertain whether the improvements in compliance reported are the result of the 24-hour monitoring protocol or the use of a wrist-worn accelerometer. Moreover, these studies have not included older adults residing in a care home setting therefore there is insufficient evidence to conclude a 24-hour monitor protocol would be advantageous in this population.

Identifying a minimum wear time criterion (i.e. the proportion of a day and the number of days) that enables valid measurement of PA behaviour in older care home residents would help to inform the length of the monitoring period required. Attempts have been made to identify appropriate wear time criteria in older adults; however, the applicability of such criteria to care home residents is questionable (Hart et al., 2011b). Moreover, empirical evidence supporting the superiority of a specific criterion is absent, especially for an older population (Ridgers and Fairclough, 2011).

4.4 Data processing decisions

4.4.1 Filter

The raw acceleration signal captured by an accelerometer undergoes some filtering in order to produce the output (i.e. activity counts) which is then used by the end-user (ActiGraph Corporation, 2013). The purpose of this filtering process is to remove any data not likely to reflect human movement (i.e. outside the frequency range of 0.25 to 2.5 Hz) (Ainsworth et al., 2015). The newer accelerometers allow the end-user to choose between applying this filter (i.e. normal-filter) or a low-frequency extension (LFE) filter. According to ActiGraph, the LFE filter extends the lower cut-off of the filter and thus enables more of the acceleration data to be retained (ActiGraph Corporation, 2012).

The premise underpinning the development of this filter was that it would be useful when measuring the PA of individuals who move slowly (for example older adults); yet no further information on the two proprietary filters is available. Recent data collected in older adults (mean age = 60.8 y ± 9.9 y) suggests accelerometer outputs vary considerably dependent on the filter used (Wanner et al., 2013). Thus, a lack of transparency regarding which filter has been used brings into question the comparability of data across studies. In the study conducted by Wanner and colleagues, the greatest discrepancies between the two filters were observed when individuals were engaging in sedentary and low intensity PA (Wanner et al., 2013). Given older care home residents likely spend the majority of their time engaging in these two behaviours further research exploring the impact of filter on accelerometer outcomes in this population is warranted (Phillips et al., 2015).

4.4.2 Epoch length

As discussed previously, current accelerometers have the capability to continuously record and store raw acceleration data (**section 2.2.2.6**, **Chapter 2**). However, the analytical approaches developed to analyse this data are inherently complex and at present, little guidance regarding the implementation of these techniques is available (Sasaki et al., 2016; Montoye et al., 2018). As a result, many researchers using accelerometers in field-based research continue to adopt conventional analytic approaches such as regression-based “cut-points” developed based on activity count data (Montoye et al., 2018; Troiano et al., 2014). Given activity counts are produced by aggregating the raw acceleration data over a user-defined epoch, the length of this will have a direct impact on the count value produced (John and Freedson, 2012; Chen and Bassett, 2005).

A key feature of the current accelerometers is that they permit the end-user to retrospectively aggregate the raw acceleration data over a discrete time period (i.e. epoch) using the proprietary software to produce count-level data (Sasaki et al., 2016). A range of different epoch lengths are provided by the software, ranging from one second to several minutes. Despite the range available, the most common epoch length used in studies involving older adults is 60 seconds (Jefferis et al., 2015; Sartini et al., 2015). This is likely to due to the fact that the first generation accelerometers had limited memory capacity; therefore in instances where continuous recording over multiple days was required (e.g. to derive estimates of habitual PA), 60 seconds was the shortest epoch permissible (Sasaki et al., 2016; Rowlands et al., 2006). Thus, to increase comparability with a wider body of literature and because the majority of the cut-points widely used, particularly for adults and older adults, are based on data collected using 60 second epochs, studies have continued to use this epoch length. However, given older adults spend a considerable amount of their time sedentary and their engagement in PA is often described as being sporadic and intermittent (Ortlieb et al., 2014; Harvey et al., 2013), it may be surmised that the use of 60 second epochs may result in short bursts of PA going undetected as they will be averaged over the minute (Chen and Bassett, 2005).

Evidently, epoch length is an important consideration as it can affect the interpretation of accelerometer data and thus impact conclusions made about the levels of PA older adults engage in and potentially alter inferences made regarding the relationship between PA and health outcomes in this population. Nevertheless, no studies to date have investigated the impact of epoch length on estimates of PA and sedentary behaviour specifically in older adults.

4.4.3 Identification of non-wear time

One of the most challenging issues associated with the use of accelerometers is the identification and removal of non-wear time from an accelerometer data set (Schrack et al., 2016; Gibbs et al., 2015). This is particularly challenging in older adults who typically spend the vast majority of their waking time engaging in sedentary behaviours (Harvey et al., 2013). Nonetheless, the correct identification and removal of non-wear time is of upmost importance for a number of reasons. First, misclassifying prolonged periods of sedentary time as accelerometer non-wear would result in the data being excluded from analysis, thus estimates of sedentary time would be underestimated (Atkin et al., 2012). It is worth noting that the opposite is also true. That is, if non-wear time is incorrectly identified as sedentary time then estimates of time spent sedentary would be inflated. Second, the removal of data incorrectly identified as non-wear time may result in an individual being excluded from analysis due to having insufficient valid data (see above). Again, this has implications in terms of the conclusions derived from the data as it likely the individuals who spend the most time sedentary are those excluded (Winkler et al., 2012).

A combination of different methods, including the use of automated algorithms, activity logs and visual inspection of data are often employed in an attempt to ensure non-wear time is correctly identified (Schrack et al., 2016). Although the use of activity logs to capture the time accelerometers are put on and removed and the reason for removal are commonplace in PA studies, they may be viewed as burdensome by participants (missing data is frequently reported) and there are concerns regarding the accuracy of the information recorded (Chase, 2013; Winkler et al., 2012). Visual inspection of the data, whilst likely to be fairly accurate (particularly if done alongside a completed activity log or automated algorithm), is labour-intensive (Shiroma et al., 2015). Hence, the feasibility of doing this in large epidemiology studies is questionable. Consequently, much emphasis is typically placed on the use of automated algorithms.

Several automatic algorithms for identifying non-wear time have been developed (Choi et al., 2012; Troiano et al., 2008). Generally these algorithms screen epoch level data and classify a pre-specified duration of consecutive zero counts, with or without an allowance for some movement (i.e. a brief interruption in the string of consecutive zeros) as non-wear time (Winkler et al., 2012). Whilst it has been suggested that the optimum algorithm may vary among different populations, limited research in this area has focused solely on older adults.

One of the few studies which explored this issue in older adults was that conducted by Keadle and colleagues. The authors found that in their large sample of older women (n = 7,650, mean age: 71 y ± 5 y) an algorithm developed by Choi et al (2012) yielded similar wear times when compared to a participant-completed activity log (Keadle et al., 2014). This algorithm defines non-wear time as 90 minutes of consecutive zeros with an interruption of two minutes of activity if the 30 minutes preceding and following this 90-minute period consists of consecutive zeros (Choi et al., 2012). However, it is important to note that this algorithm was developed in younger adults (mean age = 39 y ± 13 y) therefore its applicability to the older adults may be questioned. Another study conducted in older adults aged between 56 and 74 years (mean age = 63.5 y ± 8.3 y) reported that classifying non-wear time as 120 minutes of consecutives zeros (no interruptions) provided accurate population-based estimates of key PA outcomes in addition to wear and non-wear time (Hutto et al., 2013). The conflicting results presented above, in addition to the increased interest in exploring sedentary behaviour in older adults, suggest further work in the area is needed.

4.4.4 Wear time criteria

In studies involving community dwelling older adults a threshold of ten hours of accelerometer wear is widely used to define a valid day (Sartini et al., 2015; Jefferis et al., 2015). Nevertheless, this threshold is not universally accepted (Herrmann et al., 2014) and it has been acknowledged that what constitutes a ‘day’ is likely to vary considerably both between individuals and across days. This point is particularly pertinent when considering older care home residents as they are such a heterogeneous group (Gordon et al., 2014). Consequently, it may be inferred that the use of a sample-specific criterion to determine what constitutes a valid day would be preferable.

Previous research conducted in a sample of community-dwelling older adults (mean age = 69.3 y ± 7.4 y) suggests any five days of accelerometer data are needed to reliably predict both PA and sedentary behaviour (Hart et al., 2011b). However, a recent study exploring the PA behaviour of frail older adults (mean age = 82.6 y ± 9.2 y) residing in care homes reported that 12% of those to whom an accelerometer was administered did not complete five days of monitoring (Barber et al., 2015). It is probable that the variability in PA across days is likely reduced in care home residents as there tends to be more structure to their daily routines. Thus, it may be possible to reduce the number of days of wear without distorting data. This is supported by accelerometer data collected in the aforementioned study and also in a study involving older adults in a retirement community (mean age = 83.5 y ± 6.5 y) (Marshall et al., 2015) in which no difference in PA between days of the week was reported. Evidently further work is required to investigate the minimum wear criteria necessary to ensure estimates of PA in older adults living in LTC facilities are reliable. Such work is warranted as applying thresholds derived from studies involving different populations may result in data being needlessly excluded from analysis which can ultimately effect conclusions made.

4.4.5 Intensity classification: cut-points

As discussed previously in **Chapter 2** (**section 2.2.2.6**), in order to derive estimates of time spent in differing intensities of PA and sedentary behaviour from accelerometer data (i.e. activity counts), thresholds known as cut-points are applied. Cut-points are developed through a process referred to as value calibration which is described in detail in **section 2.2.2.6, Chapter 2**. Briefly, statistical techniques such as linear regression are used to determine the relationship between activity count and criterion data (typically EE) which has been collected concurrently while individuals perform a range of activities (Bassett Jr et al., 2012; Welk, 2005, Matthews, 2005). Once this relationship has been established, intensity-related cut-points can be identified (Ward et al., 2005) (Figure 2.5).

Ideally, cut-points should be calibrated in the population of interest as there is evidence to suggest the relationship between activity counts and EE is likely to vary dependent on factors such as: movement economy, cardiorespiratory fitness and RMR (Strath et al., 2012; Shephard, 2009; Welk, 2005). There is also evidence that the relationship between activity counts and EE differs dependent on the type of activity (Welk, 2005). For example, it is widely recognised that many lifestyle activities (e.g. ADLs) tend to be comprised of more complex movement patterns and don’t necessarily result in as much movement compared to ambulatory activities (Watson et al., 2014). Hence, activity counts recorded during lifestyle activities tend to be lower than those recorded during ambulatory activities at any given EE (Hendelman et al., 2000; Swartz et al., 2000). It is therefore important that the activities included in calibration studies range in intensity and are reflective of those the population of interest would typically engage in (Welk, 2005).

In light of the aforementioned points it is unsurprising that several calibration studies have been conducted with various different populations. To date, five sets of cut-points have been developed specifically in older adults and published in the peer-reviewed scientific literature. These cut-points, along with pertinent details of the calibration study, are provided in Table 4.1. As can be seen from the table, although all of the calibration studies were conducted with older adults, the cut-points derived varied considerably. The discrepancies in cut-points may be attributed to any of the following: differences in the calibration methods (e.g. epoch length, activity count value used); the inclusion of different activities; or different sample characteristics.

Whilst understandable, the proliferation of published cut-points, coupled with the lack of consensus on cut-point selection, has resulted in what Trost eloquently described as the “cut-point conundrum” (Trost, 2007). Choosing the most appropriate set of cut-points for the population of interest is vitally important as studies have demonstrated that they can have a profound impact on the estimates of PA derived and potentially the conclusions reached (Prince et al., 2015b; Freedson et al., 2005; Strath et al., 2003). However, there is little empirical evidence to support the superiority of one set of cut-points over another (Kim et al., 2012; Trost et al., 2011). Ideally, the accuracy of calibrated cut-points should be tested in independent validation studies before they are recommended for widespread application yet this rarely happens (Bassett Jr et al., 2012). In practice, the selection of which cut-point to use tends to be more arbitrary than scientifically-based. The decision is often based on factors such as: the widespread use of the cut-points; recommendations from colleagues or the researcher’s judgement (Kim et al., 2012). Accordingly, it is imperative that when selecting a set of cut-points to use researchers consider the original calibration study; understand the implications of choosing a particular set of cut-points; and ultimately provide sufficient rationale for their decision.

Table 4.1 Overview of ActiGraph calibration studies conducted specifically in older adults aged ≥ 65 y.

Study	Participants	Accelerometer details	Criterion measure	Activities included	Cut-points	
					VA counts	VM counts
Zisjo et al (2015)*	**Sample size**: n = 97 **Age**: range = 70 y – 77 y **% female**: 49% **Exclusion criteria**: Illness or disabilities that preclude exercise or hinder completion of the study; uncontrolled hypertension; symptomatic valvular, hypertrophic cardiomyopathy, unstable angina, primary pulmonary hypertension, heart failure or severe arrhythmia; diagnosed dementia; cancer that makes participation impossible or exercise contraindicated; chronic communicable infectious diseases; study participation deemed unsafe; participation in other conflicting studies.	**Model**: GT3X+ **Wear location**: hip **Filter**: NR	Portable indirect calorimeter system	Treadmill walking	<u>Men</u> Light: 56 - 266 cpm Moderate: 267 - 1971 cpm Vigorous: 1,972 - 3,878 cpm Near max: > 3,879 cpm <u>Women</u> Light: 20 - 212 cpm Moderate: 213 - 1,217 cpm Vigorous: 1,218 - 3,157 cpm Near max: > 3,158 cpm	<u>Men</u> Light: 611 - 1,652 cpm Moderate: 1,653 - 3,016 cpm Vigorous: 3,017 – 4,581 cpm Near max: > 4,582 cpm <u>Women</u> Light: 465 - 1,076 cpm Moderate: 1,077 - 2,424 cpm Vigorous: 2,425 - 4,078 cpm Near max: > 4079 cpm

Evenson et al (2015)†	**Sample size**: n = 200 **Age**: mean = 75.5 y ± 7.7y, range = 60y – 91y **% female**: 100% **Exclusion criteria**: symptoms of chest pain, dizziness, or severe shortness of breath while walking at a usual speed; inability to walk for up to 10 min without using a walker or cane; acute or chronic conditions that would prevent them to walk 400 m; poor balance; inability to understand questions (suggestive of cognitive impairment).	**Model**: GT3X+ **Wear location**: hip **Filter**: data processed with normal and LFE filter	Portable indirect calorimeter system	Watch DVD while sitting quietly; wash / dry dishes while standing; laundry (removing towels from basket and folding) while standing; 400 meter walk; assemble puzzle while sitting; dusting while standing; and treadmill walking at two different speeds.	<u>Normal filter</u> Sedentary: 0 counts·15s^{-1} Light low PA: 1 - 81 counts·15s^{-1} Light high PA: 82 - 330 counts·15s^{-1} MVPA: ≥ 331 counts·15s^{-1} <u>LFE filter</u> Sedentary: 0 - 4 counts·15s^{-1} Light low PA: 5 - 111 counts·15s^{-1} Light high PA: 112 - 363 counts·15s^{-1} MVPA: ≥ 364 counts·15s^{-1}	<u>Normal filter</u> Sedentary: 0 - 62 counts·15s^{-1} Light low PA: 63 - 383 counts·15s^{-1} Light high PA: 384 - 619 counts·15s^{-1} MVPA: ≥ 620 counts·15s^{-1} <u>LFE filter</u> Sedentary: 0 - 94 counts·15s^{-1} Light low: 95 - 439 counts·15s^{-1} Light high PA: 440 - 677 counts·15s^{-1} MVPA: ≥ 678 counts·15s^{-1}

Aguilar-Farias et al (2014)	**Sample size**: n = 37 **Age**: mean = 73.5y ± 7.3y **% female**: 65% **Exclusion criteria**: aged < 65y; unable to walk without physical assistance (assistive devices permitted); severe memory problems, living outside the recruitment area (greater Brisbane area, Australia)	**Model**: GT3X+ **Wear location:** hip **Filter:** LFE	activPAL	Conducted in a free-living environment	Sedentary: < 1 $count \cdot s^{-1}$ < 10 $counts \cdot 15s^{-1}$ < 25 cpm	Sedentary: < 1 $count \cdot s^{-1}$ < 70 $counts \cdot 15s^{-1}$ < 200 cpm
Santos-Lozano et al (2013)[‡]	**Sample size**: n = 35 **Age**: mean = 71.9 y ± 5.4 y **% female**: 63% **Exclusion criteria**: musculoskeletal or cardiovascular diseases that could hinder PA; any contraindications to exercise; taking medication altering metabolic rate	**Model:** GT3X **Wear location:** hip **Filter:** NR	Indirect calorimetry	Resting; treadmill walking at 3 $km \cdot h^{-1}$ and at 5 $km \cdot h^{-1}$; treadmill running at 9 $km \cdot h^{-1}$; and repeated sit-to-stands	n/r	Light: ≥ 2,751 cpm Moderate: ≥ 9,359 cpm

Copeland and Esliger (2009)	**Sample size**: n = 38 **Age**: mean = 69.7y ± 3.5y **% female**: 53% **Exclusion criteria**: none explicitly reported. Participants were described as healthy, not taking any medications that would influence EE or their ability to perform walking exercise. Clearance from a physician was obtained where necessary.	**Model**: 7164 **Wear location**: hip **Filter:** n/a	Open-circuit spirometry system	Treadmill walking at three speeds: 2.4 $km{\cdot}h^{-1}$, 3.2 $km{\cdot}h^{-1}$, 4.8 $km{\cdot}h^{-1}$	MVPA: ≥ 1,041 cpm	n/a

Note: n/r = not reported; n/a = not applicable

*Cut-points presented based on pooled analysis.

† Cut-points presented based on the approach of balancing false positives and false negatives. Intensity based on measured METs where 1 MET = 3.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$

‡ Data from older adults only

4.5 Summary, key findings and practical implications

The purpose of the current chapter was to provide an overview of the key methodological decisions which require consideration when using an ActiGraph accelerometer in field-based research with older care home residents.

In the absence of studies investigating these issues specifically in older care home residents, the decision was taken to consult the wider body of literature with evidence being drawn from studies involving older adults wherever possible. Nonetheless, some of these issues have received very little attention. Still, this in itself was an important finding as it highlighted where the knowledge gaps are.

The principal finding from this chapter is that there is a paucity of high quality measurement specific research involving older adults. As a result, there is little empirical evidence to support the decisions made. Whilst this goes some way in explaining the absence of a consensus on the “correct” methodological decisions in this population, it is concerning given that the literature reviewed suggested the decisions made can have a large impact on the interpretation of the data collected and ultimately the validity of results.

Consequently, **Chapter 6** will explore the impact of some of these key methodological decisions on the estimates of PA and sedentary behaviour in older adults (including those residing in a care home) and provide empirical evidence to support their use in the remaining studies presented within this thesis.

Chapter 5 General Methods

Aspects of this chapter have been presented at the following conference:

- Bradford Institute for Health Research Conference: "Research that changes a city", October 2016 – Poster presentation

And published in:

- Trials (2017). **18** (1) pp.182-196.
- Trials (2018). **19** (1) p. 535.

5.i. Preface

Whilst the various aims of the thesis are considered and presented in separate studies, many of the methods and procedures utilised are common to all. An overview of these common methods and procedures are presented below. Methodological considerations specific to a study will be presented where relevant in the associated chapter.

5.1 Ethical statement

Ethical approval was sought for all studies presented in this thesis (Table 5.1) in accordance with the Declaration of Helsinki. Given the recruitment of the care home residents was undertaken by NHS employed staff, ethical approval was obtained from NHS Research Ethics Committees (RECs).

Table 5.1 Overview of the ethical approvals obtained from each of the Research Ethics Committee's. Approval letters are provided in Appendices C – F.

Thesis chapter	Relevant REACH WS	REC
Chapter 6 (Study 1)	n/a	University of Leeds, Faculty of Biological Sciences REC (Ref: BIOSCI 13-022)
Chapter 6 (Study 2), and Chapter 7	2	Yorkshire and The Humber - Bradford NHS REC (Ref: 12/YH/0564)
Chapter 6 (Study 2), and Chapter 7	4	East of England - Essex NHS REC (Ref: 14/EE/1169)
Chapter 6 (Study 3) and Chapter 8	5	East of England - Cambridgeshire and Hertfordshire NHS REC (Ref:15/EE/0125)

5.2 Recruitment setting and participants

Participants in **Chapter 6, *Study 1*** were recruited from the community. All of the other participants in the studies reported in this thesis were recruited from care homes enrolled to the REACH programme (**section 1.5**). An overview of the recruitment strategies and consent procedures employed in both the community and care home setting are provided below.

5.2.1 Participant recruitment and consent in the community (Chapter 6, Study 1)

Individuals from the community were recruited via advertisements placed around the University of Leeds, local area and via contacts made with local charities. A known database of individuals interested in participating in research was also drawn upon.

Potential participants contacted the researcher either by telephone or e-mail if they were interested in participating in the study. At this stage provisional eligibility was confirmed. Eligible participants were:

- older adults aged over 65 years;
- English speaking;
- not suffering from or taking any medications relating to any unstable cardiovascular, metabolic or respiratory diseases or cancer.

Individuals were also asked to provide contact information to which written information about the study could be sent. Following information provision potential participants were not contacted for a period of ≥ 48 hours to allow them time to consider their participation.

If potential participants remained interested in participating in the study they were invited to the Sport and Exercise laboratory at the University of Leeds where the researcher provided a verbal summary of the research and they were given the opportunity to ask any questions. If individuals decided they wished to participate written informed consent was obtained.

5.2.2 Care home recruitment and consent (Chapter 6, Studies 2 and 3, Chapter 7 and Chapter 8)

Care homes (n = 10) for the studies presented in **Chapter 6**, and the pilot studies described in **Chapter 7** were recruited over two phases between June 2013 and January 2014 (n = 6, REACH WS2) and December 2014 - May 2015 (n = 4, REACH WS4). The homes were purposively selected to ensure that, whilst they were all located within the same geographical area, they differed in terms of their size, setting and ownership. All of the homes had expressed an interest in participating in the research project following provision of information regarding the study at a Care Home Forum and had received additional information during visit(s) from members of the research team. Specifically, a member of the research team met with the care home manager to discuss the research project in more detail. Following provisional agreement from the care home manager, additional visits to the home were made by members of the research team to explain what the project would involve for residents, staff and relatives. Written information in the form of posters and information sheets was used to guide discussions and was then left for circulation. Contact details were also provided for cases where additional information / clarity was sought. In cases where care homes remained interested in being involved in the research study written informed consent was obtained from the care home manager.

Care homes (n = 12) involved in the study presented in **Chapter 8** were identified and recruited between June 2015 and September 2016 (REACH WS 5) via the systematic approach described below (Ellwood et al., 2018; Forster et al., 2017).

Firstly, all residential care homes within a pre-specified geographical area were identified via the care directory of the Care Quality Commission (CQC) and assessed for eligibility, as far as is possible, via publicly available information. The eligibility criteria were as follows:

- a minimum of ten beds;
- no involvement in previous phases of the REACH programme or other conflicting research programmes and
- not classified as ‘inadequate’ or requiring improvements in any area as per the CQC website.

Following this preliminary screening, those homes deemed potentially eligible were sent an information sheet, accompanied by a reply slip to indicate interest (or non-interest) in the post. Contact details were provided on the information sheet if the homes wished to receive additional information. Two weeks following information provision a member of the research team contacted homes which had not returned the reply slip by telephone to determine interest.

If a care home returned the reply slip (or gave indication over the phone), expressing interest in the study, a member of the research team contacted them via telephone and further assessed the eligibility of the home. If eligibility was confirmed, a visit to the home was arranged so that the study could be discussed in more detail with the care home manager. During this visit the researcher was able to answer any questions about the home's involvement in the study, and if appropriate, gained provisional agreement from the care home manager for the home to be involved in the research project. Agreement from the owner or a representative of the care home was required to complete recruitment. That is, both the care home manager and owner provided informed consent for the home to be involved in the project.

Nine care homes were recruited via the methods outline above. However, over the course of the recruitment phase the eligibility criteria were “relaxed” due to poor uptake from care homes. Specifically, in January 2016 a decision was made to amend the eligibility criterion relating to the CQC status of the care homes such that, following re-screening, all homes rated as ‘good’ or requiring improvements in one area of the CQC report were invited to participate, using the process outlined above.

An additional three care homes were recruited from the York and Harrogate areas of North Yorkshire in close liaison with the local clinical research network staff. Care homes were identified from both a network of “research-ready” care homes (the Enabling Research in Care Homes (ENRICH) Network) (Davies et al., 2014) and the care directory of the CQC website as previously mentioned, with the amended filter of the York and Harrogate local authorities. The procedures outlined above for the recruitment of care homes in West Yorkshire were mirrored here, with the exception that homes were initially provided with information via email.

5.2.3 Participant recruitment and consent within a care home (Chapter 6, Studies 2 and 3, Chapter 7 and Chapter 8)

A schematic detailing the participant recruitment and consent process is detailed in Figure 5.1. All residents within each of the care homes were screened for eligibility. The eligibility criteria were as follows:

- aged 65 years or over;
- a permanent resident;
- not bed bound or in receipt of palliative care.

A permanent resident was defined as someone who was residing in the care home and not in receipt of respite, day-care, or short-term rehabilitation. The care home managers identified those residents they felt were not eligible to participate in the study. Additional inclusion criteria are detailed in individual chapters within this thesis if relevant to the studies.

5.2.3.1 Capacity assessment

Given most individuals residing in care homes are likely to have some kind of age-related cognitive impairment (Stewart et al., 2014; Comas-Herrera et al., 2007) an initial assessment of the mental capacity, defined here as the ability to make a decision (Johnston and Liddle, 2007), of all eligible residents was undertaken by the care home manager or an (appropriate) nominated person (Figure 5.1). The ethical approval attained covered the inclusion of participants deemed to lack capacity as it was felt that excluding those without capacity would compromise the generalisability of findings. Further, it was deemed to be inappropriate to exclude this vulnerable population given the potential benefits of research evidence in improving the quality of care for this group.

As per the Mental Capacity Act (MCA) guidance, all prospective participants were assumed to have capacity unless it was established that they did not (Mental Capacity Act; 2005). The following question was used to guide this process: "Does the individual have the capacity to consent (or refuse) to take part in the research study at this point in time?" (Dobson, 2008). Highlighting that an individual's mental capacity is "decision-specific" was deemed particularly important as it is possible that whilst an individual may be deemed unable to make a decision about their finances (as an example) they may be capable of making a decision about taking part in a research study.

Prospective participants were only deemed to lack capacity if there was evidence that:

a) they did not have a general understanding of the research project and what was expected of them (following the provision of information in an appropriate way, e.g. large print information sheets, verbal explanation of the research project);
b) they were unable to retain the information long enough to be able to consider it and make an informed decision;
c) they were unable to consider the potential benefits or risks of taking part in the research project;
d) they were unable to communicate their decision (Johnston and Liddle, 2007).

In light of the definition above, the care home manager / nominated person was asked to categorise residents as either: a) having capacity b) lacking capacity or c) unsure about capacity (Figure 5.1). It was acknowledged that mental capacity can fluctuate, therefore in cases where the manager / nominated individual did not feel able to make a judgement on a resident's capacity the researcher conducted this assessment (Figure 5.1). Moreover, following the provision of consent or assent the processes of "on-going consent" were adopted. That is, a resident's mental capacity was assessed at each point of contact throughout the study and if they indicated they no longer wished to participate this decision was respected.

5.2.3.2 Individuals with capacity

Prospective participants deemed to have capacity were approached and (with the assistance of care home staff where appropriate, for example in cases where their presence would aid communication) were provided with an information leaflet detailing the study and a verbal summary of what participation in the study would involve. Following information provision, potential participants were not contacted for a period of ≥ 24 hours to allow them time to consider their participation. Potential participants were provided with the opportunity to ask any questions and were encouraged to discuss the study with their family and / or care home staff. If residents decided they wished to participate written informed consent was obtained. In cases where it was not possible to take written consent, verbal consent was taken in the presence of a relative, close friend or staff member from the care home who signed the consent form to confirm they had witnessed consent being taken.

5.2.3.3 Individuals without capacity

For those residents who were considered not to have capacity by either the care home staff or researcher, enquires were made as to whether there was an Advanced Directive relevant to research in place. The care home manager / nominated individual was also asked identified a personal consultee (PC) who could be consulted regarding assent. Where identified, PCs were contacted in writing through the care home and were asked to consider whether, to the best of their knowledge, the resident would have chosen to take part in the research if they were able to make the decision themselves. PCs were requested to respond within two weeks using a pre-paid envelope provided. They were provided with a covering letter which outlined the role of a PC, a participant information leaflet, a declaration form and an objection slip. If there was no response from the PC within two weeks a reminder letter along with the declaration form and objection slip was sent.

In cases where an appropriate PC could not be identified; the PC did not feel able to take on the role or did not respond within the pre-determined timeframes, the care home manager identified an appropriate member of staff to act as a nominated consultee (NC) (Figure 5.1). The NC was approached in person and provided with the following: an information sheet detailing the role of a NC; a study information sheet and a declaration form. A verbal overview of the study was also provided and the NC was given the opportunity to consider the information and to ask any questions before making a decision. If the NC was happy for a resident to take part they were asked to sign the declaration form.

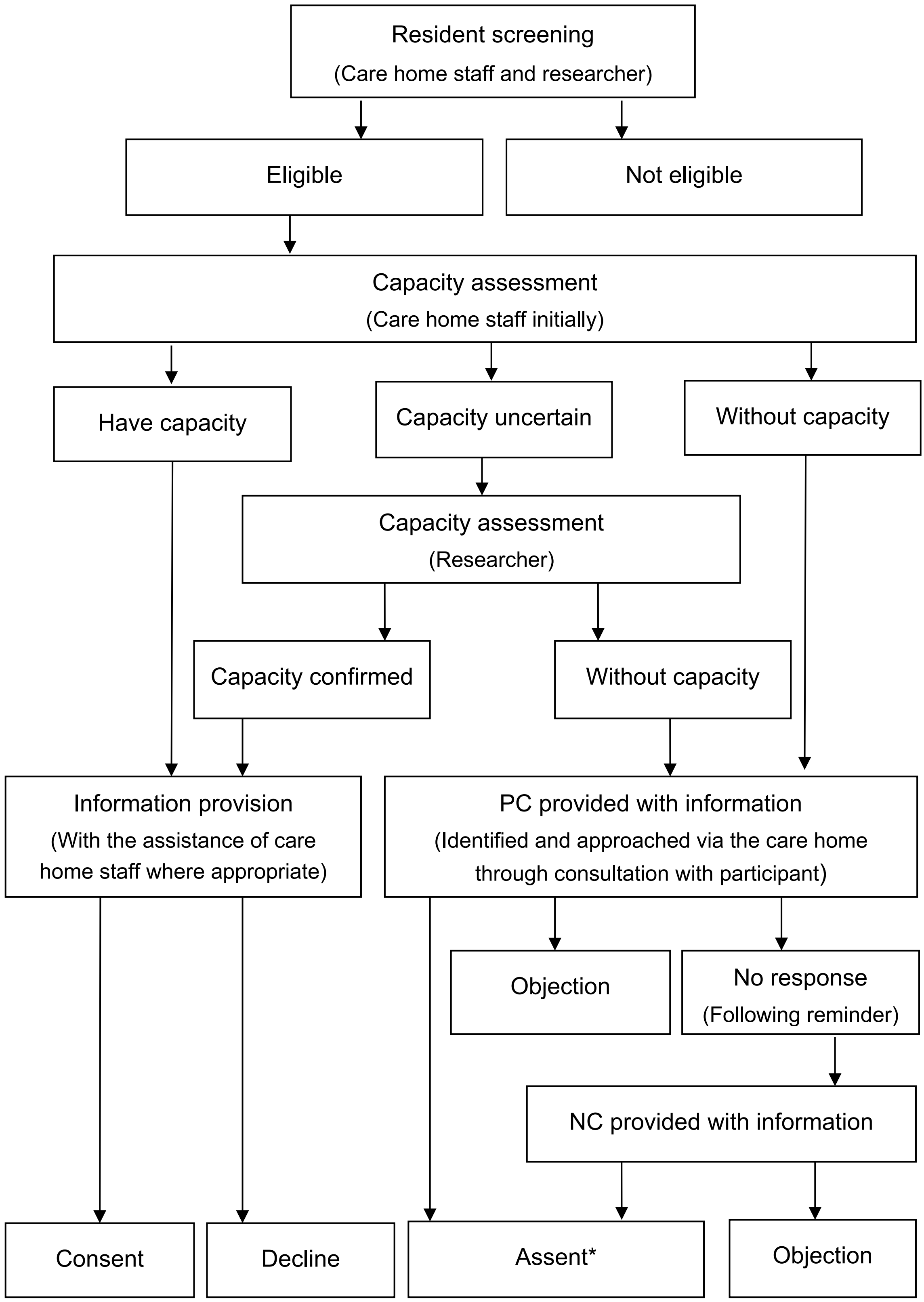


Figure 5.1 Process for assessing capacity and obtaining consent.*Involved participant consultation.

5.3 Overview of experimental protocols

The specific protocols for each study are outlined in the relevant chapters. To allow for the objective measurement of PA all participants were fitted with an ActiGraph accelerometer (ActiGraph, Pensacola, FL, USA). Details regarding the wear location (either hip or wrist) of the accelerometer are detailed in each of the relevant studies. Accelerometers were positioned such that the USB port cover was facing upwards. In an effort to ensure the accelerometer did not move from its position, either an elasticated belt or wrist strap fitted tightly, but comfortably around the body / wrist was used to secure it. Accelerometers were worn either on top of or underneath clothing dependent on the preference of the participant (Figure 5.2). Participants were advised that they were to remove the accelerometer if they were going to be engaging in any water-based activities (e.g. bathing) and were reassured that if they wished to remove the accelerometer for any reason (e.g. discomfort) they were permitted to do so. However, participants were encouraged to keep the accelerometer on during all waking hours for the duration of the monitoring period. Participants were also reassured that they did not need to “do anything” with the accelerometer other than wear it.

For all participants (with the exception of participants in ***Study 1*, Chapter 6**), an appropriate staff member (identified as someone who knew the participant well) was asked to complete a range of questionnaires about participants’ PA, physical function and mobility and perceived health. Participants themselves were also asked to complete a questionnaire (via researcher interview) assessing their perceived health. In cases where participants were unable to answer the questions themselves a reason as to why was noted. A nominated staff member within the care home was also asked to complete a booklet to provide basic demographic information about each of the participants.

Figure 5.2 Accelerometer placement and orientation

5.4 Measures of physical activity behaviour

5.4.1 ActiGraph accelerometer

As discussed in **Chapter 2, section 0** the validity of ActiGraph accelerometers (Actigraph, Pensacola, FL, USA) is well established amongst the general adult population (Crouter et al., 2006; Matthews, 2005; Freedson et al., 1998) and has been demonstrated more recently in older adults (Evenson et al., 2015; Copeland and Esliger, 2009). Furthermore, the feasibility of using accelerometers has been demonstrated in population studies of older adults (Jefferis et al., 2014; Lohne-Seiler et al., 2014; Ortlieb et al., 2014), including those residing in LTC facilities (**Chapter 3**).

The ActiGraph monitors utilised over the course of this thesis were the GT3X, GT3X+ and wGT3x-BT models (Figure 5.3). These particular accelerometers comprise a micro-electromechanical system (MEMS) sensor capable of measuring static and dynamic acceleration in three individual orthogonal planes (vertical, medio-lateral and anterior-posterior) (John and Freedson, 2012). A composite vector magnitude (VM) value of the three axes is also produced (see Equation 5.1, ActiGraph Corporation 2016).

$VM = \sqrt{(Axis1^2 + Axis2^2 + Axis3^2)}$

Equation 5.1

Where Axis 1, 2 and 3 reflect accelerations collected in the vertical, medio-lateral and anterior-posterior planes respectively.

A MEMS sensor is made up of two major components: a sensing element (a transducer) and a data acquisition element (Chen et al., 2012). The transducer samples accelerations at high time resolutions (between 1 and 100 Hz) and converts the raw accelerations into an analog signal (Chen et al., 2012). This signal is then filtered using a proprietary band-pass filter so that only data which is likely to be physiological (i.e. reflects human movement) is extracted (Ainsworth et al., 2015). The data acquisition element then converts this signal into a digital string of numbers referred to as raw counts (Chen and Bassett, 2005).

a) 

b) 

Figure 5.3 a) The ActiGraph GT3X measuring 3.8 cm × 3.7 cm × 1.8 cm and weighing 27g and b) the ActiGraph GT3X+ measuring 4.6 x 3.3 x 1.5cm and weighing 19 grams

ActiLife software version 6.8.0 (or higher as new releases were provided; ActiGraph Pensacola, Florida, USA) was used to initialise (i.e. prepare for data collection) the accelerometers and to download and process the raw accelerometer data. In all studies presented in this thesis, raw acceleration data were recorded at a sampling frequency of 30 Hz. This sampling frequency was chosen as the proprietary band-pass filters which are applied to the analog signal were developed based on this frequency and thus the distortion of the raw acceleration signal is minimised (Brønd and Arvidsson, 2016).

As discussed in **Chapter 4** several methodological decisions pertaining to accelerometer data processing, reduction and analysis need to be considered as they have an impact on the PA outcomes derived. Given the dearth of information specific to older adults, the impact of accelerometer wear location, filter, epoch length, identification of non-wear time, monitoring period and wear time criteria were explored in the studies presented in **Chapter 6** of this thesis. The findings from each of the studies presented were summarised and used to inform the methodological decisions used in the remaining studies presented. As a result, details regarding the specific methodological decisions made are outlined in the relevant studies.

5.5 Measures of physical function and mobility

5.5.1 The Barthel Index

The Barthel Index (BI) is considered a valid and reliable assessment of mobility and ADLs (Collin et al., 1988; Wade and Collin, 1988) and is used routinely in the assessment of older adults. The BI assesses functional status on a 20-point scale by recording ability to complete ten ADLs: bathing, bladder function, bowel function, dressing, feeding, grooming, mobility, stairs, toilet use and transfers (**Appendix G**). Higher scores on the BI indicate greater independence and scores of <11 indicate dependence on a carer for ADLs (Gupta and Rehman, 2008).

5.5.2 Functional Ambulation Classification

The Functional Ambulation Classification (FAC) scale, developed at Massachusetts General Hospital by Holden, Gill and Magliozzi (1984), assesses the level of human assistance an individual requires to ambulate (i.e. walk). The scale has previously achieved a kappa inter-rater reliability of 0.72 when tested by nine therapists on five patients (Holden et al., 1984). The scale is scored from zero (non-functional ambulation) to five (ambulator-independent) with a higher score being indicative of more independence (**Appendix H**).

5.6 Overview of statistical analysis

All analysis were completed using a standard statistical software package (SPSS Statistics V.21, IBM Corporation, Somers, NY, USA). Data were first assessed for normality of distribution visually (via histograms) and using the Shapiro-Wilk test. In cases where data were non-normally distributed, data were log transformed to permit the use of parametric statistics. Alternatively, if log transformation was not appropriate or did not result in a normal distribution of data, non-parametric statistics were utilised. Data are presented as mean ± standard deviation (SD) unless otherwise specified and alpha was accepted as $p < 0.05$. Details regarding the specific statistical tests utilised in each of the studies are outlined in the relevant chapters.

Chapter 6 Exploration of the impact of key methodological decisions on accelerometer-determined estimates of physical activity and sedentary behaviour in older adults.

Aspects of this chapter were presented at the following conferences:

- The International Association of Gerontology and Geriatrics European Region (IAGG-ER) 8th Congress, Dublin, Ireland, April 2015 – Poster presentation
- Annual Faculty of Biological Sciences Postgraduate Symposium, University of Leeds, UK, July 2015 – Poster presentation

6.i. Preface

As the systematic review conducted in the **Chapter 3** demonstrates, the use of accelerometers to objectively measure PA and sedentary behaviour in older care adults residing in care homes is increasing. However, as became apparent in the previous chapters, little consideration has been given to the methodological issues and questions which surround the use of these activity monitors specifically in this population. Indeed, **Chapter 4** highlighted that there is a paucity of high-quality measurement specific research involving older adults, with no such studies conducted with care home residents. Whilst this goes some way to explaining the absence of a consensus on the "correct" methodological decisions in this population, it is concerning given the literature reviewed suggested the decisions made can have a large impact on the interpretation of the data collected and ultimately the validity of results.

The purpose of this chapter was not to provide "hard" recommendations on accelerometer methods but rather to explore the impact of the key methodological decisions on estimates of PA and sedentary behaviour in older adults (including those residing in a care home) and provide empirical evidence to support their use in the remaining studies presented within this thesis.

The chapter is comprised of three separate studies, each with a different objective and distinct methodology. Briefly, the aim of ***Study 1*** was to explore the impact of three decisions, namely the filter used to process the raw data, the count value considered and accelerometer wear location, on the criterion validity of estimates of EE in a population of community-dwelling older adults. ***Study 2*** then examined the impact of the count value considered and epoch length on the criterion validity of estimates of PA and sedentary time in care home residents. Finally, ***Study 3*** investigated the minimal wear time criteria needed to achieve reliable estimates of PA and sedentary behaviour in older care home residents.

6.1 Study 1: Exploration of the impact of data processing and reduction practices on the criterion validity of hip- and wrist-worn accelerometers to estimate energy expenditure in community-dwelling older adults

6.1.1 Introduction

Several analytical approaches to translating accelerometer data into key PA outcomes exist and are continually evolving. Nonetheless, the use of simple regression equations to derive estimates of EE from accelerometer counts remains one the most popular (Troiano et al., 2014). Numerous equations exist and are widely used with older adults (aged ≥ 65 years); yet relatively few were developed specifically for this population (Santos-Lozano et al., 2013; Sasaki et al., 2011; Freedson et al., 1998). Studies involving community dwelling older adults have explored the validity of accelerometers for estimating EE (Copeland and Esliger, 2009). However, participants are typically described as “healthy” and active therefore the applicability of these equations to care home residents who are typically characterised as being the frailest segment of the population (Gordon et al., 2014) is questionable given the physiological cost of engaging in activity varies dependent on factors such as CRF and body composition (Evenson et al., 2012). Moreover, little consideration has been given to how the methodological decisions made may influence the association between EE and activity counts (**Chapter 4**). In the current study, the impact of three key decisions, namely the filter used to process the raw accelerometer data; the count value used to derive PA outcomes and accelerometer wear location will be investigated.

Current accelerometers allow the end-user to choose between two filtering options: normal or a low-frequency extension (LFE) (**section 4.4.1**). The premise underpinning the development of the LFE filter was that it would be more sensitive to measuring the PA of individuals who move slowly; therefore it has been recommended for use with older adults (ActiGraph white paper, 2012). Recent data collected in older adults demonstrated that the accelerometer counts recorded did vary considerably dependent on the filter used, particularly when participants were engaging in sedentary behaviours or low intensity PA (Wanner et al., 2013). However, to date no study has explored whether the discrepancies in count values observed between the two filters persists when these data are converted into PA outcomes of interest such as EE. Moreover, there is no evidence to suggest that the use of the LFE filter is indeed preferable. Thus, further investigation is warranted.

Data collected using the newer tri-axial accelerometers can be analysed for each axis separately (vertical, medio-lateral and anterior-posterior) (John and Freedson, 2012) or as the composite VM value of the three axes (ActiGraph Corporation 2016). Theoretically, VM counts should provide better estimates of EE; yet this issue has received limited attention in older adults and many studies continue to rely on vertical axis (VA) counts. A recent study did compare EE measured with indirect calorimetry and EE estimates derived from two separate regression equations, one based on VA counts and another on VM counts, in 97 adults aged 18 y - 80 y (Santos-Lozano et al., 2013). The authors reported better agreement between EE measured by indirect calorimetry and EE derived from VM, compared to VA activity counts. These results were mirrored by a large-scale study conducted by Chomistek et al (2017) which compared estimates of EE derived from both VA and VM counts to EE measured by DLW in 1,295 adults aged between 43 y and 83 y. Again, the authors found EE estimates derived from the VM counts were in closer agreement with the criterion measure than the estimates derived from the VA counts; thus offering empirical evidence to support the aforementioned hypothesis that VM counts provide better estimates of EE in comparison to VA counts. Nevertheless, neither of these studies were conducted specifically in older adults. It would therefore seem premature to draw conclusions regarding which count value (VA or VM) provides the most accurate estimation of EE in this population.

Accelerometers can be attached to various body sites. Hence, one of the key decisions which needs to be made prior to data collection relates to accelerometer wear location (**section 4.3.2**). Whilst it is acknowledged that activity counts recorded are likely to differ markedly dependent on where the accelerometer is worn (LaMunion et al., 2017), guidance on how to interpret activity counts recorded by an accelerometer worn on a location other than the hip in a meaningful way is limited. Nonetheless, wrist-worn accelerometers are increasingly being used in large-scale epidemiological studies in light of reports of improved compliance compared to a hip-worn monitor (Troiano et al., 2014). Furthermore, there is some evidence that an accelerometer worn on the wrist rather than the hip may be better suited to measuring the PA of frail older adults as it can capture upper body movements typical of non-ambulatory activities (for example ADLs such as dressing) and the influence of atypical gait patterns is likely minimised (Schrack et al., 2016). However, there is a paucity of studies comparing the outputs derived from hip- and wrist-worn accelerometers in older adults. Kamanda et al (2016) found a moderate correlation ($r = 0.73$) between daily VM counts measured separately by a hip- and wrist-worn accelerometer in a group of older adults ($n = 94$, mean age: 71.9 y ± 6.0 y). The authors also reported a classification agreement (i.e. participants were classified in the same quintile based on daily VM counts per day measured separately by a hip- and wrist-worn accelerometer) of 46.8% (range 21 – 72%). However, the authors did not assess agreement with a criterion measure therefore it is not possible to make inferences about which wear location results in the most valid measure of PA in this population.

Understanding the impact of different data processing and reduction practices is imperative to ensure outcomes such as estimates of EE which are derived from accelerometer counts are interpreted appropriately. Thus, the aims of this study are as follows:

a) To explore the effect of the filter used to process the raw accelerometer data and any differences between the VA and VM counts recorded by both a hip- and wrist-worn accelerometer.
b) To assess the validity of both the hip- and wrist-worn accelerometer for the assessment of EE using VO_2 as the criterion measure.

6.1.2 Methods

6.1.2.1 Participants

Community dwelling older adults aged ≥ 65 years (n = 15, age: 77 y ± 7 y) were recruited between January and December 2014, via strategies described in the general methods chapter, **section 5.2.1**.

6.1.2.2 Experimental Protocol

Participants visited the Sport and Exercise Sciences laboratory at the University of Leeds on a single occasion for approximately 1.5 hours. Basic demographic information was collected via completion of a self-report health status questionnaire. Height was measured to the nearest 0.5 cm using a stadiometer and body mass to the nearest 0.1 kg using a balance scale. Participants were then familiarised with the validation protocol (Figure 6.1) and fitted with all recording equipment just prior to the start of the test. This included a sterile facemask, electrocardiogram (ECG) electrodes and both a hip- and wrist-worn accelerometer.

The validation protocol started and ended with a five-minute period of seated rest. The protocol involved the following four activities: chest passes, toe taps, dumbbell raises and knee raises, performed in a standardised order. Each activity performed was sustained for three minutes as this time period has been shown to be sufficient to reach VO_2 steady state during low intensity PA (Whipp and Wasserman, 1972).Consistent with similar research conducted with older adults, each activity was separated with five minutes of seated rest (Taylor et al., 2012). It was surmised that balance and / or strength impairments characteristic of frail older adults likely affect their ability to stand for any length of time. Hence, all activities were completed in a seated position as it was felt that this better reflected the PA frail older adults would typically engage in. The specific activities were chosen as they involved the use of upper and lower body movements and both large and small muscle groups, and it was deemed important to determine whether the accelerometer is able to accurately estimate EE across a range of different activities. It was also felt they would replicate the movement patterns typical of many ADLs which likely make up a large component of the PA many older adults engage in. Time was recorded at the beginning and end of each activity to ensure appropriate data comparisons could be made across recording devices.

5 minute rest period

Activity 1: Chest passes

Participants were asked to place their hands behind the ball and chest pass the ball to a researcher standing opposite them in time to a metronome (45 beats/min).

5 minute rest period

Activity 2: Toe taps

Participants were asked to lift their foot and stretch their leg out in front of them; tap the floor with their toes before returning their foot to it its starting position. Participants alternated between their right and left foot and completed the movement pattern in time to a metronome (45 beats / min).

5 minute rest period

Activity 3: Dumbbell front raises

Participants started holding the dumbbell across their thighs horizontally before gently lifting it upward (as far as was comfortable), arms out in front with palms facing down, and lowering it again in time with a metronome (45 beats / min).

5 minute rest period

Activity 4: Knee raises

Participants were asked to gently lift their knee (right and left knees alternately) as far as was comfortable for them whilst maintaining their posture and lower it again in time to a metronome (45 beats / min).

5 minute rest period

Figure 6.1 A flow chart of the validation protocol. For all activities participants were asked to sit upright in their seat and start with their feet placed flat on the floor, shoulder width apart. Each activity was completed for a period of three minutes.

6.1.2.3 Measures

Indirect calorimetry

To allow for the recording of both breath by breath VO_2 and HR data, participants were fitted with a sterile facemask which covered their nose and mouth and a 12-lead ECG. HR data and the ECG were observed throughout the validation protocol to ensure no abnormalities occurred and to maintain participant safety. Both VO_2 and HR were recorded throughout the validation protocol using the Ultima CardiO2 metabolic stress testing system (Medgraphics Cardiorespiratory Diagnostics). The system was fully calibrated prior to the commencement of each testing session. Specifically, flow of air across the pneumotach was calibrated using a 3-litre syringe (Hans Rudolph, Kansas City, MO) using 10 flow profiles and known gas concentrations were used to calibrate O_2 and CO_2analysers.

6.1.2.4 Data Reduction

Accelerometer count data

Data collected from the hip and wrist accelerometers were treated the same unless otherwise stated. Raw activity count data were processed using two different filters and thus produced two separate datasets: normal and LFE. For each of these datasets activity counts recorded in the VA and as the composite VM were utilised. Thus, for both the hip and wrist accelerometer, and for each activity separately, four sets of data were produced: normal VA counts, LFE VA counts, normal VM counts and LFE VM counts.

To enable direct comparison between counts recorded by the hip and wrist accelerometers, all four sets of data (i.e. the normal VA counts, LFE VA counts, normal VM counts and LFE VM counts) recorded by the wrist accelerometer were adjusted according to the recommendations of the manufacturer (Table 6.1). These adjusted wrist counts were used in all analyses.

Table 6.1 Equations utilised to adjust accelerometer counts collected by the accelerometer when worn on the wrist (ActiGraph, 2018).

Wrist Count	Equivalent Counts
0	0
0-644	0.5341614 * wrist count
645-1272	1.7133758 * (wrist count - 759.414013)
1273-3806	0.3997632 * (wrist count + 911.501184)
≥ 3807	0.0128995 * (wrist count + 2383.904505)

Next, to align with the VO_2 data, only the final two minutes of each activity was utilised. In order to facilitate direct comparison with estimates of EE derived from VO_2 (as measured via indirect calorimetry), the four sets of activity count data were converted into MET values using separate pre-validated equations for VA and VM counts (Santos-Lozano et al., 2013). These equations (Equation 6.1and Equation 6.2) were developed in a sample of 97 adults (48 males and 49 females) aged 12 y – 80 y:

Energy expenditure (METs) = 3.14153 + (0.00057 * VA cpm) - (0.01380 * BM) - (0.00606 * Age)

Equation 6.1

Energy expenditure (METs) = 2.7406 + (0.00056 * VM cpm) - (0.008542 * Age) - (0.01380 * BM)

Equation 6.2

Where cpm is counts per minute and BM is body mass measured in kilograms (kg)

Oxygen uptake (VO_2) data

Breath by breath VO_2 data were used for analysis. Data were analysed using Origin Lab software (OriginPro V.8, Northampton, MA, USA). In order to ensure a physiological steady state was reached, the first minute of each activity was considered an equilibrium period and thus excluded. In addition, the final two minutes of raw breath by breath data were checked for erroneous breaths (for example the result of a participant coughing). 99% confidence limits were applied to the data and any breaths outside of these limits (i.e. 4 standard deviations away from the mean) were excluded. Data captured in the final two minutes of each activity were then averaged and converted to estimates of EE by calculating MET values. In light of debate around the applicability of the standard convention for calculating METs (i.e. 1 MET = 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$) in older adults (Kwan et al., 2004), the group mean VO_2 measured during the five rest periods (2.6 $mL \cdot kg^{-1} \cdot min^{-1}$) was used to define a MET in this study.

6.1.2.5 Statistical analysis

Treatment of the data in preparation for statistical analysis is detailed in the general methods chapter, **section 5.6**. The accelerometer count data were not normally distributed. Attempts to log transform this data were unsuccessful therefore these data were treated non-parametrically. Both pooled data (i.e. data from all activities) and data for each activity separately were considered in all analyses.

In order to determine the impact of filter and axis upon recorded count data, the four sets of data (normal VA, LFE VA, normal VM and LFE VM activity counts) were compared using Friedman's ANOVA and Bonferroni corrected pairwise comparisons to explore where differences lay. This analysis was done separately for the hip and wrist. The data were then examined to determine whether activity count values varied with wear location (hip vs. wrist). For each data set, Wilcoxon signed rank tests were used to compare the count values recorded by the hip to those recorded by the wrist accelerometer (e.g. hip normal VA vs. wrist normal VA counts).

A repeated measures ANOVA was then utilised to determine whether any differences between the four data sets remained following conversion to METs. Data violating the assumption of sphericity were adjusted using Greenhouse-Geisser. As above, these analyses were undertaken separately for each wear location. Data were then examined to determine whether MET values varied with wear location (hip vs. wrist). For each data set, the MET values derived from hip activity counts were compared to those derived from the wrist activity counts using paired samples t-tests.

Finally, the magnitude of agreement between each of the MET values derived from the four accelerometer count datasets and that measured via VO_2 was assessed using the Bland-Altman method (Bland and Altman., 1986). The mean difference (i.e. bias) and the limits of agreement (LoA) were considered and interpreted “practically”. That is, a bias close to zero and narrow LoA were viewed favourably as they are indicative of better agreement.

6.1.3 Results

6.1.3.1 Participant characteristics

Fifteen participants were recruited but one participant withdrew from the study prior to data collection. Thus, 14 participants completed the validation protocol and were included in the analysis. However, due to accelerometer malfunction (n = 1) and refusal to wear the facemask (n = 1) data for two participants were incomplete. The personal characteristics of these two participants were not different from those with complete data ($p > 0.05$), therefore the characteristics of all 14 participants are described in Table 6.2.

Table 6.2 Participant characteristics (n = 14).

	N (%) or Mean ± SD
Gender (male)	3 (21%)
Age (y)	76 ± 7
Height (m)	1.6 ± 0.1
Weight (kg)	74.9 ± 12.6
Chronic condition present (yes)	13 (93%)

6.1.3.2 Accelerometer count data

Accelerometer counts for the pooled data and each activity separately are presented in Table 6.3. The following will focus on the pooled data unless otherwise stated. For both the hip and wrist data, a significant difference between the four sets of accelerometer data was observed (hip: $\chi^2(3) = 108.35$, $p < 0.01$ and wrist: $\chi^2(3) = 143.44$, $p < 0.01$). Pairwise comparisons revealed that for both the hip and wrist data, LFE VA and LFE VM activity counts were significantly higher than normal VA and normal VM counts respectively ($p < 0.05$). Similarly, both hip and wrist VM counts were significantly higher than VA counts, irrespective of the filter used to process the data ($p < 0.05$, Table 6.3). Moreover, as can be seen from the table, the activity counts recorded by the wrist accelerometer were significantly higher than those recorded by the hip accelerometer, irrespective of the data set considered ($p < 0.01$).

As was the case with the pooled data, across each of the activities both the VA and VM activity counts recorded by the hip- and wrist-worn accelerometers were higher when the LFE filter was utilised. However, when considering VA counts, the only significant difference was observed during knee raises where wrist LFE counts were significantly higher than normal counts. Similarly, when considering VM counts the difference between filters only reached significance during two of the four activities: chest passes (hip data) and toe taps (hip and wrist data). In contrast, pairwise comparisons revealed that the significant difference between VA and VM activity counts was more consistently observed across each of the activities, particularly when the LFE filter was applied. When considering the wrist data, VM counts were significantly higher than VA counts during three of the four activities (chest passes, dumbbell raises and knee raises) regardless of the filter applied. However, during toe taps the difference between VM and VA counts was only deemed significant when the LFE filter was applied. For the hip data, VM counts were significantly higher than VA counts during all four of the activities when the LFE filter was applied. Yet when the normal filter was applied, the only significant difference was observed during knee raises where VM counts were significantly higher than VA counts (Table 6.3).

6.1.3.3 Estimated MET values

MET values derived from the accelerometer count data for the pooled data and each activity separately are presented in Table 6.4. The following section will focus on the pooled data. For both the hip and wrist data, a significant main effect of filter was observed, with MET values derived from activity counts processed using the LFE filter being significantly higher than those processed using the normal filter ($p < 0.05$). Although the difference was statistically different the magnitude of the difference was small. For example, for the hip data, the METs derived from LFE counts were 0.09 METs (95% CI: 0.07, 0.12 METs) higher than when normal counts were used. Similarly, the METs derived from counts recorded by the wrist-worn accelerometer were only 0.03 METs (95% CI: 0.01, 0.05 METs) higher when the LFE rather than normal filter was used.

The effect of axis was also significant for both the hip and wrist data with MET values based on VA activity counts being significantly higher than those based on VM activity counts ($p < 0.05$). The magnitude of the difference between the two count values was also similar for both the hip and wrist data. MET values derived from the VA counts were on average 0.53 METs (95% confidence intervals: 0.51- 0.55 METs) higher than those derived from VM counts. Similarly, for the wrist-worn accelerometer, the METs derived from VA counts were 0.54 METs (95% confidence intervals: 0.51- 0.57 METs) higher than those derived from VM counts.

A significant interaction between filter and axis was observed for both the hip and wrist data ($p < 0.05$). This indicated that the VA and VM counts were affected differently by the filter chosen to process the data. Specifically, using the LFE rather than the normal filter to process the count data resulted in a larger increase in the MET values derived from the VM counts than the VA counts. Furthermore, all four MET values derived from counts recorded by the wrist accelerometer were significantly higher than those derived from hip counts ($p < 0.01$, Table 6.4).

In considering each of the activities separately, when MET values were derived from activity counts recorded by the hip-worn accelerometer the main effect of axis and the interaction between filter and axis remained across all activities. Moreover, the effect of filter on MET values was observed across all activities bar chest passes (Table 6.4). Conversely, when considering the MET values derived from wrist activity counts, the effect of the processing criteria was more variable across activities (Table 6.4). The interaction between filter and axis was only significant during the two lower body activities (toe taps and knee raises).

Table 6.3 Accelerometer count data (median [IQR]) across all activities and by each activity separately.

Activity	Accelerometer Data (counts per minute)									
	Hip accelerometer					Wrist accelerometer				
	*n**	normal VA	LFE VA	normal VM	LFE VM	*n**	normal VA	LFE VA	normal VM	LFE VM
All activities† ‖	52	0 (1)‡ §	1 (14)‡ §	0 (76)‡ §	23 (168)‡ §	56	1584 (2438)‡ §	1641 (2411)‡ §	2436 (2460)‡ §	2469 (2388)‡ §
Chest Passes† ‖	13	0 (2)	4 (10)§	0 (78)‡	22 (164)‡ §	14	2458 (31)§	2460 (31)§	2523 (43)§	2525 (43)§
Toe Taps† ‖	13	0 (0)	0 (1)§	0 (0) ‡ ‖	3 (32)‡ §	14	7 (56)	34 (78)§	67 (125)‡	99 (171)‡ §
Dumbbell Raises† ‖	13	0 (0)	0 (3)§	0 (11)	7 (32)§	14	2481 (70)§	2482 (62)§	2554 (98)§	2561 (92)§
Knee Raises†	13	3 (138)§	95 (236)§	185 (330)§	342 (455)§	14	28 (248)‡ §	134 (928)‡ §	118 (960)‡ §	306 (1106)‡ §

*13 and 14 participants provided hip and wrist accelerometer data respectively; thus, a total of 52 and 56 values were used to calculate the averages across the four activities.

† significant difference between activity counts dependent on the data processing criteria for both the hip and wrist data ($p < 0.05$);

‡ indicates significant difference between counts dependent on filter applied (normal vs. LFE) ($p < 0.05$);

§ significant difference between counts dependent on axis considered (VA vs. VM) ($p < 0.05$);

‖ significant effect of wear location difference in activity counts (hip vs. wrist), irrespective of data set considered ($p < 0.05$).

Table 6.4 Measured and estimated MET values derived from accelerometer count data across all activities and by each activity separately. Data are presented as mean ± SD.

Activity	Measured METs	Estimated METs									
		Hip accelerometer					Wrist accelerometer				
		*n**	normal VA counts	LFE VA counts	normal VM counts	LFE VM counts	*n**	normal VA counts	LFE VA counts	normal VM counts	LFE VM counts
All activities † ‡ § ‖	1.95 ± 0.49	52	1.66 ± 0.20	1.71 ± 0.20	1.09 ± 0.21	1.22 ± 0.20	56 † ‡ §	2.38 ± 0.70	2.40 ± 0.68‡ ‖	1.83 ± 0.71	1.87 ± 0.68
Chest Passes ‡ § ‖	2.18 ± 0.48	13	1.65 ± 0.21	1.66 ± 0.21	1.09 ± 0.23	1.13 ± 0.24	14 † ‡	3.03 ± 0.22 ‡	3.03 ± 0.21‡ ‖	2.47 ± 0.21	2.47 ± 0.21
Toe Taps † ‡ § ‖	1.82 ± 0.36	13	1.65 ± 0.21	1.73 ± 0.21	1.06 ± 0.21	1.26 ± 0.18	14 † ‡ §	1.67 ± 0.21	1.69 ± 0.20† ‡	1.12 ± 0.23	1.14 ± 0.23
Dumbbell Raises† ‡ § ‖	1.61 ± 0.46	13	1.65 ± 0.21	1.73 ± 0.21	1.07 ± 0.21	1.26 ± 0.18	14 ‡	2.99 ± 0.23	2.99 ± 0.22‡ ‖	2.48 ± 0.19	2.49 ± 0.20
Knee Raises † ‡ §	2.25 ± 0.40	13	1.69 ± 0.21	1.73 ± 0.21	1.15 ± 0.18	1.26 ± 0.18	14 ‡ §	1.84 ± 0.46	1.89 ± 0.44‡	1.26 ± 0.45	1.38 ± 0.45

*13 and 14 participants provided hip and wrist accelerometer data respectively; thus, there were a total of 52 and 56 values were used to calculate the averages across the 4 activities.

† indicates a significant main effect of filter (normal vs. LFE) ($p < 0.05$);

‡ indicates a significant main effect of axis (VA vs. VM) ($p < 0.05$);

§ indicates a significant filter (normal vs. LFE) x axis (VA vs. VM) interaction ($p < 0.05$);

‖ significant effect of wear location (hip vs. wrist), irrespective of data set considered ($p < 0.05$).

6.1.3.4 Agreement between MET values derived from VO_2 and those estimated from the four accelerometer data sets

The key results of the Bland-Altman analysis for the pooled data and each activity separately are presented in Table 6.5. As can be seen from the table, the width of the LoA were fairly consistent across data sets for both the pooled data and each activity separately, whereas the width of the LoAs observed for the wrist data were more variable. Furthermore, regardless of the accelerometer data set used, the widths of the LoA were narrower when MET estimates were derived from activity counts recorded by the hip- compared to the wrist-worn accelerometer. This is highlighted by the Bland-Altman plots for the pooled data presented in Figure 6.2. The LoA's for both the hip and wrist data were narrower for the lower body activities (i.e. toe taps and knee raises) compared to those for the upper body activities (i.e. chest passes and dumbbell raises).

Additionally, the results of the Bland-Altman analysis suggest that in general (i.e. inferences were based on the pooled data) EE was slightly underestimated when it was derived from activity counts recorded by the hip-worn accelerometer (mean bias: -0.30, 0.25, 0.87 and 0.73 METs respectively for the normal VA, LFE VA, normal VM and LFE VM data sets). Conversely, EE estimates derived from accelerometer data recorded by the wrist-worn accelerometer were more variable with VA counts resulting in a slight overestimation in EE (mean bias: -0.45 and -0.26 respectively when the normal and LFE filters were applied), while the use of VM counts resulted in a slight underestimation of EE (mean bias: 0.07 and 0.27 respectively when the normal and LFE filters were applied).

Table 6.5 The bias and width of the LoAs between the MET-value derived from VO_2 data (criterion) and MET values derived from each of the four accelerometer count data sets using the Santos-Lozano equations for VA and VM data. Results for the pooled data and each activity separately are presented.

	Hip-worn accelerometer					Wrist-worn accelerometer				
Activity	***n****	**normal VA counts**	**LFE VA counts**	**normal VM counts**	**LFE VM counts**	***n****	**normal VA counts**	**LFE VA counts**	**normal VM counts**	**LFE VM counts**
All activities	12					13				
Bias		0.30	0.25	0.87	0.73		-0.45	-0.26	0.07	0.27
Width of LoAs		2.23	2.31	2.15	2.22		3.57	2.81	3.51	2.79
Chest passes										
Bias		0.59	0.50	1.06	1.03		-0.92	-0.93	-0.37	-0.37
Width of LoAs		2.29	2.30	2.26	2.27		2.30	2.31	2.31	2.31
Toe taps										
Bias		0.17	0.09	0.76	0.56		0.12	-0.11	0.68	0.41
Width of LoAs		1.70	1.80	1.72	1.68		1.67	2.15	1.76	2.21

Dumbbell raises								
Bias	-0.04	-0.12	0.54	0.35	-1.39	-0.31	-0.88	0.21
Width of LoAs	2.15	2.22	2.16	2.06	2.36	2.41	2.11	2.43
Knee raises								
Bias	0.56	0.52	1.09	0.99	0.38	0.32	0.87	0.84
Width of LoAs	2.09	2.09	1.89	1.84	2.32	2.10	2.01	2.05

*12 and 13 participants provided both VO_2 and hip and wrist accelerometer data respectively; thus the SD of the mean difference (bias) between a total of 48 and 52 MET values were used to calculate the LoAs.

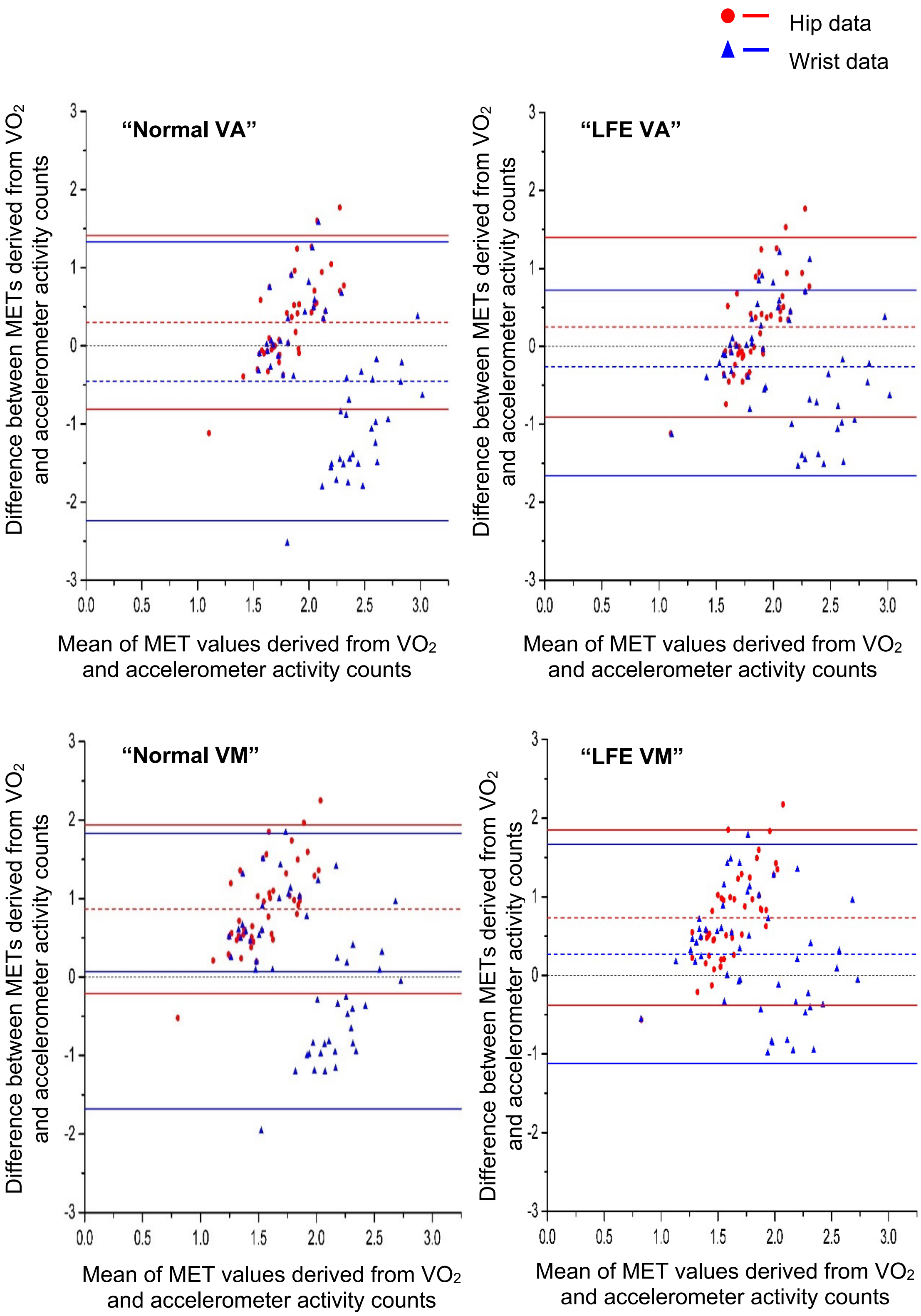


Figure 6.2 Agreement between the MET values derived from VO_2 data (criterion) and MET values derived from each of the four accelerometer count data sets using the Santos-Lozano equations for VA and VM data. Results for the pooled data are presented. Red and blue dashed lines represent the bias for hip and wrist data respectively. Red and blue solid lines represent the 95% LoA for hip and wrist data respectively.

6.1.4 Discussion

In the absence of a consensus on how to process, reduce and analyse accelerometer data in older adults the first aim of this study was to explore the impact of three key methodological decisions. Namely, the filter used to process the raw accelerometer data (normal vs. LFE); the activity count value used for analysis (VA vs. VM) and accelerometer wear location (hip vs. wrist).

The findings of this study suggest that in older adults the activity counts recorded by both a hip- and wrist-worn accelerometer differ significantly dependent on the processing filter used and the axis of data considered. In accordance with the literature (Cain et al., 2013a), pairwise comparisons revealed that both VA and VM activity counts were significantly higher when the LFE, rather than the normal, filter was utilised to process the pooled data ($p < 0.05$). Furthermore, irrespective of the filter used, the pooled VM counts were significantly higher than VA counts ($p < 0.05$). These findings were not unexpected given previous studies have presented findings which suggest VA and VM counts differ (Keadle et al., 2014). Both of the aforementioned findings were observed regardless of the accelerometer wear location.

Although it was anticipated given accelerometers measure the acceleration of the body segment to which they are attached (LaMunion et al., 2017), it is important to acknowledge the finding that when considering the pooled data, and three of the four activities separately, activity counts recorded by the wrist-worn accelerometer were significantly higher than those recorded by the hip-worn accelerometer, irrespective of the dataset used. Interestingly, no difference in the activity counts recorded by the hip- and wrist-worn accelerometers were observed during the knee raising activity. This finding may be explained by the observation that some of the participants used their hands to help move their legs during the knee raising activity which would explain the latter result.

For both the hip and wrist data, the difference between each of the accelerometer data sets remained following the conversion of activity count data to MET values. Taken together the findings discussed thus far lend support to the suggestion that all three of the methodological decisions pertaining to accelerometer data processing and reduction examined (i.e. filter, axis and wear location) do have an impact on EE estimates. Consequently, it may be inferred that simply referring to the validity of accelerometers in older adults without consideration of how that data is derived is inadequate. It has recently been suggested that it is more appropriate to consider the validity of the “obtained data” rather than the measurement instrument itself (Kelly et al., 2016). In light of this, the second aim of this study was to explore which of the eight accelerometer data sets (four recorded by the hip-worn accelerometer and four by the wrist-worn accelerometer) resulted in the MET value closest to that derived from VO_2 data.

The findings from the Bland-Altman analysis suggested that the activity counts recorded by a hip-worn accelerometer provided more valid estimates of EE compared to the wrist activity counts, irrespective of the data set used. This finding is not unsurprising given the equations utilised were based on the relationship between EE and activity recorded by a hip-worn accelerometer and it is likely that the relationship between EE and wrist activity counts is markedly different (LaMunion et al., 2017). Perhaps more interesting was the finding that, although both filter and axis had an effect on the resultant MET values, the difference in terms of the agreement observed between the MET values derived from each of the four hip accelerometer data sets and the MET value derived from VO_2 was minimal. This may be explained by the fact that anteroposterior and mediolateral movements (which would only be accounted for by the VM count) were limited as all activities in the validation protocol were undertaken in a seated position. Having said this, when considering the pooled data, the normal VM activity counts resulted in marginally better agreement.

It is important to acknowledge there are some limitations with this study. Firstly, the study was conducted in a laboratory setting which may limit the ecological validity of the findings. Moreover, whilst an effort was made to select activities “typical” to older adults residing in a care home it could be argued that it is not appropriate to generalise the findings to this population given the relationship between activity counts and EE may differ considerably. The relatively small sample included in this study may also be a cause for concern with regards to the generalisability of results given older adults are a particularly heterogeneous population.

Nevertheless, indirect calorimetry is considered the gold standard measure of EE (Strath et al., 2013). Furthermore, the current study utilised measures of agreement to determine the validity of the EE estimates derived from the accelerometer data sets rather than correlational analysis. This represents a major strength of this study given correlations simply offer evidence that two measures are related and do not provide any information regarding the systematic differences between two measures.

6.1.5 Conclusions and future work

In conclusion, the findings from this study demonstrated that the methodological decisions pertaining to the processing, reduction and analysis of accelerometer data do have an impact on EE estimates in a population of community-dwelling older adults. Consequently, it is important to consider the “obtained data” rather than the measurement instrument itself.

The validity of EE estimates were considerably better when the accelerometer was worn on the hip rather than the wrist, irrespective of the accelerometer data set used to derive the MET values. For this reason, the hip remains the preferred wear location when using accelerometers to derive estimates of EE in older adults. Accordingly, participants in the remaining studies presented within this thesis were asked to wear a hip-worn accelerometer.

Although both filter and axis had a significant effect on the MET values derived from activity counts recorded by the hip-worn accelerometer, there was little difference in the validity of EE estimates derived from each of four the hip accelerometer data sets considered in this study. In the absence of a substantial improvement in the validity of EE estimates following the application of the LFE filter, the use of the normal filter to process raw accelerometer data is advised and was used in the remaining studies presented within this thesis to enable comparison with a wider body of literature.

In general, EE estimates derived from VM counts showed marginally better agreement with the criterion measure compared to estimates based on VA counts. Nevertheless, further work using independent samples of older adults is warranted to further explore the potential improvement in the validity of PA and sedentary behaviour outcomes derived from VM counts compared to VA counts. It is also important to acknowledge that outcomes other than EE may be more relevant to older adults, particularly those who are frail and / or residing in a care home.

6.2 Study 2: Exploration of the impact of data processing and reduction practices on the criterion validity of accelerometer estimates of sedentary and physical activity time in care home residents

6.2.1 Introduction

The ability of accelerometers to quantify differing intensities of PA and sedentary behaviour mean they have great potential in terms of their use with care home residents. Even so, measurement specific research involving this unique population is scarce. One of the few studies conducted was that by Taylor et al (2014) who evaluated the validity of an accelerometer to classify gait and different postures (i.e. sitting, standing and lying) in 22 older adults aged ≥ 80 y residing in either LTC or independent living facilities. The authors concluded that the accelerometer provided a valid measure of gait and lying; however, they acknowledged that the error of approximately 25% when discriminating between sitting and standing was problematic (Taylor et al., 2014). Nonetheless, this study employed the DynaPort accelerometer and it is unclear whether these findings would be replicated if the ActiGraph accelerometer had been used; thus further work is warranted.

Whilst the current (ActiGraph) accelerometers have the capability to continuously record and store accelerations at a high resolution, across multiple axes, appropriate methods of analysing this raw acceleration data are still under development therefore they are not consistently implemented (Troiano et al., 2014). Many researchers continue to use conventional analytic approaches such as regression-based “cut-points” to classify time spent engaging in PA and sedentary behaviour from activity counts accumulated over a given epoch (**Chapter 4, section 4.4.5**). Accordingly, both the count value and epoch length used are key methodological decisions which require consideration as they may affect the interpretation of data and thus impact inferences made.

Indeed, in the previous study, estimates of EE derived from VM counts showed better agreement with the criterion measure compared to estimates based on VA counts. Still, further work is warranted to investigate whether the count value used has an impact on the validity of estimates of time spent engaging in PA and sedentary behaviours. Keadle et al. (2014) compared estimates of PA and sedentary behaviour derived from VA and VM counts in a large sample of older women (n = 7,650, mean age: 71 y ± 5 y) and reported that the estimates were substantially different. However, they did not compare the estimates to a criterion measure, therefore it is not possible to make inferences regarding which estimate was most valid.

Studies assessing habitual PA and sedentary behaviour in older adults have typically used 60 second epochs with little thought afforded to the research question or measurement context (Ward et al., 2005). Care home residents' engagement in PA is typically sporadic and of low intensity (Marmeleira et al., 2017; Barber et al., 2015) therefore the use of 60 second epochs may result in these short periods of PA being "averaged out" and misclassified as sedentary behaviour (Chen and Bassett, 2005). Although it seems intuitive that the use of shorter epochs would be preferable to further understanding of the patterns of PA and sedentary behaviour and potentially increase the strength of associations with health outcomes, the impact of epoch length has not been explored in older adults.

The aim of the current study was to explore the impact of the count value and epoch length used on the criterion validity of estimates of PA and sedentary time. Estimates of PA and sedentary time were derived from activity counts recorded by a hip-worn accelerometer, whilst the criterion measure was obtained using direct observation (DO) in in a group of care home residents.

6.2.2 Methods

6.2.2.1 Participants

A full description of care home and participant recruitment procedures, including details regarding screening and the process of obtaining consent are provided in Chapter 5, **section 5.2.2**. Recognising that care home residents are a particularly heterogeneous population, observing residents with varying degrees of functional ability and mobility in a free-living environment was deemed particularly important in the current study in order to determine what types of movement the accelerometer would capture. Thus, a purposive sample of eligible residents (n = 16, mean age: 85 y ± 7 y) were recruited from five care homes involved in WS 2 and WS 4 of the REACH programme (previously described in **section 1.5**) between June 2013 and March 2015.

6.2.2.2 Experimental Protocol

Participants were fitted with a hip-worn accelerometer as per the procedures described in the general methods chapter (**section 5.3**). Once it was established that the participant was comfortable wearing the accelerometer they were encouraged to continue with their "usual" activities in the care home while they were directly observed by the researcher for a two-hour period.

The researcher used a pre-determined list of activities to systematically record what they observed participants doing every 15 seconds over the monitoring period. The list of activities, complied following a period of observation in the care homes participating in the study, included both PAs and sedentary behaviours which were deemed typical of care home residents (**Appendix I**). Any additional details that would facilitate the accurate classification of activities during analysis were also noted. For example, if a participant was observed walking, a note was made regarding the speed. The time the two-hour monitoring period started was documented to ensure appropriate data comparisons could be made across the two recording methods.

6.2.2.3 Data reduction

Accelerometer count data

Raw activity count data were aggregated over two different epoch lengths (15 seconds and 60 seconds) therefore two separate datasets were produced: 15 s and 60 s. For each of these datasets, activity counts recorded in the VA and as the composite VM were utilised. Data were thus configured into four separate sets: 15 s VA counts, 60s VA counts, 15 s VM counts and 60 s VM counts.

To align with the observational data, each of the four accelerometer data sets were reviewed alongside the observational tool. Equivalent epochs where participants were unavailable for observation (either due to being out of a communal area or due to the observer being unavailable) were manually removed. A minimum of 60 minutes were required for a data set to be included in analysis.

Next, to enable direct comparison with observational data, accelerometer counts were coded as either PA or sedentary behaviour. Each dataset was categorised according to cut-points relevant to 15 s and 60 s data using published accelerometer cut-points (Aguilar-Farias et al., 2014), (Table 6.6). These cut-points were developed in a sample of community-dwelling older adults (n = 37, 13 males and 24 females) aged ≥ 65 y (mean age: 73.5 y ± 7.3 y).

Table 6.6 Cut-points used to categorise 15 s and 60 s accelerometer count data as either PA or sedentary behaviour.

Accelerometer data set	PA	Sedentary behaviour
15 s VA counts	≥ 10 counts	< 10 counts
60 s VA counts	≥ 25 counts	< 25 counts
15 s VM counts	≥ 70 counts	< 70 counts
60 s VM counts	≥ 200 counts	< 200 counts

Observational data

The pre-determined list of activities used to systematically record what participants were doing were categorised as either PA or sedentary behaviour based on MET values assigned to the same (or similar) activity in the Compendium of Physical Activities (Ainsworth et al., 2011) (Table 6.7). Thus, each observation was coded as either PA or sedentary behaviour.

Next, in order to explore the effect of epoch length and enable direct comparison with 60 s accelerometer counts, an additional separate dataset in which the 15 s observational data were aggregated over 60 second epochs was created (i.e. four consecutive 15 s epochs were summed to produced one 60 s epoch). Each 60 s epoch was then re-coded. An epoch was coded as PA when ≥ 50% of the epoch was categorised as PA.

Table 6.7 List of activities used to code participants' behaviour as either PA or sedentary behaviour.

PA	Sedentary behaviour
Low intensity PA (e.g. craft activities)	Active social interaction (e.g. talking with others)
Light intensity PA (e.g. moving to music, clapping)	Passive social interaction (e.g. listening or watching others)
Moderate PA (e.g. performing exercises)	Eating and / or drinking
Walking (with or without aid)	Sedentary activities (e.g. reading, watching television)
	Wheelchair transference
Sit-stand transfer	Receiving care
Stand-sit transfer	Socially / recreational inactive (i.e. no engagement in any activity)
Standing still	Sleeping / dozing

6.2.2.4 Statistical analysis

The agreement between the categorisation of PA and sedentary behaviour derived from the observational data and each of the four accelerometer data sets (15 s VA counts, 60 s VA counts, 15 s VM counts and 60 s VM counts) was evaluated separately. Specifically, for each accelerometer data set, the sensitivity, predictive value (PV), overall agreement (see equations below) and the kappa statistic (κ) were calculated

Sensitivity = (the number of identical categorised epochs for the observational and accelerometer data * 100) / total number of categorised epochs observed

Equation 6.3

PV = (the number of identical categorised epochs for the observational and accelerometer data * 100) / total number of categorised epochs identified as the chosen outcome (i.e. PA or sedentary behaviour) by the accelerometer data

Equation 6.4

Overall agreement = (the number of identical categorised epochs for observation and monitor) * 100 / total number of categorised epochs

Equation 6.5

For sensitivity, PV and overall agreement, values close to 100% were deemed indicative of good agreement between the observational and accelerometer data. Values close to zero suggested the estimated time spent engaging in PA and sedentary behaviour categorised by the accelerometer data was very different to that derived from the observational data. In line with recommendations from Landis and Koch (1977), the kappa statistic was interpreted as: 0 - 0.2 indicative of slight agreement; 0.2 - 0.4 fair agreement; 0.4 - 0.6 moderate agreement; 0.6 - 0.8 substantial agreement and 0.8 - 1.0 reflecting almost perfect agreement.

6.2.3 Results

6.2.3.1 Participant characteristics

Sixteen care home residents were recruited but three participants were excluded from analysis due to practical issues (two participants did not accumulate 60 minutes of data) and technology-related issues (accelerometer malfunction, n = one). Although the personal characteristics of these participants were found to be no different from those who were included in the final analysis ($p > 0.05$), the three participants excluded had been residents within the care home for longer than those included in the final sample (mean length of residence: 25 ± 5 months and 15 ± 8 months respectively, $p < 0.05$). Characteristics and the physical function and mobility assessment scores of the final sample (n = 13) are presented in Table 6.8 and Table 6.9.

Table 6.8 Participant characteristics (n = 13).

	N (%) or Mean ± SD
Gender (male)	3 (23%)
Age (y)	85 ± 7
Age group	
< 85 y	5 (38%)
≥ 85 y	8 (62%)
Height (cm)*	160.7 ± 7.9
Weight (kg)	62.7 ± 17.9
Capacity to consent (yes)	5 (38%)
Number of comorbidities†:	
None	0 (0%)
1 - 2	11 (85%)
≥ 3	2 (15%)

*Data relates to 12 participants due to missing data

† based on the Charlson Comorbidity Index (CCI) (Charlson et al., 1987).

Table 6.9 Scores of physical function and mobility assessment (n = 13).

	N (%) or Mean ± SD
BI score (score on a 21-point scale; 0-20)	11 ± 6
BI score ≤ 11 (dependent)	6 (46%)
BI score > 11 (independent)	7 (54%)
FAC	
Level 0 (non-functional ambulation)	1 (8%)
Level 1 (ambulatory-dependent for physical assistance – level II)	1 (8%)
Level 2 (ambulatory-dependent for physical assistance – level II)	1 (8%)
Level 3 (ambulatory-dependent for supervision)	0 (0%)
Level 4 (ambulatory-independent on level surfaces)	5 (38%)
Level 5 (ambulatory-independent)	5 (38%)

6.2.3.2 Categorisation of physical activity and sedentary behaviour

A total of 25 hours and 16 minutes of activity were available for analysis with a mean of 1 hour 57 minutes ± 3 minutes per participant. The average time categorised as PA and sedentary behaviour according to the observational data and each of the four accelerometer data sets is presented in Figure 6.3.

Irrespective of the method used to categorise time, the average values indicate the sample as a whole engaged in very little PA (Figure 6.3). However, when considering individuals, the percentage of the direct observation period categorised as PA varied greatly from as little as 1% up to 48%. Despite the heterogeneity amongst individuals, when participants were grouped according to their characteristics (male or female; aged < 85 years or ≥ 85 years and whether or not they were deemed to have the capacity to consent) and participation in ADLs (BI score ≤ 11 or > 11) no significant differences in the length of time categorised as PA and sedentary behaviour (irrespective of method used) were noted between groups.

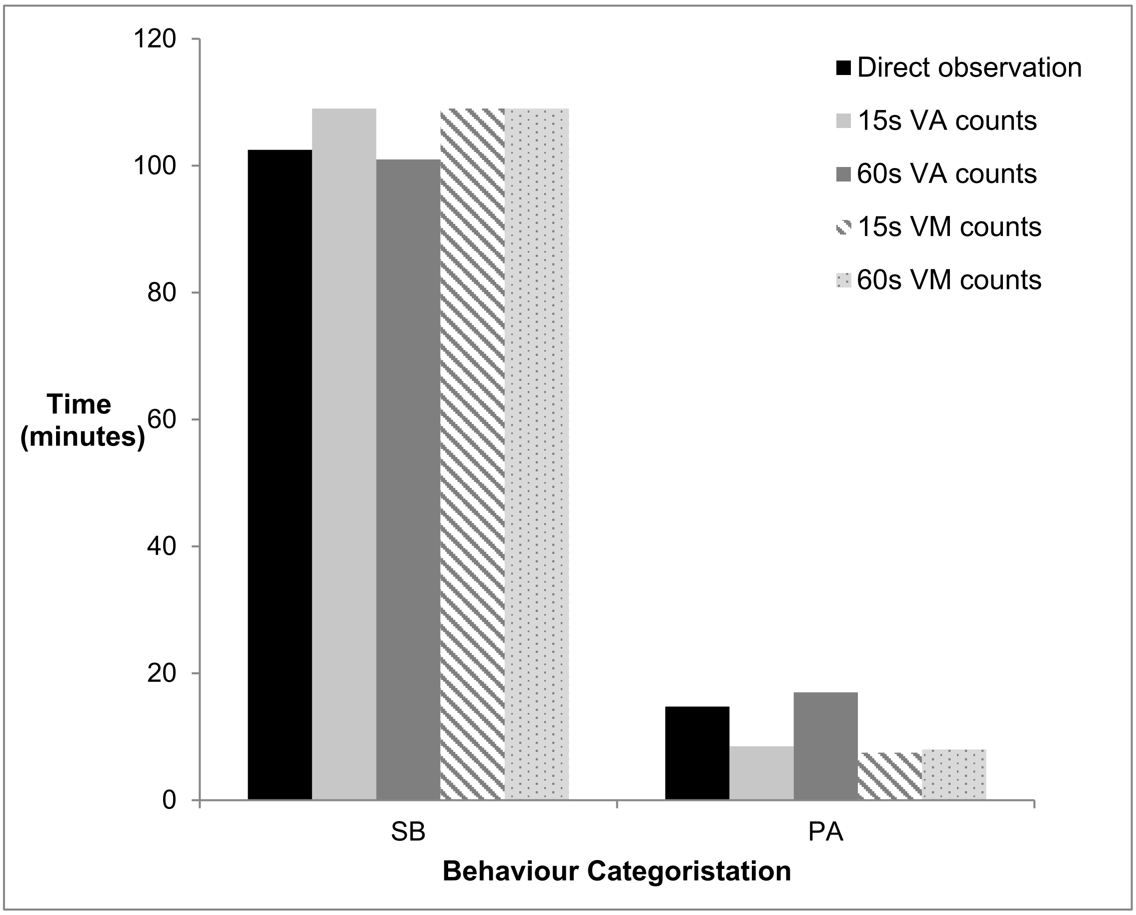


Figure 6.3 The median (IQR) time categorised as PA and sedentary behaviour according to the observational data and each of the four accelerometer data sets (n = 13).

6.2.3.3 Agreement between the categorisation of physical activity and sedentary behaviour derived from the observational data and each of the four accelerometer data sets

Sensitivity, PV, overall agreement and the kappa statistic are presented in Table 6.10. The sensitivity and PV were lower for PA compared to sedentary time, irrespective of the accelerometer data set considered. Little variation in the sensitivity and PV for time spent sedentary across accelerometer data sets was observed. Conversely, the sensitivity and PV for time spent engaging in PA were higher for VM counts compared to VA counts, regardless of epoch length. Moreover, the kappa statistic indicated the agreement for VM counts was moderate, whereas the agreement for VA counts was fair. Nonetheless overall agreement was consistently high (> 80%) across all of the accelerometer datasets.

Table 6.10 Sensitivity, PV, overall agreement, the kappa statistic and mean difference for each of the four accelerometer data sets (n = 13).

	15 s VA counts	15 s VM counts	60 s VA counts	60 s VM counts
Sensitivity for PA time (%)	38	52	38	54
Sensitivity for sedentary time (%)	96	95	94	95
PV for PA time (%)	69	71	57	71
PV for sedentary time (%)	88	90	87	90
Overall agreement (%)	86	88	83	88
Kappa statistic	0.41	0.53	0.35	0.54

6.2.4 Discussion

This study explored the validity of four accelerometer data sets in estimating the amount of time older care home residents spend engaging in PA and sedentary behaviour. Although the overall agreement was consistently high across the datasets (> 80%), this measure does not take into account the possibility that the agreement with the observational data occurred by chance (Cohen, 1960). The other measures reported suggest the classification agreement (particularly for PA) varied according to the methodological decisions made.

Based on the kappa statistic (κ), the agreement with direct observation was moderate when VM counts were used whereas it was only fair when VA counts were used, regardless of epoch length. Similarly, the sensitivity and PV values for PA time were higher for VM counts compared to VA counts, irrespective of the epoch length. This finding is not unexpected as the PA typical of care home residents (for example ADLs) likely necessitate more anteroposterior and mediolateral movements which would only be accounted for by the VM count (Sasaki et al., 2011). Perhaps more interesting was the finding that that there was little difference in the sensitivity and PV for sedentary time across the four accelerometer data sets (all values were > 85%). This may be attributed to the high levels of sedentary behaviour in the sample.

Theoretically, a shorter epoch length should improve the validity of estimates of PA and sedentary time. However, the results of the current study did not reflect this. Nonetheless, the results are in accordance with the findings of a recent study involving older adults (n = 62, mean age: 78.4 y ± 5.7 y) which found there was no real difference in estimates of PA and sedentary time based on the same two epoch lengths (Koster et al., 2016). Whilst it is not entirely clear why no meaningful difference was observed between the 15 s and 60 s epoch lengths, it is important to acknowledge that much of the literature which recommends the use of a shorter epoch is based on studies involving children and adolescents (Sanders et al., 2014; McClain et al., 2008). It is possible that both the type and pattern of PA typical of care home residents is markedly different.(Dale et al., 2002).

There were several strengths to this study. Firstly, a considerable gap in methodological research was addressed as the impact of two important methodological decisions (namely the count value and epoch length used) on estimates of PA and sedentary time in care home residents was examined. In addition, although estimates of PA and sedentary behaviour based on cut-points are a common PA outcome, the current study is novel insomuch as it examined classification accuracy based on a pre-determined cut-point developed specifically with older adults in a free-living setting (n = 37, mean age: 73.5 y ± 7.3 y, Aguilar-Farias et al., 2014). Moreover, no other study to date has validated the ActiGraph accelerometer in a care home setting using DO as the criterion measure. DO was deemed the most appropriate criterion measure as time spent engaging in PA and sedentary behaviours are behavioural outcomes (Lyden et al., 2014b). Furthermore, the observational protocol employed facilitated comparison of classification accuracy at the epoch level.

Nonetheless, the study was not without limitations and these should be considered when interpreting the results. The participants in this study comprised a small (n = 13) sample which might have implications for the generalisability of the results given care home residents are a particularly heterogeneous population (Gordon et al., 2014). In addition, although direct observation is widely considered an appropriate criterion measure of PA and sedentary behaviour (Montoye et al., 2016; Vanhees et al., 2005), it is possible that, despite efforts to standardise data collection through the use of the observational tool and limiting the observational period to two hours, inconsistencies in data collection arose as a consequence of human error. Furthermore, it is possible that the proximity of the observer to the participant may have caused the participant to alter their behaviour (Wilcox and Ainsworth, 2009).

The use of cut-points for categorising accelerometer data collected by a hip-worn accelerometer as either PA or sedentary behaviour, whilst common practice, is not without limitations (Ellis et al., 2016). It is possible that had different cut-points been applied the impact of count value epoch length may have differed as it is probable that estimates of time spent engaging in PA and sedentary behaviour would differ (Gorman et al., 2014). Also, cut-points do not take into account posture, simply a lack of movement, thus standing may not be distinguished from sitting (Hart et al., 2011a).

Furthermore, the position of the accelerometer on the hip means upper body activities typical of care home residents may not be captured as it is likely that the counts recorded fall under the cut-point for sedentary time (i.e. 100 cpm) (Kozey et al., 2010). Similarly, the altered gait pattern characteristic of many care home residents means the range of motion at the hip is limited therefore even walking may be misclassified as sedentary time based on the cut-point approach (Rikli, 2000).

It is also important to acknowledge that a single cut-point to distinguish between PA and sedentary behaviour was used in this study. Thus, it was not possible to comment on the ability of the accelerometer to classify differing intensities (i.e. light or moderate) of PA. However, for most individuals, and for care home residents in particular, MVPA comprises a small proportion of their time (Marmeleira et al., 2017; Barber et al., 2015). In recognition of this and emerging evidence of the negative effects of excessive sedentary time, more pragmatic health recommendations are being promoted (Sparling et al., 2015). Thus, being able to correctly distinguish between PA and sedentary behaviour is likely sufficient.

6.2.5 Conclusion

This study is the first to assess the validity of accelerometer data to categorise PA and sedentary behaviour in a free-living setting using direct observation as the criterion measure in a population of care home residents. In general, VM counts showed better agreement than VA counts for the classification of both PA and sedentary behaviour. However, there was little difference between the two epoch lengths (15 s and 60 s). Amongst the accelerometer data sets considered in this study, the 60 s VM had the highest overall criterion validity to measure PA and sedentary time as compared with DO. Thus, the analysis presented provides additional support for using VM activity counts collected over 60 s epochs in future research with care home residents and within this thesis.

6.3 Study 3: An investigation into the optimal accelerometer wear time criteria necessary to reliably estimate physical activity and sedentary behaviour in care home residents

6.3.1 Introduction

Wear time criterion that enable valid measurement of PA and sedentary behaviour are a hallmark of PA behaviour research. Nevertheless, this issue has received limited attention in older adults and to date no studies have involved care home residents. Participants in habitual PA studies are typically asked to wear an accelerometer during all waking hours over a seven-day period (Mâsse et al., 2005). However, compliance to this wearing protocol in care home residents is variable (Barber et al., 2015). Furthermore, 19% of residents approached to wear an accelerometer by Barber and colleagues (2015) declined and cited not wishing to wear the accelerometer for so many days as their reason for doing so. Although numerous wear time criteria are reported in the literature, these are typically derived from studies in younger adults and empirical evidence supporting the superiority of a specific criterion is absent, especially for an older population (Ridgers and Fairclough, 2011).

In studies involving community dwelling older adults, a threshold of ten hours of accelerometer wear is widely used to define a valid day (Jefferis et al., 2014). However, this threshold is not universally accepted (Herrmann et al., 2014) and it has been acknowledged that what constitutes a ‘day’ is likely to vary considerably between individuals. This point is particularly pertinent when considering older adults as they are such a heterogeneous group, with those residing in a care home typically frailer than their counterparts living in a community setting (Gordon et al., 2014). At the same time, it is probable that the variability in PA across days is likely reduced in care home residents given there is likely more structure to their daily routines. This is supported by recent studies involving older adults in both a retirement community (mean age: 83.5 y ± 6.5 y) (Marshall et al., 2015) and a care home setting (Barber et al., 2015) which report no difference in PA across days of the week. Consequently, whilst five days wear has previously been deemed necessary to ensure reliable estimates of PA behaviour in a sample of community-dwelling older adults (mean age= 69.3 y ± 7.4 y) (Hart et al., 2011b), it may be the number of days of wear could be reduced in care home residents without distorting data.

Thus, the aim of this study was to identify the minimal wear time criteria required to achieve reliable estimates of PA behaviour in older care home residents.

6.3.2 Methods

6.3.2.1 Participants

A full description of care home and participant recruitment procedures, including details regarding screening and the process of obtaining consent are provided in Chapter 5, **section 5.2.3**. Briefly, older adults aged ≥ 65 years were recruited from ten care homes involved in WS 2 and WS 4 of the REACH programme (previously described in **section 1.5**) between June 2013 and March 2015.

6.3.2.2 Experimental Protocol

Participants were fitted with a hip-worn accelerometer as per the procedures described in the general methods chapter, **section 5.3**. If participants were comfortable and happy wearing the accelerometer, they were asked to wear this during all waking hours for the next seven to ten days.

For all participants, it was requested that a daily log of wear time (i.e. the time the monitor was put on and removed) was kept for the duration of the monitoring period (**Appendices J and K**). Participants capable of completing the log and putting the accelerometer on themselves were encouraged to do so; though the process of completing the activity log was also explained to staff and they were asked to offer support with this where appropriate. Accelerometers were collected once it was reported that between five and seven days' worth of data (not necessarily on a consecutive basis) had been recorded, or when residents indicated that they no longer wanted to wear the accelerometer.

6.3.2.3 Data reduction

Accelerometer count data

Based on the analysis presented in the previous two studies (**section 6.1 and section 6.2**), raw activity count data were processed with the normal filter and aggregated over 60 second epochs. VM activity counts were used for analysis.

As discussed is **section 4.4.3**, the correct identification and removal of non-wear time from an accelerometer dataset is imperative to ensure accelerometer data is interpreted and analysed correctly (Schrack et al, 2016). Hence, the use of automated algorithms and / or activity logs have become commonplace as researchers attempt to ensure non-wear time is correctly identified. However, based on data collected during this doctoral work, both of these methods pose unique challenges in a care home population.

Whilst several automatic algorithms for identifying non-wear time have been developed (Choi et al., 2012; Troiano et al., 2008), the applicability of these to a care home population who spend the majority of their time sedentary is questionable. Indeed, in the previous study (**section 6.2.3**) some residents were sedentary for the full two hour period they were observed and it is likely that this behaviour continues for longer. Thus, employing one of the algorithms may lead to the removal of data incorrectly identified as non-wear time and may ultimately lead to individuals being excluded from analysis due to having insufficient data (Atkin et al., 2012, Winkler et al., 2012). Consequently, whilst it was acknowledged that completion of activity logs may be viewed as burdensome, much emphasis was placed on attempting to collect accurate information about accelerometer wear using an activity log.

Efforts were made to administer the activity logs in way in which the care home managers / research lead within the homes felt would meet with greatest success. For example, in many of the homes it was felt that a considerable proportion of residents would have some degree of cognitive impairment which would hinder their ability to complete the activity logs themselves either because they would forget or they would become confused about how to complete them correctly. Hence, the activity logs were often stored within care plans or in a centralised file and their completion was deemed the responsibility of staff. Nevertheless, completion of the logs was poor and there were concerns regarding the accuracy of the data recorded.

Thus, in order to reduce the risk of distorting data provided by the least active residents (Hutto et al., 2013) all data were manually screened (guided by the rules detailed in Table 6.11) alongside the activity logs and periods of non-wear time were removed. Daily wear time was determined by subtracting non-wear time from total possible minutes in a day (1,440 minutes). Data were then reviewed and the first monitoring day was removed if the monitor was administered after 1pm. Partial days, defined as being < 4 hours, were also removed as this amount of wear time was deemed insufficient to provide a reliable estimate of PA outcomes. In cases where participants had more than seven days of data only the first seven days were included in the analysis.

Next, in the absence of cut-points developed specifically with care home residents, a published cut-point developed in a sample of community-dwelling older adults (n = 37, mean age: 73.5 ± 7.3 y) was applied to the VM activity cpm to identify time spent engaging in PA (≥ 200 cpm) and sedentary behaviour (< 200 cpm) (Aguilar-Farias et al., 2014).

Table 6.11 Rules utilised to guide the manual screening of the accelerometer data to identified periods of accelerometer non-wear time

Accelerometer administration was indicated if one of the following conditions were met:	The removal of an accelerometer was indicated if one of the following conditions were met:
a) If 60 minutes of consecutive 0's (with the allowance of a 5 minute interruption in the string of consecutive zero's) in the VM axis precedes a VA count value of ≥ 760 cpm (i.e. light intensity PA) then this value is assumed to indicate the accelerometer being put on. Note, if another light count is identified in the following 5 minutes use the latter count as the on time.	a) If the 60 minutes following a VA count value of ≥ 760 cpm (i.e. light intensity PA) contains is a string of consecutive 0's (with the allowance of a 5 minute interruption in the string of consecutive zero's)) in the VM axis.
b) If 120 minutes of consecutive 0's (with the allowance of a 5 minute interruption in the string of consecutive zero's) in the VM axis precedes a VA count value of ≥ 100 cpm (i.e. low intensity PA) then this value is assumed to indicate the accelerometer being put on. Note, if another count ≥ 100cpm identified in the following 5 minutes use the latter count as the on time	b) If the 120 minutes following a VA count value of ≥ 100 cpm (i.e. low intensity PA) contains is a string of consecutive 0's (with the allowance of a 5 minute interruption in the string of consecutive zero's)) in the VM axis.

6.3.2.4 Statistical analysis

In order to explore the impact of different wear time criteria on the assessment of both PA and sedentary behaviour a pragmatic, staged approach was adopted.

Firstly, given the hierarchical structure of the data (i.e. repeated measures within participants) and the fact that not all participants had an equal number of repeated measures (i.e. not all had data on seven days), linear mixed effect models were used to explore the effect of monitoring day on four key outcomes derived from the accelerometer data: counts.minute^{-1}, counts.day^{-1}, PA time and sedentary time. Given the strong relationship between wear time and sedentary time, all data were adjusted for daily wear time (Aadland and Ylvisåker, 2015). Each model included a random intercept for participants.

The data were then examined to determine the impact of five different minimum daily wear time criteria (i.e. 6 hours, 7 hours, 8 hours, 9 hours and 10 hours) on the four outcomes described above. Only data from participants who provided one day of data with a minimum daily wear time of ten hours were included in this section of analysis to ensure the sample was consistent. As above, linear mixed effect models were conducted for each outcome as not all participants had seven days of data. The models included a random intercept for participants. Where the outcomes differed between the minimum daily wear time criteria, Bonferroni corrected pairwise comparisons were conducted.

Finally, in order to inform how many of the monitoring days were required to produce reliable estimates of the four PA outcomes, data from participants who provided seven valid days were averaged over an increasing number of days of data collection (i.e. day one average, day one and two average, day one, two and three average etc.). Linear mixed effect models were then conducted to explore the effect of varying the number of monitoring days. As above, the models included a random intercept for participants. Where outcomes differed according to the number of monitoring days, Bonferroni corrected pairwise comparisons were conducted. The magnitude of the difference in outcomes based on fewer days of monitoring was also determined using standardised effect size (Coe, 2002).

6.3.3 Results

6.3.3.1 Participant characteristics

A hip-worn accelerometer was administered to 94 participants. However, data from three participants were not considered further as it did not meet the initial screening criteria (i.e. 1 day with a minimum daily wear time of four hours). Thus, the analysis sample was comprised of 91 residents. Neither the personal characteristics nor the scores on the physical function and mobility assessments differed between those participants not included in the analysis sample and those who met the initial screening criteria ($p > 0.05$). Thus, the personal characteristics and scores on the physical function and mobility assessments of all residents (n = 94) are presented in Table 6.12 and Table 6.13.

Table 6.12 Participant characteristics (n = 94).Number of participants (*n*) is not equal to the total number of residents recruited due to missing data.

	n	N (%) or Mean ± SD
Gender (male)	94	32 (34%)
Age (y)	87	84 ± 9
Age group	87	
< 85 y		40 (46%)
≥ 85 y		47 (54%)
Length of residence (months)	86	29 ± 33
Height (cm)	74	161.9 ± 10.6
Weight (kg)	85	66.6 ± 15.3
Capacity to consent (yes)	94	70 (75%)
Number of comorbidities*:	75	
None		4 (5%)
1 – 2		56 (75%)
≥ 3		15 (20%)

* based on the CCI (Charlson et al., 1987)

Table 6.13 Scores of physical function and mobility assessments (n = 94). Number of participants (*n*) is not equal to the total number of residents recruited due to missing data.

	n	N (%) or Mean ± SD
BI Score (score on a 21-point scale; 0-20)	89	12 ± 5
BI score ≤ 11 (dependent)		38 (43%)
BI score > 11 (independent)		51 (57%)
FAC	82	
Level 0 (non-functional ambulation)		11(13%)
Level 1 (ambulatory-dependent for physical assistance – level II)		9 (11%)
Level 2 (ambulatory-dependent for physical assistance – level I)		4 (5%)
Level 3 (ambulatory-dependent for supervision)		3 (4%)
Level 4 (ambulatory-independent on level surfaces)		35 (43%)
Level 5 (ambulatory-independent)		20 (24%)

6.3.3.2 Effect of monitoring day on PA outcomes

Estimates of the PA outcomes of interest (i.e. counts.minute^{-1}, counts.day^{-1}, PA time and sedentary time) across monitoring days are displayed in Figure 6.4. No main effect of monitoring day on any of the PA outcomes was observed (p > 0.05).

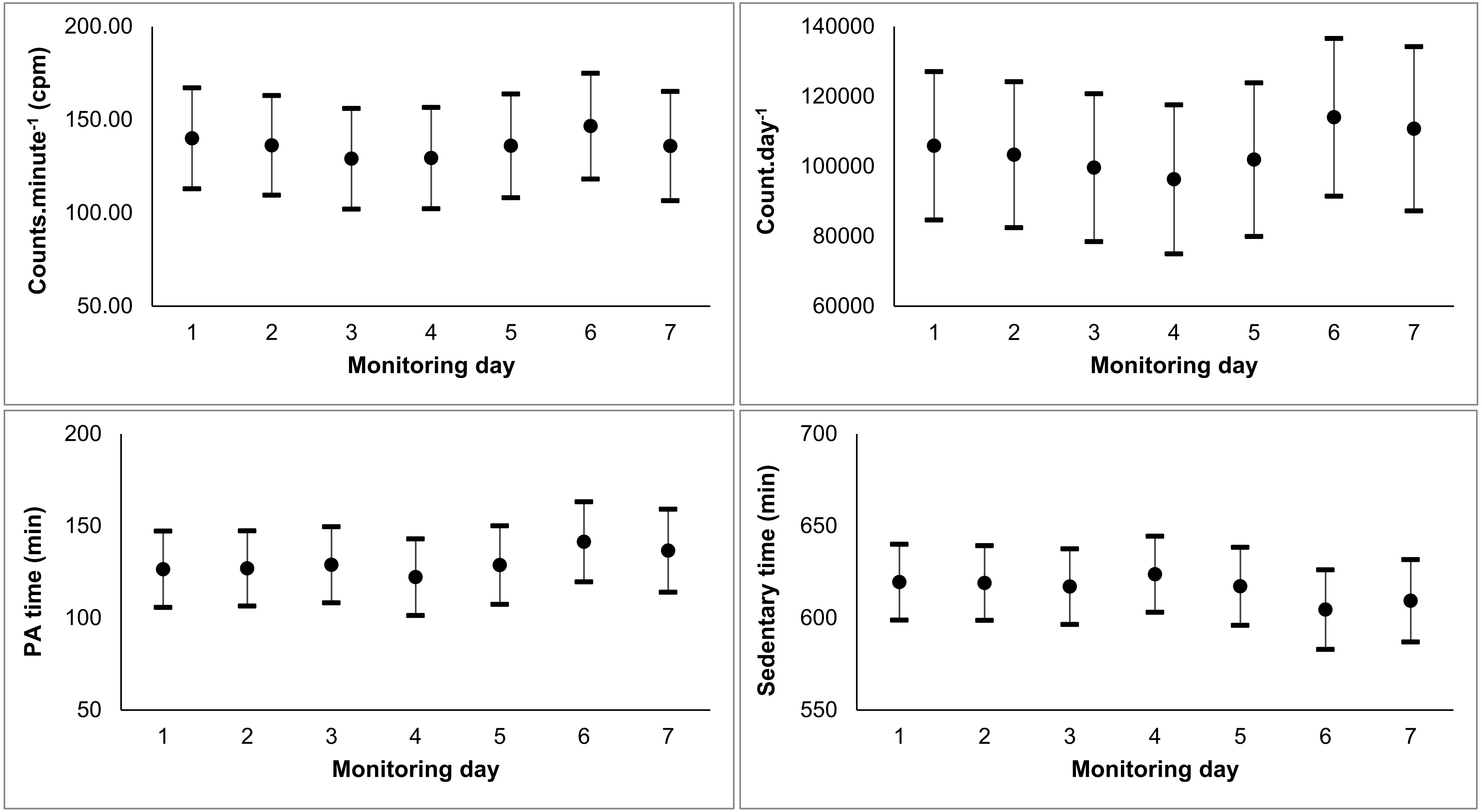


Figure 6.4 Mean and 95% confidence intervals of (reading left to right): counts.minute^{-1}, counts.day^{-1}, PA time and sedentary time across monitoring days (one-seven) (n = 91).

6.3.3.3 Exploration of minimal wear time requirement on PA outcomes

Data from participants (n = 85) who provided one day of data with a minimum daily wear time of ten hours were included in this section of analysis. The number of days available for analysis increased as the minimum number of hours used to define a valid day decreased (Table 6.14). As can be seen from Table 6.14 population estimates of counts.minute^{-1}, counts.day^{-1} and PA time were similar, irrespective of the minimum daily wear time criteria ($p > 0.05$). Conversely, estimates of sedentary time were affected by the minimum wear time criteria applied ($F (4) = 4.209$, $p < 0.01$). Specifically, estimates of sedentary time were significantly lower when valid days were defined as seven hours (Mean difference: -24 min, 95% CI: -41 min, -2 min) or six hours (Mean difference: -26 min, 95% CI: -45 min, -7 min) compared to ten hours ($p < 0.05$) (Table 6.14).

Table 6.14 Estimates of counts.minute^{-1}, counts.day^{-1}, PA time and sedentary time calculated based on different definitions of a valid day (minimum wear time of six - ten hours). Data are presented as mean (95% confidence intervals) (n = 85).

Minimum daily wear time criteria (h)	Days (n)	PA outcomes			
		counts.minute^{-1} (cpm)	counts.day^{-1}	PA time (h and min)	Sedentary time (h and min)
≥ 10 h	413	140 (114, 166)	111,695 (90,870, 132,520)	2 h 20 min (1 h 58 min, 2 h 41 min)	10 h 54 min (10 h 25 min, 11 h 20 min)
≥ 9 h	457	140 (113, 166)	109,297 (88,545, 130,049)	2 h 17 min (1 h 55 min, 2 h 38 min)	10 h 41min (10 h 14 min, 11 h 8 min)
≥ 8 h	482	139 (113, 165)	107,976 (87,262, 128,690)	2 h 15 min (1 h 53 min, 2 h 36 min)	10 h 35 min (10 h 8 min, 11 h 2 min)
≥ 7 h	494	139 (113, 166)	107,569 (86,870, 128,269)	2 h 14 min (1 h 52 min, 2 h 36 min)	10 h 31 min* (10 h 4 min, 10 h 58 min)
≥ 6 h	502	139.14 (113, 165)	107,054 (86,364, 127,744)	2 h 13 min (1 h 52 min, 2 h 35 min)	10 h 29 min * (9 h 59 min, 10 h 53 min)

* denotes that the mean difference from the estimates based on 10 h wear time criteria is significant at the 0.05 level. Bonferroni correction applied

6.3.3.4 Exploration of number of days required to produce reliable estimates of PA outcomes

Data from participants (n = 35) who provided seven days of data with a minimum daily wear time of eight hours were included in this section of analysis. Importantly these participants did not differ from those who did not meet this wear time criterion (Table 6.15, $p > 0.05$).

Table 6.15 Characteristics of participants who did and did not meet the wear time criteria of ≥ eight hours on seven days. Number of participants (*n*) is not equal to the total number of residents recruited due to missing data.

Did participants provide seven days with a minimum daily wear time of eight hours?	Yes (n = 35)		No (n = 59)	
	n	N (%) or Mean ± SD	*n*	N (%) or Mean ± SD
Gender (male)	35	12 (34%)	59	20 (34%)
Age (y)	31	83 ± 8	56	85 ± 9
Length of residence (months)	31	44 ± 97	56	30 ± 34
Height (cm)	28	161.3 ± 10.3	46	162.3 ± 10.9
Weight (kg)	30	67.8 ± 17.8	55	65.9 ± 13.9
Capacity to consent (yes)	35	24 (69%)	59	46 (78%)
Number of comorbidities*:	28		47	
None		1 (4%)		3 (6%)
1 – 2		21 (75%)		35 (75%)
≥ 3		6 (21%)		9 (19%)

* based on the CCI (Charlson et al., 1987)

Table 6.16 Scores of physical function and mobility assessments of participants who did and did not meet the wear time criteria of ≥ eight hours on seven days (n = 94). Number of participants (*n*) is not equal to the total number of residents recruited due to missing data

Did participants provide seven days with a minimum daily wear time of eight hours?	**Yes (n = 35)**		**No (n = 59)**	
	n	**N (%) or Mean ± SD**	***n***	**N (%) or Mean ± SD**
BI score (score on a 21-point scale; 0-20)	35	13 ± 5	54	12 ± 6
BI score ≤ 11 (dependent)		15 (43%)		23 (43%)
BI score > 11 (independent)		20 (57%)		31 (57%)
FAC	31		51	
Level 0 (non-functional ambulation)		1 (3%)		10 (20%)
Level 1 (ambulatory-dependent for physical assistance – level II)		3 (10%)		6 (12%)
Level 2 (ambulatory-dependent for physical assistance – level I)		1 (3%)		3 (6%)
Level 3 (ambulatory-dependent for supervision)		1 (3%)		2 (4%)
Level 4 (ambulatory-independent on level surfaces)		16 (52%)		19 (37%)
Level 5 (ambulatory-independent)		9 (29%)		11 (21%)

Estimates of the PA outcomes derived by averaging over an increasing number of repeated days are presented in Table 6.17. The number of monitoring days included in analysis had an impact on estimates of counts.day^{-1} ($F (6) = 2.713$, $p = 0.05$); PA time ($F (6) = 4.641$, $p < 0.01$) and sedentary time ($F (6) = 22.013$, $p < 0.01$). Estimates of sedentary time based on one, two and three days of monitoring all significantly differed from the seven-day average ($p < 0.05$). However, estimates based on a minimum of four days and above did not ($p > 0.05$). For counts.day^{-1} and PA time, only the estimate based on one monitoring day differed significantly from the seven-day average ($p < 0.05$). Counts.minute^{-1} was the only PA outcome not to differ dependent on the number of monitoring days included in analysis ($p > 0.05$).

Table 6.17 Estimates of counts.min^{-1}, counts.day^{-1}, PA time and sedentary time calculated based on an increasing number of days (one – seven) of data collection. A valid day being defined as a having a wear time of ≥ eight hours

Counts.minute^{-1} (cpm)							
Day (n)	1	2	3	4	5	6	7
Mean ± SD	181 ± 123	186 ± 129	174 ± 123	171 ± 124	170 ± 119	172 ± 123	172 ± 125
Mean difference (95% CI)†	9	14	2	1	2	0	n/a
Effect Size	0.08	0.11	0.02	0.01	0.02	0.00	n/a
Counts.day^{-1}							
Day (n)	1	2	3	4	5	6	7
Mean ± SD	124,046 ± 85,406*	140,581 ± 94,191	137,584 ± 97,130	136,500 ± 96,012	136,262 ± 93,744	139,427 ± 98,997	141,510 ± 104,549
Mean difference (95% CI)†	17,463	929	3,926	5,010	5,248	2,082	n/a
Effect Size	0.18	0.01	0.04	0.05	0.05	0.02	n/a
PA time (h and min)							
Day (n)	1	2	3	4	5	6	7
Mean ± SD	2 h 27 min ± 1 h 34 min*	2 h 44 min ± 1 h 40 min	2 h 45 min ± 1 h 46 min	2 h 45 min ± 1 h 46 min	2 h 45 min ± 1 h 44 min	2 h 48 min ± 1 h 45 min	2 h 50 min ± 1 h 46 min
Mean difference (95% CI)†	23 min	6 min	5 min	5 min	5 min	2 min	n/a
Effect Size	0.23	0.06	0.05	0.04	0.04	0.02	n/a
Sedentary time (h and min)							
Day (n)	1	2	3	4	5	6	7
Mean ± SD	9 h 3 min ± 2 h 2 min*	9 h 50 min ± 2 h 2 min*	10 h 15 min ± 1 h 51 min*	10 h 28 min ± 1 h 51 min	10 h 34 min ± 1 h 51 min	10 h 35 min ± 1 h 49 min	10 h 38 min ± 1 h 45 min
Mean difference (95% CI)†	1 h 35 min	45 min	23 min	10 min	5 min	3 min	n/a
Effect Size	0.83	0.44	0.21	0.09	0.04	0.03	n/a

* denotes that the mean difference from the estimate based on 7 days is significant at the 0.05 level. Bonferroni correction applied.

† Mean difference was calculated as the difference from the estimate based on 7 days

6.3.4 Discussion

Although accelerometers are increasing being used with care home residents (**Chapter 3**), the current study is the first to explore the minimal wear time criteria necessitated to achieve reliable estimates of PA behaviour in this unique population.

In the absence of a consensus on how many hours of wear constitutes a valid day it seemed prudent to explore whether population estimates of PA and sedentary time varied dependent on the criteria used to define a valid day in care home residents. Whilst estimates of counts·minute^{-1}, counts·day^{-1} and PA time were similar irrespective of the minimum daily wear time criteria used ($p > 0.05$), estimates of sedentary time were significantly lower when the minimal wear time criteria was lowered from ten hours (reference) to seven or six hour hours ($p < 0.05$). Accurate measurement of both PA and sedentary behaviour is imperative therefore a minimum daily wear time of eight hours is recommended for this population. Although a threshold of eight hours of accelerometer wear has been used previously in studies with older adults (Orme et al., 2014; Gerdhem et al., 2008) the current study is the first to provide empirical evidence to support this decision.

While it may be surmised that a seven-day monitoring protocol may be too burdensome for older care home residents (Barber et al., 2015) there is a concern that using fewer days would lead to inaccurate estimates of PA behaviour if there is considerable variation between days. However, it may be inferred that the variability in PA across days is likely reduced in care home residents given the functional impairments characteristic of this population and structured routine typical of a care home setting (Hawkins et al., 2017; Gordon et al., 2014). The results presented in the current study support this hypothesis, as key PA outcomes (i.e. counts·minute^{-1}, counts·day^{-1}, PA time and sedentary time) were consistent across monitoring days. These findings are in accordance with recent studies conducted in both a retirement community and care home setting which reported no difference in PA outcomes across days of the week (Barber et al., 2015; Marshall et al., 2015). Moreover, in the present study, estimates of PA outcomes based on as few as four days of monitoring did not differ significantly from estimates based on seven days ($p > 0.05$). Taken together these findings suggest it is not necessary to be prescriptive regarding the ‘type’ of day (i.e. weekend day or weekday) included in analysis and that the number days wear could be reduced without distorting data. Nevertheless, it is recommended that whenever possible the seven-day monitoring period should be implemented to ensure participants accumulate at least four days.

In considering the findings presented it is important to acknowledge the current study is not without limitations. Firstly, it is probable that the characteristics and PA behaviour profile of the participants included will have had an impact of the findings of the current study therefore the results are only likely to be relevant to “similar” populations. Having said this, throughout each stage of the analysis there were no differences in the participant characteristics or the physical function and mobility assessment scores between those participants who were included in the analysis sample and those who were not. This finding supports the generalisability of the results.

Secondly, four specific PA outcomes (i.e. counts·minute^{-1}, counts·day^{-1}, PA time and sedentary time) were considered therefore the results presented are specific to these. It is not appropriate to assume that the minimal wear time criteria proposed would be sufficient to achieve reliable estimates of different outcomes. Previous research conducted in adults and older adults suggests the number of valid days needed to achieve reliable estimates of PA decreases as the intensity of the PA increases (Hart et al., 2011b; Rowe et al., 2007; Matthews et al., 2002). This may be attributable to the fact engagement in moderate-vigorous (MV) PA tends to be planned therefore is less variable. Although estimates of differing intensities of PA were not considered in the present study, it may be postulated that the reverse would be true for care home residents. Any engagement in higher intensity PA is likely to be sporadic thus more valid days would be required to ensure estimates were reliable. Nevertheless, given the profile of PA behaviour in older care home residents (Marmeleira et al., 2017; Barber et al., 2015), the outcomes included in this study were deemed to be most relevant to this population. Furthermore, in the absence of a consensus on wear time criteria and lack of empirical evidence supporting the superiority of one criterion over another, the current study offers a considerable contribution to the existing literature. As discussed previously, accurate measurement of PA behaviour in older care home residents is imperative to evaluate interventions and ensure any ensuing conclusions and / or recommendations are accurate and appropriate in a care home environment. Ensuring the wear time criteria utilised is appropriate is key to guarantee the quality of any data collected.

6.3.5 Conclusion

Determining the volume of data required to reliably estimate PA behaviour whilst minimising participant burden and ensuring compliance is challenging. A balance between measurement reliability and sample size is needed to warrant confidence in the PA outcomes reported. Based on the analysis presented in this study, a minimum wear time of eight hours on any four days (not necessarily on a consecutive basis) is sufficient to achieve reliable estimates of PA behaviour in older care home residents. Consequently, a seven-day monitoring protocol should be utilised wherever possible to increase the likelihood of participants meeting the minimal wear time requirements and increase the chances of achieving reliable estimates of various PA outcomes simultaneously.

6.4 Summary, key findings and practical implications

The purpose of this chapter was not to provide “hard” recommendations on accelerometer methods but rather to explore the impact of key methodological decisions associated with the use of accelerometers on estimates of PA behaviour in older adults (including those residing in a care home) and provide empirical evidence to support their use in the remaining studies presented within this thesis.

Given the added difficulties with recruiting care home residents, ***Study 1*** explored the impact of three of these methodological decisions, namely the filter used to process the raw data, the axis of data considered and accelerometer wear location, on the criterion validity of estimates of EE in a population of community-dwelling older adults. ***Study 2*** then examined the impact of the axis of data and epoch length on the criterion validity of estimates of PA and sedentary time in care home residents. Finally, ***Study 3*** investigated the minimal wear time criteria needed to achieve reliable estimates of PA behaviour in older care home residents.

The principal finding from this chapter is that the methodological decisions pertaining to the processing, reduction and analysis of accelerometer data do have an impact on estimates of PA behaviour in older adults, including those residing in care homes. Subsequently, based on the findings of the three studies presented, the following methodological decisions were made and applied in Chapters 7, 8 and 9.

- **Wear location:** hip
- **Filter:** normal filter
- **Axis:** VM
- **Epoch length:** 60 s
- **Wear time criteria**: ≥ 8 h on ≥ 4 d

Chapter 7 Development of a protocol to collect accelerometer data in field-based research with older care home residents

7i. Preface

The studies presented in the previous chapter demonstrated that a hip-worn ActiGraph accelerometer can be used to collect valid and reliable data relating to PA and sedentary behaviour in older adults residing in a care home setting. Still, in order to be confident in promoting the use of accelerometers in field-based research with older care home residents, further work is required to explore practical issues associated with using accelerometers and determine the most effective means of collecting data in this population.

7.1 Introduction

As stated, the use of accelerometers in PA and ageing research has increased substantially in recent years (Shiroma et al., 2018). The inclusion of 18 studies in the systematic review conducted to examine accelerometer use in field-based research with older adults residing in care homes (presented in **Chapter 3**) is testament to this. Nonetheless, the complexity of accelerometers means the use of these devices in field-based research is not as straightforward as other PA assessment methods such as self-report questionnaires. In addition to having to make several important methodological decisions (**Chapter 4**), researchers also need to consider practical issues associated with using accelerometers and determine the most effective means of collecting high-quality data.

Existing best practice recommendations for using accelerometers in field-based research such as those outlined by Matthews and colleagues discuss an array of practical issues related to accelerometer data collection. Of the issues discussed, participant compliance with data collection procedures is arguably the most important as accelerometer non-wear and subsequent missing data compromise the validity of the data collected (Ridgers and Fairclough, 2011; Ward et al., 2005). Indeed, accelerometer non-wear can result in a smaller sample size than anticipated, potentially bias results and ultimately alter the conclusions made (Matthews et al., 2012). Yet surprisingly, compared to some of the other methodological issues associated with accelerometer use such as wear location and the minimum wear requirements, compliance is a relatively under-researched issue, particularly in populations deemed ‘hard-to-reach’ such as older adults residing in care homes (Shepherd et al., 2015; Ridgers and Fairclough, 2011).

Studies employing accelerometers to measure PA in care home residents are increasingly reporting the number of participants who provide valid accelerometer data (Marmeleira et al., 2017; Barber et al., 2015). However, few explicitly report the compliance rate and very little is published on the factors associated with compliance or non-compliance to accelerometer data collection protocols. As a result, there remains a paucity of information regarding the feasibility of using accelerometers with this population.

One of the few studies to explore the feasibility of using accelerometers to measure the PA behaviour of older adults residing in LTC facilities is that described by Reid et al (2013). The authors used both quantitative and qualitative measures to evaluate the feasibility of using the activPAL3 accelerometer to describe the PA and sedentary behaviour of older adults aged ≥ 60 y residing in residential care facilities in Australia. They concluded that the collection of objective PA data using an accelerometer was both acceptable and feasible in their population. However, they did acknowledge that there were factors which threatened to undermine the acquisition of data (Reid et al., 2013). Notably, over 50% of eligible participants declined to take part in the study with the majority stating that they “didn’t want to participate”. Furthermore, over the course of interviews, some staff commented that they didn’t feel that they had capacity to support participants with completing the activity diary and / or answer any queries relating to the study (Reid et al., 2013).

Whilst Reid and colleagues address an important gap in the PA monitoring literature by evaluating the feasibility of using an accelerometer in a LTC setting, the generalisability of the results may be questioned. The study sample was relatively small (n = 41) and those residents unable to provide consent or classified as non-ambulatory were excluded from taking part in the study. Furthermore, it is unclear whether the findings of this study would have been the same had another accelerometer (e.g. the ActiGraph) been utilised given key differences between devices (e.g. wear location and method of attachment) likely impact feasibility (Granat, 2012). In addition, whilst the authors made an effort to collect data on both the residents’ and staff experience of the accelerometer data collection protocol, non-compliance to accelerometer protocols is a complex issue and their discussion of the factors which facilitated and / or hindered compliance is limited. Understanding the factors which facilitate and / or hinder compliance is central to developing a data collection protocol which maximises accelerometer wear and ultimately ensures data quality. Thus, further work is warranted to elucidate the factors associated with participant compliance to accelerometer data collection protocols in a more representative sample of care home residents.

Researchers also need to consider methods for encouraging compliance to accelerometer data collection protocols in this population (Ridgers and Fairclough, 2011). As part of their review which sought to address some of the methodological issues related to using accelerometers in field-based research, Trost and colleagues summarised strategies to improve compliance. These included: reminders (e.g. phone calls); offering incentives contingent on compliance (e.g. gift certificates, money) and showing participants examples of accelerometer data collected from compliant and non-compliant participants to highlight that in most cases non-wear can be easily identified (Trost et al., 2005). Whilst all of these strategies have been used with some degree of success in studies involving children and adults (Howard et al., 2015; Sharpe et al., 2011; Sirard and Slater, 2009), the efficacy of these strategies in older adults residing in care homes is yet to be established.

The purpose of the next two chapters is to describe the process of using accelerometers with older care home residents. For clarity, the aim of the current chapter is to explore the practical issues (particularly compliance) associated with using accelerometers to measure PA and sedentary behaviour in field-based research with older care home residents. Data collected will be used to inform the development and refinement of an accelerometer data collection protocol, including compliance-enhancing strategies, which is both appropriate to the population and context specific. The refined protocol will then be evaluated within the context of a cRCT in **Chapter 8**.

7.2 Protocol development framework

In the absence of clear guidance on how best to optimise accelerometer data collection protocols to ensure high-quality data are collected, a phased, iterative approach was adopted. In line with published frameworks (typically used to guided intervention development), different sources and types of data (both quantitative and qualitative) were used to ensure the accelerometer data collection protocol developed was suitable for use in field-based research with care home residents.

Figure 7.1 provides an overview of the three phases of work conducted in the development of the accelerometer data collection procedures. Briefly, the first phase involved the conceptualisation of the first iteration of the data collection protocol; the second phase was dedicated to the testing and refinement of these protocols and the final phase was used to evaluate of the refined data collection protocols in an independent sample of care home residents. For clarity, the current chapter focuses on phases 1 and 2 (the conceptualisation and optimisation work (Figure 7.1). A comprehensive description of the evaluation of the refined accelerometer data collection protocol developed (phase 3) is provided in **Chapter 8**.

Phase 1: Conceptualisation	Phase 2: Optimisation	Phase 3: Evaluation
First iteration of the data collection protocols based on a review of published literature and previous experience.	Cyclical process of testing and refinement of the data collection protocols through two pilot studies.	Testing of the refined data collection protocols in a cRCT.

Figure 7.1: Overview of the phases of work conducted in the development of the accelerometer data collection procedures.

7.3 Phase 1: Conceptualisation

7.3.1 Overview

The initial accelerometer data collection protocol and associated materials developed were informed by published literature, previous experiences of using accelerometers in field-based research and the views of colleagues within the AUECR who had previous experience of collecting outcome data in older adults, including those residing in a care home setting (Figure 7.2).

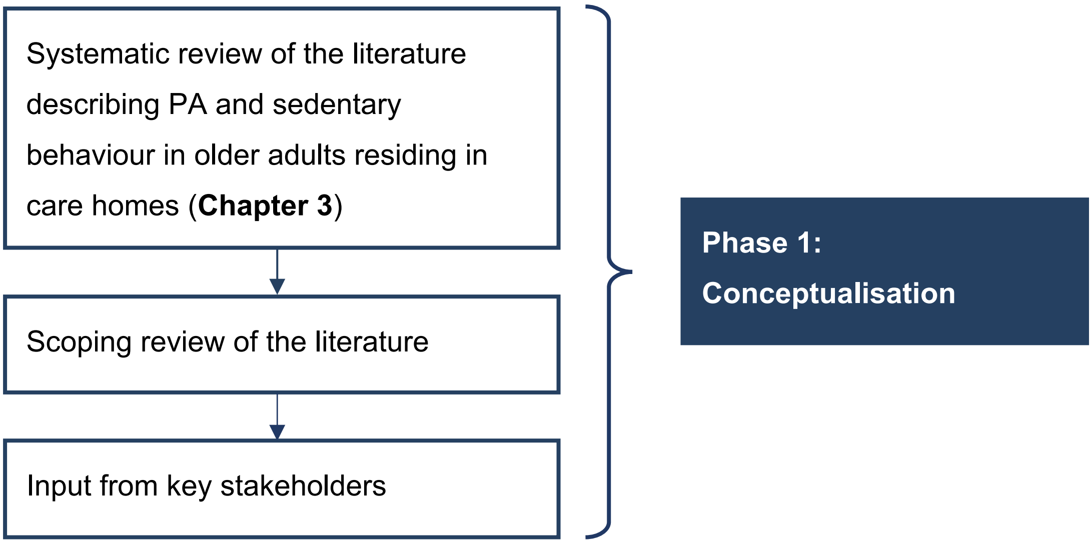


Figure 7.2: An overview of the first phase of the study

Informed by the literature (particularly Matthews, 2012), the key components of the initial accelerometer data collection protocol developed are discussed in more detail below under three key headings: preparation, accelerometer distribution and accelerometer collection.

7.3.2 Preparation

A spreadsheet was created and maintained over the course of study to track the accelerometers. The following details were recorded: accelerometer number, accelerometer serial number, date of administration, name of care home, participant initials, date of collection, date of data download.

Prior to distributing the accelerometers, the researcher ensured all accelerometers were fully charged, initialised as per the procedures detailed in **Chapter 5, section 5.4.1** and programmed with an appropriate date and time to start recording. As accelerometers were being distributed face-to-face, they were set to record from 8:00 am on the day of distribution as care homes typically requested that visits occurred after breakfast and no earlier than 9:30 am. No stop time for recording was entered to allow for flexibility in wear time.

Once fully charged and initialised, all accelerometers were labelled with a number. This number was documented alongside the relevant accelerometer serial number on the tracking spreadsheet (described above). The numbers of the accelerometers prepared were also recorded on a paper tracking form. This form was used to document, in real time, which accelerometers were distributed to which participants and the time they were fitted. This information was then added to an electronic tracking spreadsheet at the first opportunity.

Finally, the researcher ensured that a variety of different belt sizes, along with activity logs (**Appendix J**) and copies of the activity monitor instructions were available.

7.3.3 Accelerometer distribution

In liaison with the research lead at the each of the care homes a convenient time was arranged to distribute accelerometers to participants. Recognising that care home residents are likely to be frail and experience fluctuations in their health status, accelerometers were administered face-to-face as soon as possible once informed consent / assent had been attained. All participants were provided with a verbal explanation of what the accelerometer was and details on how to wear it correctly. Accessible language was used (for example the accelerometer was described as a “movement meter”) and the level of detail provided to participants varied dependent on their understanding.

As the accelerometer used in the study (ActiGprah wGT3X-BT) measures accelerations in three axes (vertical, medio-lateral and anterior-posterior) it is important that the accelerometer is orientated correctly when it is fitted. Details regarding how the accelerometers were positioned when fitted are provided in **Chapter 5, section 5.3**. Participants were invited to “try the accelerometer on” and provide feedback on how this felt.

Once it was established that the participant was comfortable wearing the accelerometer, those participants who were deemed able to comprehend additional information were asked to wear the accelerometer during all waking hours for the next seven days. Participants were advised that they were to remove the accelerometer if they were going to be engaging in any water-based activities (e.g. bathing) and were reassured that if they wished to remove the accelerometer for any reason (e.g. discomfort) they were permitted to do so. In cases where it was felt the provision of additional information would cause undue confusion for the participant, they were simply asked to keep the accelerometer on for the rest of the day and informed that someone would come and visit them again. All participants were reassured that they did not need to “do anything” with the accelerometer other than wear it and they were encouraged to continue with their usual daily routine. However, if they did have any questions or concerns then they were free to contact the researcher on the number provided on the information sheet and activity monitor instructions. The researcher made a note of the participants’ initials and time of administration next to the appropriate accelerometer number on the paper tracking form (**Appendix M**).

For all participants, it was required that a daily log of the time the accelerometer was put on and removed (i.e. wear time) was kept for the duration of the monitoring period. The researcher noted the accelerometer number and participant initials in the appropriate places and completed the first entry on the activity log. The process of completing the log was then explained to the participant where appropriate (i.e. when participants had the capacity to understand this process). The process of completing the activity log was also explained to care home staff and the importance of this being completed was emphasised. Participants capable of completing the log and putting the accelerometer on themselves were encouraged to do so; though they were reminded that staff were aware of the study and could offer support. For those participants who were unable to maintain a written log, staff were asked to complete the logs on their behalf. Activity logs were administered in a way in which the care home manager / research lead felt would be met with the greatest success.

7.3.4 Accelerometer collection

Accelerometers and activity logs were collected in person at the end of the seven-day monitoring period. Collecting the accelerometers in person reduced the chance of them getting lost and, in cases where the accelerometer was not removed by the researcher at the collection visit, enabled the researcher to ask the participant / care staff when the accelerometer was last worn if it was not documented on the activity log. This mode of collection also offered an opportunity to ask participants (where appropriate) about their experience of wearing the accelerometer and completing the activity log. The researcher was transparent about the purpose of the study (to explore the feasibility of using accelerometers to measure PA behaviour in care home residents) and therefore encouraged participants to be open and honest about their experience.

After collection, data were downloaded using the ActiLife software at the earliest convenience in an effort to reduce the chances of data being lost (**Chapter 5, section 5.4.1**). All data were downloaded using the same naming convention (i.e. participant ID) and any demographic data collected (e.g. age, height, weight) were saved to the data file. Once the data were downloaded, an initial review of the data was undertaken by the researcher. The main purpose of this review was to identify whether there were any technical issues which would warrant asking participants to wear the accelerometer again and / or indicate whether an accelerometer needed to be tested further before being re-administered to participants.

Following data download and review, any labels detailing the participant ID and / or participant initials were removed from the accelerometer which was then cleaned ready for re-administration. All belts were removed and washed.

7.4 Phase 2: Optimisation

7.4.1 Overview

In light of the limited evidence regarding the use of accelerometers in a care home population, two pilot studies were conducted in order to test and further refine the provisional data collection protocol and associated materials developed in the conceptualisation phase (Phase 1) (El-Kotob and Giangregorio, 2018). An overview of the optimisation work conducted is provided in Figure 7.3.

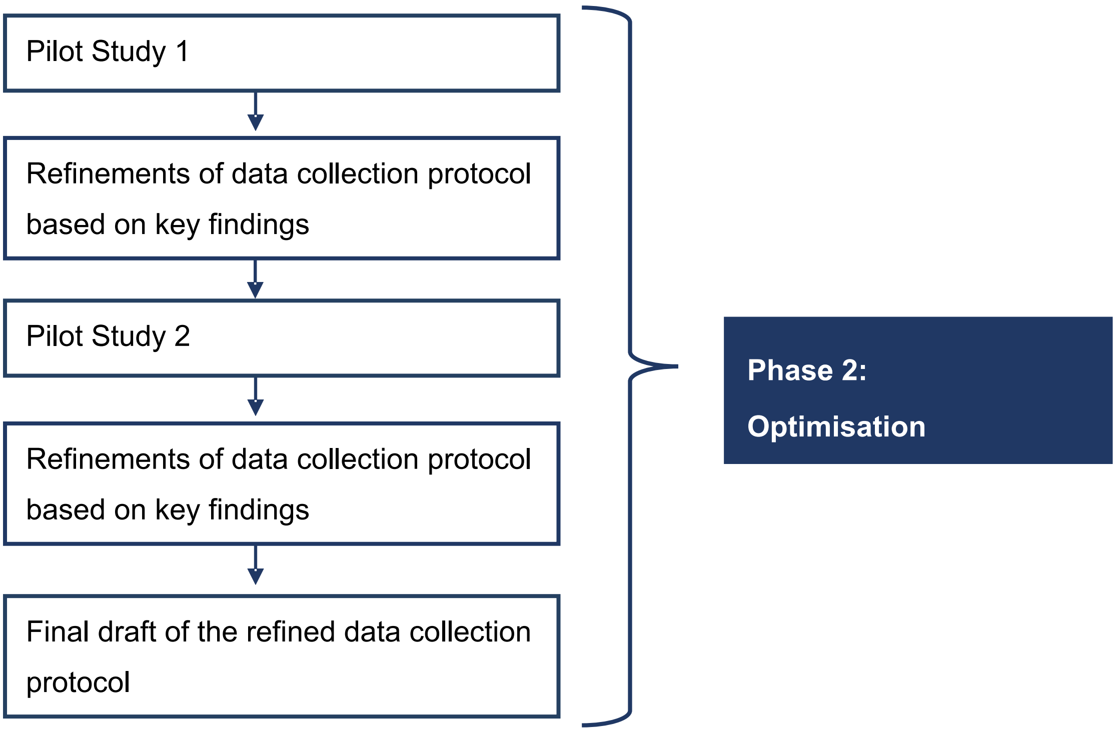


Figure 7.3 An overview of the second phase of the study

For ease of reference, the methods used in both ***Pilot Study 1*** and ***Pilot Study 2*** are presented first as they are consistent across both studies.

The results from each of the pilot studies, including the interpretation of the key quantitative and qualitative findings and the subsequent refinements made to the data collection protocol, are then presented separately.

7.4.2 Methods

7.4.2.1 Setting and participants

A full description of care home and participant recruitment procedures, including details regarding screening and the process of obtaining consent are provided in **Chapter 5, section 5.2.3**. Briefly, nine care homes involved in WS 2 and WS 4 of the REACH programme (previously described in **Chapter 1, section 1.5.1**) were selected to take part in this phase of the work. All care homes were screened and recruited by researchers based within the AUECR. The care homes recruited varied in terms of size, setting and ownership (Table 7.1).

Following care home agreement to participate, all residents were screened and recruited by researchers from the AUECR with experience of working with older people. REC approval for both WS 2 and WS 4 included agreement to involve residents lacking capacity therefore an assessment of the mental capacity of all eligible residents was undertaken prior to taking consent. For those eligible residents deemed to lack capacity, PC or NC agreement was sought.

Table 7.1 Characteristics of the participating care homes (n = 9).

Pilot Study 1					
Care home	**Number of beds***	**Location**	**Local authority**	**Ownership**	**Care provision***
1	46	Rural	Bradford	Independent	Residential, nursing
2	40	Semi-rural	Bradford	Independent	Residential
3	30	Suburban	Bradford	Chain	Residential
4	23	Urban	Bradford	Local authority	Residential, dementia
5	63	Suburban	Bradford	Chain	Residential, nursing
6	40	Suburban	Kirklees	Chain	Residential
Pilot Study 2					
Care home	**Number of beds***	**Location**	**Local authority**	**Ownership**	**Care provision***
7	28	Rural	Bradford	Independent	Residential; dementia
8	96	Suburban	Leeds	Chain	Residential
9	40	Semi-rural	Bradford	Chain	Residential; nursing
10	40	Suburban	Kirklees	Chain	Residential

* in the unit involved if whole care home not recruited

7.4.2.2 Data collection and reduction

Data for this chapter were collected in the context of the REACH programme (**Chapter 1, section 1.5.1**). Given the ultimate aim of REACH was to work with care home staff and residents to increase the time residents spend engaging in PA with the intention of improving their physical, psychological and social well-being, appropriate outcome measures to assess these domains in care home residents were needed. Still, given the focus of the current chapter was on exploring the feasibility of using an accelerometer to collect objective PA data in care home residents, only data collection related to this objective is detailed here.

The dynamic nature of the care home environment, coupled with the intended flexibility and multicomponent nature of the accelerometer data collection protocol, meant examination of the feasibility and acceptability of data collection procedures was complex. Thus, in an effort to ensure a thorough understanding, compliance to the data collection protocol was explored using several different sources of data, both quantitative and qualitative.

Quantitative data

The following quantitative data were collected in relation to the feasibility of using the accelerometers:

- the number of residents screened for eligibility and reasons for ineligibility;
- the number of residents providing consent / assent;
- the proportion of residents consented via PCs and NCs;
- the number of accelerometers administered and the number lost;
- reasons for accelerometer non-wear;
- the total number of log entries and the proportion of entries made by participants, care home staff and researchers;
- a record of the contact by the research team with the care homes regarding the accelerometer data collection was maintained.

These data were interpreted alongside the qualitative data collected.

Qualitative data

Whilst the predominant data collection method employed in this study was quantitative, in order to gain a more in-depth understanding of how the accelerometer data collection protocol was delivered and determine the acceptability of the proposed protocol, different sources and types of qualitative data were drawn upon including ethnographic observations and informal conversations.

Ethnographic observations (Atkinson et al., 2001; Spradley, 1980) were conducted overtly within the communal spaces of the care homes over the course of both pilot studies (Sands, 2002). Every effort was made to ensure that both residents and staff were fully informed and were comfortable with being observed. Posters giving brief details of the REACH study and a contact number for further information were displayed clearly in each of the care homes prior to commencement of any observations. Over the course of the study, verbal consent to observe was sought and efforts were made to let staff and residents know when the next visit was going to be.

Observations were conducted as unobtrusively as possible, in different areas of the home, on different days of the week (including weekends) and encompassed different times of day as the researcher worked flexibly in an effort to facilitate contact with care home staff and prompt accelerometer wear. Observations were focused on exploring the contextual factors which both facilitated and / or hindered the implementation of the proposed data collection protocol. Detailed field notes were produced to capture the observations and the researcher's initial impressions and reflections on what had been observed. Regular research meetings were held to support the on-going focusing of the observations.

Additionally, the views of key stakeholders (i.e. residents and care home staff) on aspects of the data collection protocol were captured during informal conversations which occurred in the course of observations. These conversations were particularly helpful for involving those residents with dementia and busy staff who did not have time to participate in formal qualitative interviews. Conversations centred on residents' perceptions of wearing the accelerometer and staff opinions on the accelerometer data collection. As was the case with the observations, the researcher documented these conversations and their reflections on them in detailed field notes and discussed these with the wider research team on a regular basis.

7.4.2.3 Data reduction and analysis

Quantitative data

Treatment of the quantitative data in preparation for statistical analysis is detailed in the **general methods chapter, section 5.6**.

Participant recruitment and participant characteristics

The number of resident's screened, eligible, and providing consent / assent were summarised, alongside reasons for non-participation. To provide context, the personal characteristics and physical function and mobility assessments scores of participants were also summarised.

Accelerometer wear

The number and proportion of participants who wore an accelerometer were summarised alongside reasons for non-wear where appropriate.

Next, raw activity count data collected from the accelerometers were processed with the normal filter and aggregated over 60 second epochs (**Chapter 6, Study 1**). VM activity counts were used to determine daily wear time as per the procedures described in **Chapter 6, section 6.3.2.3**.

For each participant, the number of valid days of PA monitoring (defined as ≥ 8 h, based on analysis presented in **Chapter 6**) were determined. Compliance was then discussed in terms of the number of participants meeting the minimum wear time criterion (i.e. ≥ 8 hours on ≥ 4 days), previously identified in **Chapter 6 (Study 3)** as being sufficient to achieve reliable estimates of PA behaviour in older care home residents.

Finally, differences in the personal characteristics and mobility scores between those who were deemed compliant, and those who were not, were explored using independent sample t-tests and chi-squared tests as appropriate.

Activity log completion

The number and proportion of activity logs returned was summarised overall and by care home. The total number of log entries and the proportion of entries made by participants, care home staff and researchers were summarised.

Qualitative data

Ethnographic observations and informal conversations, along with the researcher reflections, were written up as expanded accounts as soon as possible after each care home visit (Emerson et al., 1995; Spradley, 1980). Pseudonyms (including the names of the care homes) are used throughout and efforts have been made to remove identifiable information.

As this doctoral work was not initially designed as a mixed methods project, a pragmatic approach to the analysis of the qualitative data collected (ethnographic observations and informal conversations) was adopted. First, the data were read and re-read and notes were made about anything of interest. Next, the data were revisited and each piece of data that was relevant to the research question was coded (Braun et al., 2016). In order to ensure findings were not simply descriptive but provided insight into the factors and mechanisms which either facilitated or hindered compliance to data collection procedures within different care contexts, the data were revisited and codes were clustered to identify patterns (themes) in the data (Green and Thorogood, 2014). The analysis was discussed with colleagues regularly throughout this process to ensure they were relevant to the research question, appeared ‘reasonable’ and were not misrepresenting the data (Braun et al., 2016).

7.4.3 Pilot Study 1: Results

7.4.3.1 Quantitative findings

Participant recruitment

Two hundred and twenty residents across six care homes were screened for participation between June 2013 and February 2014 (mean number of residents per care home: 37; range 23 - 55). Of these, 151 (69%) were eligible; 49 consented / had consultee agreement (32% of eligible residents; 22% of those screened) and 46 participated in the study (31% of eligible residents; 21% of those screened) (Figure 7.4).

Regarding those eligible reisdents who were deemed to have capacity (n = 63), one (2%) died before consent counld be taken; 30 (48%) consented and 32 (51%) refused. The most common reason given by residents for not wanting to participate was that they did not want to be involved in research (n =14). Other reasons given were: they did not think that they could be useful (n = 3); a recent fall (n = 2); depression (n= 1); they felt it would be too burdensome for staff (n = 1) and they felt that they had ‘too much going on’ (n = 1). The remaining 10 residents did not give a reason for not wishing to participate.

Of the 84 residents who did not have capacity to consent, one resident moved out of the home and eight residents refused permission for researchers to approach a PC, with two residents stating that the reason for this was that they would not like to wear an accelerometer. PCs of 75 potential participants were sent a letter requesting their agreement for their relative / friend to participate in the study. Nineteen (25%) of these PCs agreed for the resident to take part in the study; 33 (44%) declined and there was no response from 22 (29%). Reasons for declining agreement are shown in Table 7.2.

Table 7.2 Reasons for PC non-agreement (n = 33).

Reason	N (%)
Relative / friend would not choose to participate	16 (33%)
Resident not well enough	15 (31%)
Resident's lack of comprehension / unable to converse (dementia)	6 (12%)
Resident's anxiety / worry / agitation / confusion	5 (10%)
Resident not mobile / inactive	4 (8%)
Resident unable to converse (deaf / suffered stroke)	1 (2%)
Unable to comply to protocol / participate in previous research	1 (2%)
No reason given	1 (2%)

Note some PCs provided more than one reason.

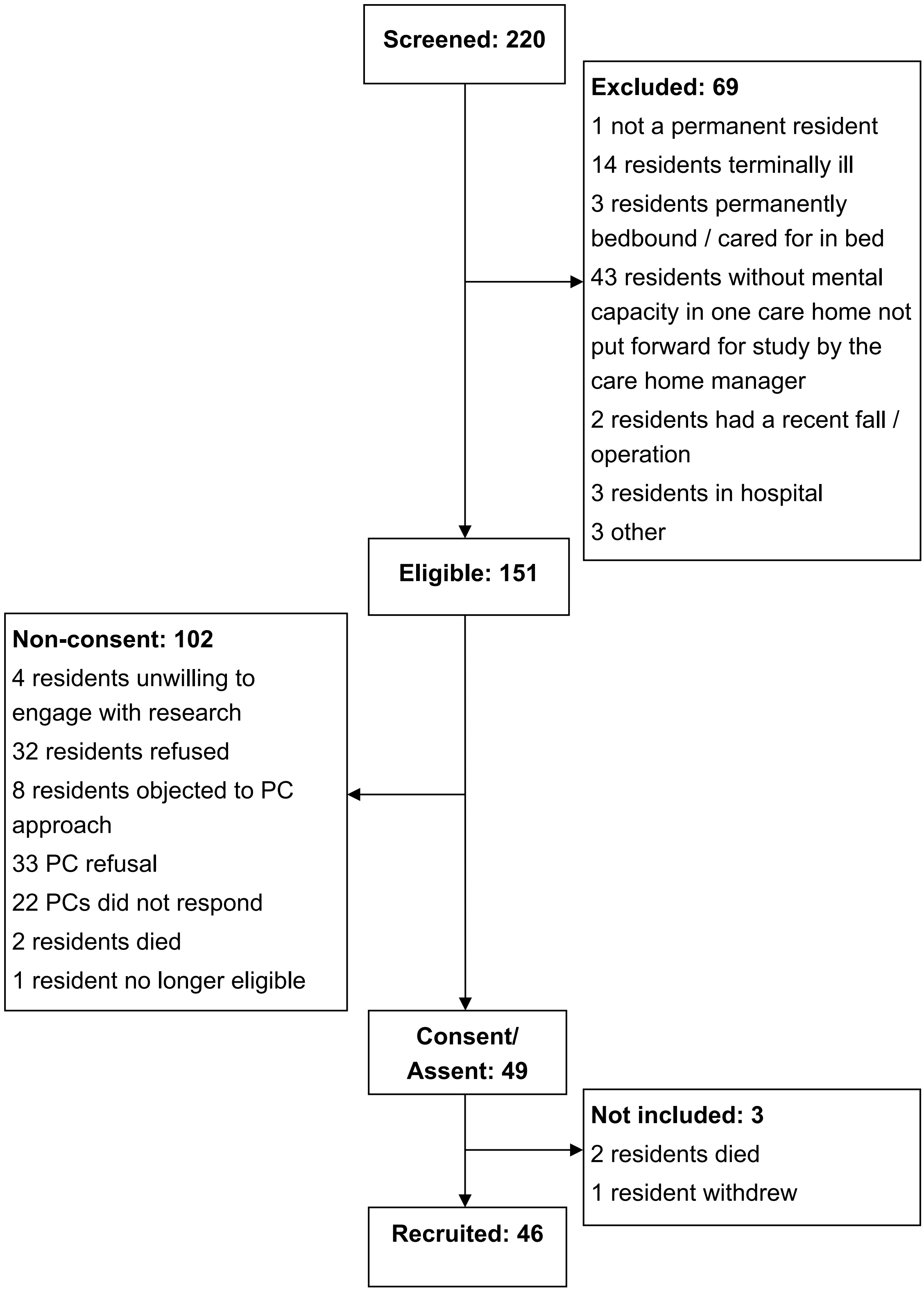


Figure 7.4 Consort diagram demonstrating the recruitment of participants from six care homes participating in the study. Recruitment was undertaken in two waves. The first wave involved four care homes and was completed between June and September 2013. The second wave was undertaken in two care homes between November 2013 and February 2014

Participant characteristics

To provide context, the characteristics and physical function and mobility assessment scores of recruited participants (n = 46) are provided in Table 7.3 and Table 7.4. Participants had resided in a care home for an average (median [IQR]) of 1 year 3 months [1 year 9 months]; however, there was a wide range in length of residence (< 1 month – 13 years 1 month). A considerable proportion of participants were females and over half were aged over 85 years. Over a quarter (n = 17, 37%) of participants were deemed not to have the capacity to consent themselves therefore it may be inferred that they suffer from some form of cognitive impairment. Further, a number of participants had more than one comorbidity (n = 13, 35%). A large percentage of the participants were judged to be physically able with 69% (n= 27) considered independent in ADLs based on their BI score and 59% (n= 27) of participants being able to ambulate independently on level surfaces (i.e. FAC level of 4 or 5).

Table 7.3 Participant characteristics (n = 46). Number of participants (n) is not equal to the total number of residents recruited due to missing data.

	n	N (%) or Mean ± SD
Gender (male)	46	15 (33%)
Age (y)	44	85 ± 8
Age group	44	
< 85 y		20 (45%)
≥ 85 y		24 (55%)
Height (cm)	35	164.8 ± 9.7
Weight (kg)	45	67.9 ± 12.8
Capacity to consent (yes)	46	29 (63%)
Number of comorbidities*:	37	
None		1 (3%)
1 - 2		30 (81%)
≥ 3		6 (16%)

* based on the CCI (Charlson et al., 1987)

Table 7.4 Scores on physical function and mobility assessments (n = 46).

	N (%) or Mean ± SD
BI score (score on a 21-point scale; 0-20)	12 ± 5
BI score ≤ 11 (dependent)	19 (41%)
BI score > 11 (independent)	27 (69%)
FAC	
Level 0 (non-functional ambulation)	11(24%)
Level 1 (ambulatory-dependent for physical assistance, level II)	6 (13%)
Level 2 (ambulatory-dependent for physical assistance, level I)	0 (0%)
Level 3 (ambulatory-dependent for supervision)	2 (4%)
Level 4 (ambulatory-independent on level surfaces)	14 (30%)
Level 5 (ambulatory-independent)	13 (28%)

Accelerometer wear

The research leads in two of the care homes did not see the benefit of ‘their’ residents wearing a hip-worn accelerometer as they believed them to be too frail. Hence, the decision was made to invite those participants (n = 10, 22% of recruited participants) to wear a wrist-worn accelerometer and examine the utility of this wear location. In addition, one resident was asked to wear a commercially available monitor so that the data collected by this device could be explored.

Thirty-five (76%) participants were invited to wear a hip-worn accelerometer. Hip-worn accelerometers were not administered to five participants, either because the participant refused to wear one (n = 1) or the participant was deemed too unwell to wear an accelerometer by care home staff (n = 4). A hip-worn accelerometer was administered to 30 (65%) of the 46 participants recruited (Figure 7.5).

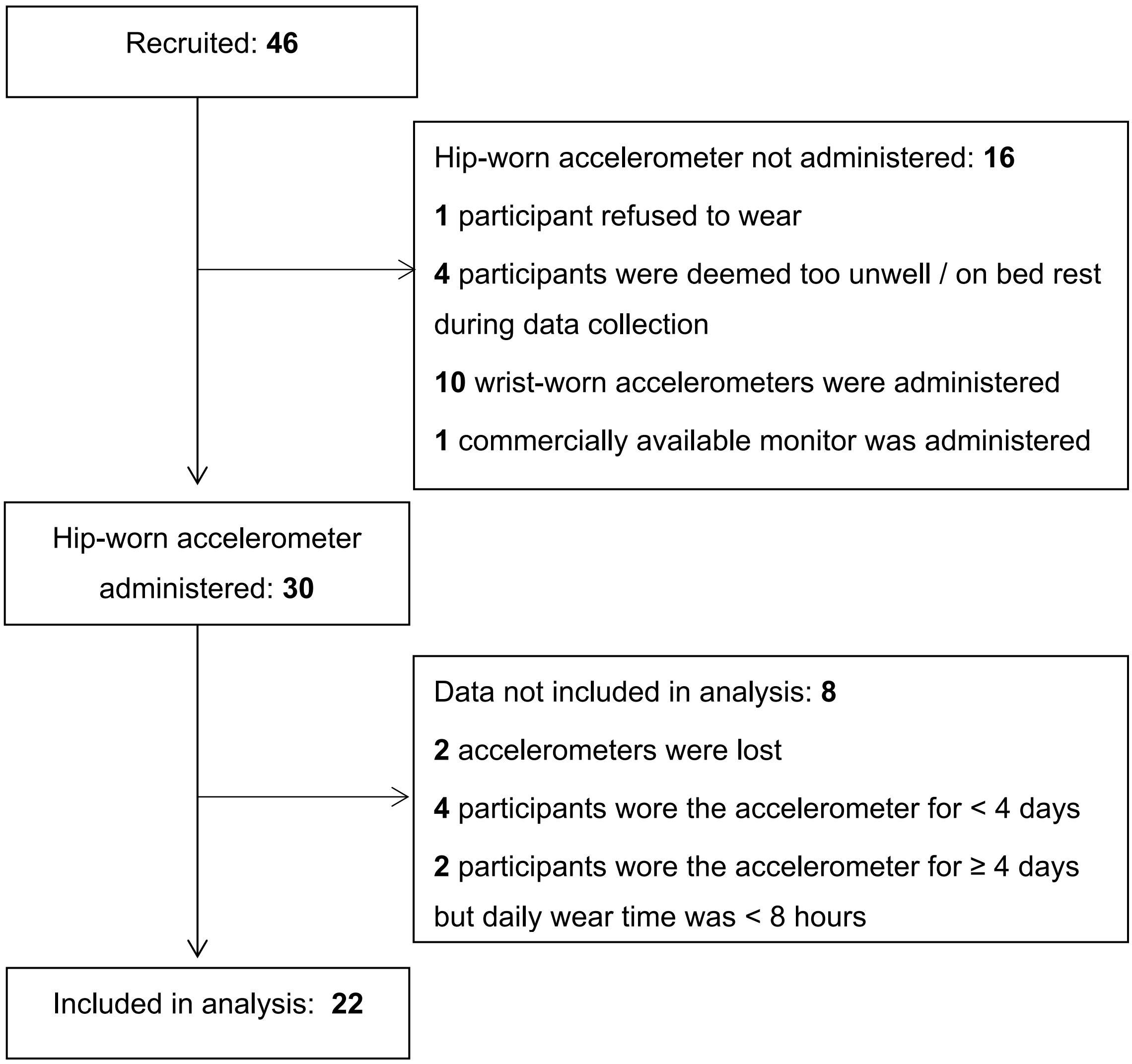


Figure 7.5 Consort diagram demonstrating the flow of recruited participants in to those meeting the accelerometer wear time requirements to be included in analysis.

There were no significant differences in the personal characteristics of those participants who were fitted with a hip-worn accelerometer and those who were fitted with a wrist-worn accelerometer ($p > 0.05$). However, those participants who wore a hip-worn accelerometer had better physical function as indicated by their BI score compared to those participants who wore a wrist-worn accelerometer (mean scores = 13 ± 5 and 9 ± 6 respectively, $p < 0.05$).

Whilst wrist-worn accelerometers are increasingly being used in large-scale studies as a result of reports of improved compliance compared to hip-worn accelerometers (Troiano et al., 2014), there is a paucity of studies comparing the outputs derived from hip- and wrist-worn accelerometers in older adults. The results of the lab-based study presented in the **previous chapter** suggest the validity of EE estimates were considerably better when the accelerometer was worn on the hip rather than the wrist. Furthermore, there is limited guidance available on how best to interpret data collected from a wrist-worn accelerometer. For this reason, the decision was taken not to analyse further the wrist data collected in this study.

Of the 30 hip-worn accelerometers administered, five (all in the same home) were misplaced over the course of the monitoring period. Whilst three of the misplaced monitors “showed up” (one had been through the washing machine), the remaining two accelerometers were never found. Both of the accelerometers lost had been administered to participants who were deemed to lack capacity. Data was successfully downloaded from all (n = 28) of the accelerometers collected; however, data was lost from the accelerometer which had been through the washing machine.

Twenty-two participants were judged to be compliant to the data collection protocol as they met the pre-determined criteria for valid wear time (i.e. ≥ 8 hours of data ≥ 4 days) (Figure 7.5). Encouragingly, eight participants (27% of those whose data was downloaded) actually provided seven valid days (Table 7.5). Of the six who did not meet the valid wear time criteria, one participant provided one valid day; two participants provided two valid days and three participants did not provide any valid data (Table 7.5). There were no differences in the personal characteristics (based on the items measured) or mobility scores of those participants who met the criteria for valid accelerometer data (n = 22) and those who did not (n = 6) ($p > 0.05$).

Table 7.5 Number of valid days of accelerometer wear among participants to whom an accelerometer was administered (n = 30).

Number of valid days (defined as ≥ 8 hours)	N (%) of participants
Monitor lost	2 (7%)
0	3 (10%)
1	0 (0%)
2	2 (7%)
3	1 (3%)
4	8 (27%)
5	3 (10%)
6	3 (10%)
7	8 (27%)

Activity log completion

Despite repeated visits and reminders from a member of the research team at the end of the study, a third (n = 9) of the original activity logs administered were never collected by the researcher at the end of the study as they had been misplaced. Interestingly, of the nine activity logs never recovered, the decision had been made to store the majority of them centrally (for example in either the care plans or at the nurse's station) rather than in residents' bedrooms.

Overall log completion was highly variable (median [IQR] number of log entries = 6 [5]; range: 1 – 23); with only two (7%) of the logs being completed in their entirety. Notably, when looking at the two activity logs completed in their entirety, all of the log entries, with the exception of the first entry completed by the researcher on accelerometer administration, were made by the participant themselves. Only three residents made any log entries. This finding is not surprising given a considerable proportion of the entries were attributable to a member of the research team (47%) rather than participants themselves (22%) or a member of care home staff (31%) (Table 7.6).

According to the data collected on the activity logs, accelerometers were "with" participants for a median of ten (IQR: 19, range: 1-20) days. Nevertheless, the mean number of days the accelerometer was worn (as indicated by a single daily log entry) was considerably lower (4 ± 2 days). What is more, the documented times the accelerometer was put on and taken off suggest the number of valid days (defined as ≥ 8 hours) of wear varied considerably across participants (median [IQR] = 0 [3]; range: 0 – 8).

Table 7.6 Details regarding activity log completion (n = 30).

Percentage (%) of total log entries made by:	
Participant	22%
Care home staff	31%
Researcher	47%

7.4.3.2 Qualitative findings

An extensive amount of qualitative data was collected over the course of the study. A number of interacting factors and social processes were identified as being important in determining how the accelerometer data collection protocol was implemented in practice. These included:

- the organisation, management and delivery of care;
- awareness and understanding of the research project;
- engagement with the study;
- staff knowledge of residents;
- perception of the role of the care assistant;
- resident profile

Each of these are discussed in more detail below, drawing on data collected from each of the participating care homes where appropriate.

Organisation, management and delivery of care

Across all the participating care homes the organisation of the day-to-day running of the home was largely structured around regenerative work (i.e. getting resident up and dressed; mealtimes and medications). As is the case in many organisations, there is a requirement for some kind of routine to ensure the institution functions and achieves its purpose. Even so, within this organisational routine, how care was delivered was largely dependent on the philosophy of care adopted by the care home.

There were different philosophies of care at each of the participating homes and this certainly appeared to have implications in terms of how the research project was perceived by care home staff and ultimately, how the accelerometer data collection was implemented in practice. For the purposes of this discussion, data were drawn from two of the homes: Care Home 3 and Care Home 4 as the differences between them provide an interesting comparison.

At Care Home 3 the philosophy of care was closely aligned with the managerial and audit culture, in that the emphasis was on procedures, documentation and a task-focused approach to care delivery. However, this philosophy was not universally accepted and tensions arose between the manager and care staff. This tension was evident through the conduct of staff meetings and staff demeanour. There was a general sense of low morale amongst the whole staff group, who seemed to be overwhelmed by their workload. Thus, it was unsurprising that the care home manager’s enthusiasm for the study was not mirrored by the wider staff group. There appeared to be a feeling amongst care staff that they “had enough to do” and supporting the accelerometer data collection was an additional, unnecessary task.

Over the course of the observations it was not uncommon for there to be prolonged periods of time where there was no visible staff presence within the communal areas such as the lounge as they were tending to the needs of those residents opting to stay in their rooms. For the most part staff seemed harassed and this did not go unnoticed by the residents. One resident remarked how she did not want to take part in the study as she felt the staff had enough to contend with and that she didn’t want to burden them further. Similarly, when one of the residents who agreed to take part in the study was asked why she wasn’t wearing her accelerometer she indicated that staff had been very busy that morning and that she hadn’t wanted to “add to their workload” and ask for help with putting it on.

This atmosphere was in stark contrast to what was observed at Care Home 4 where the philosophy of care championed by the care home manger was much more holistic and enabling. Mechanisms and structures were in place to help facilitate this approach as the manager recognised that staff busyness and their fear of putting residents at risk did challenge this notion. The care home manager openly acknowledged that enabling residents to do more themselves meant that routine activities would take longer. This reinforced the value attached to enabling work and made it clear that such work was considered a central part of a care assistant’s role. It also demonstrated that the care home manager had an awareness of the environment in which care assistants were working and an appreciation of the difficulties they faced. This “openness” between the care home manager and wider staff group ensured good working relationships were maintained and helped to foster a shared understanding of how care should be delivered.

This shared understanding and sense of responsibility was also observed with regards to the accelerometer data collection. Given the emphasis placed on enabling residents and trying to keep them as mobile as possible, for as long as possible, staff did not need to be convinced of the benefits engaging in PA could have for residents. Further, the home was very proactive in terms of monitoring changes in residents’ physical mobility and behaviour and taking reactive action if needed following consultation with external professionals and / or family members. Hence, as a group, staff appreciated the importance of measuring the PA and sedentary behaviour of residents. Furthermore, as the home specialised in caring for older adults with dementia, staff were aware of the challenges this posed in terms of using indirect methods such as questionnaires. They understood the need to explore the feasibility of using accelerometers as a means of collecting objective PA data and perceived the task as worthwhile.

Awareness and understanding of the research project

The researcher explained to all care home managers that, given the aim of the overall research project, the recruitment process was to be as inclusive as possible and that the ethical approval attained covered the inclusion of residents deemed to lack capacity. Nevertheless, the manager in Care Home 6 was not comfortable with including residents who they categorised as lacking capacity. Further, even in the remaining five homes where the care home managers appeared on board with the inclusive approach to recruitment being adopted, the concept that an individual’s mental capacity is “decision-specific” appeared difficult for some care home staff to grasp. For example, in Care Home 1, whilst supportive of the REACH research programme, the manager was of the view that many of ‘his’ residents were vulnerable and he did not feel it was appropriate for them to be approached by the researcher, a person unknown to them. This meant that some residents were not offered the opportunity to consent to take part in the research project themselves.

There also appeared to be a lack of understanding on the part of some of the care staff about the necessity of asking residents to wear accelerometers, particularly in cases where residents were immobile:

> *I asked one of the care staff on shift if she is working the rest of the week, she informed me she was so I asked if she could try and ensure residents wear their monitors. I went through the list of participants currently wearing them. As I was doing so, she pointed at a couple of the names and tetchily told me that those residents rarely walked and are transported in a wheelchair. I explained that we were aware of this and would still be grateful if staff would help them to wear a monitor and complete the recording sheet as we are “testing the monitors out”.*
>
> *(Extract from researcher field-notes, Care Home 2)*

Despite efforts to explain the importance of offering all residents the opportunity to wear an accelerometer and the value of collecting data from residents with varying mobility levels, not all staff shared this view. As a result they were less inclined to be proactive in terms of supporting data collection.

Engagement with the study

The research project, and the accelerometer data collection in particular, was met with some scepticism from care assistants. Several commented that they thought residents were “too frail” to take part in the research:

> *I ‘caught’ Alison (senior carer) and explained that I was there to administer the accelerometers to two residents: Sophie and Phillip. Alison commented that she didn’t understand why we were going to “all this effort” as neither resident was able to do anything for themselves. I explained that we had received agreement from their relatives for them to take part. She reluctantly beckoned me to follow her and introduced me to Philip.*
>
> (Extract from researcher field-notes, Care Home 5)

Notwithstanding some resistance from staff, those residents wearing the accelerometer did not appear to be burdened by it and importantly no adverse events associated with the accelerometers were reported. Nevertheless, during the “check in” visits at the first care home not all of the participants were wearing their accelerometer. Still, when approached by the researcher, the majority of participants were happy to wear the accelerometer. Also, when asked why they were not wearing their accelerometers, they rarely reported any issues with wearing the monitor, but often stated that they had forgotten to put it on:

> *Resident indicated no problems wearing the accelerometer and suggested they would wear the monitor again. Admitted to forgetting to wear the accelerometer on one day.*
>
> *(Extract from researcher field-notes, Care Home 2)*

Having said this, there were many instances where residents failed to provide an explicit reason for not wanting to wear their accelerometer. For example, during a researcher visit one of the participants was agitated and emotional and when the researcher engaged in conversation with her, she indicated that she had “had enough” of wearing the accelerometer but did not offer any explanation as to why she felt this way. This kind of response was not unsurprising given reports suggest that as a group, this population is not only physically and mentally fragile but are also susceptible to fluctuations in mood (Gordon et al., 2014; Stewart et al., 2014).

Perception of the role of the care assistant

Across all of the participating care homes, care assistants were kept busy attending to the physical needs of residents, including those who were nearing the end of life, and keeping up-to-date with their paperwork. Thus, many care assistants were of the opinion that anything outside of this remit (for example, supporting the research project) was not part of their role. Indeed, many care assistants displayed indifference to assisting residents to put their accelerometer on / take it off and also to completing the activity logs. The following extract highlights this:

> *I arrived at the care home at approximately 10:15am. I found a carer in the lounge and explained that I had just come to "check in" to see how residents were getting on with the accelerometers. I showed her the list of residents wearing the accelerometers. She noted that June was wearing her monitor, however admitted that she did not know about the other residents. I asked if I could have a wander round and check with residents – she said this was fine, and almost appeared relieved I wasn't asking her to do anything.*
>
> *(Extract from researcher field notes, Care Home 5)*

Having said this, there were individual members of staff across all of the homes, particularly those who were more experienced or had worked at the care home for a longer period of time, who had a more 'universal' view of their role and were therefore more proactive in terms of supporting the study.

Staff knowledge of residents

In general, across all of the participating homes and amongst most staff, communication with residents was warm, respectful and responsive. Having said this, not all staff demonstrated meaningful knowledge of residents and differences in how staff engaged with residents were observed both within and across the participating care homes.

Knowing individual residents, including their likes, dislikes, abilities and impairments, as well as having knowledge of their past and social connections, often facilitated care staff in delivering care in a more resident-focused manner. As the extract below demonstrates, there were also examples over the course of the observations of care assistants drawing on their knowledge of individual residents, both in terms of their individual needs and abilities, and also their identity as persons, in order to encourage them to wear their accelerometer.

> *Alison (activities co-ordinator) walked over to Jim and asked him "would you wear this belt (accelerometer) for me?" Jim frowned a little as he asked "why?" Alison light-heartedly replied, "why not?" Some verbal jousting between the two of them followed. It was clear Jim enjoyed engaging in this "banter" which was mainly focused on his idiosyncrasies. After a few minutes, Alison held the accelerometer out in front of her – "are you going to give it a go then?" Jim, laughing, nodded and let Alison fasten the belt around his waist.*

(Extract from researcher field notes, Care Home 1)

It also became evident over the course of the observations that in those homes where staff engaged with residents in a personally meaningful way, there appeared to be a genuine rapport between staff and residents. As a result, if staff were "on board" with the study, and willing to assist residents with putting on their accelerometers, this appeared to have a positive effect on compliance.

Nevertheless, a considerable proportion of the interactions observed between residents and care assistants across the participating care homes tended to be focused on the task (for example administering medications or fitting the accelerometer) with little or no attention to the resident as a person. This practice appeared to hinder the development of positive relationships between residents and staff which, in some cases, effected the atmosphere within the whole home. Indeed in some of the homes, it became clear that there were residents who were less forthcoming in communicating with staff which in turn had implications in terms of compliance to the data collection protocol.

Resident profile

Conversations with care home staff in all of the participating homes typically centred on the changing resident profile. Many staff had worked within a care home setting for a number of years and felt that, at the point of admission, residents were typically more physically frail compared to five - ten years ago and that the number of residents experiencing some degree of cognitive impairment was increasing. This view was supported by the observations, with the researcher reflecting that residents appeared to be frailer than anticipated. It was also noted that in some cases residents were admitted to the care home following a ‘crisis’ such as a fall, hospital stay or bereavement of an informal caregiver.

Although there was some variation in terms of residents’ physical abilities, mobility and level of cognitive impairment, both within and across the homes, a considerable proportion of residents in all of the homes required some support (either physical or verbal) from staff with undertaking ADLs. Even those residents who were categorised as “independent” according to the BI tended to need assistance to fasten the belt used to secure the accelerometer as poor dexterity, often due to conditions such as Parkinson’s disease and arthritis in their fingers and / or hands, made this very difficult for them:

> I spoke to Brian who indicated that he had been wearing his monitor (he lifted his jumper to show me he was wearing it). However he did remark that he had trouble with the fastening on the belt so had been stepping into and out of the belt *rather than ‘battling with the buckle’.*
>
> (Extract from researcher field notes, Care Home 5)

Similarly, although less than half of the participants in the current study (47%) were deemed to lack the capacity to consent, it became apparent over the course of the observations that a considerably higher proportion of participants had some degree of cognitive impairment which hindered their ability to complete the activity logs themselves either because they forgot or they became confused about how to complete them correctly. For example, in a conversation with a researcher when their activity log was collected, a participant explained how they had documented the times they got up and went to bed, not the times they put the accelerometer on.

7.4.3.3 Summary of the key challenges to the collection of high-quality accelerometer data and refinements made to the data collection protocol prior to Pilot Study 2

The proportion of residents in the current study who had valid data compared favourably to recent studies conducted in LTC settings which have employed similar criteria to define valid wear time (Leung et al., 2017; Marmeleira et al., 2017). Whilst this is encouraging, the qualitative data collected suggests there is scope to improve compliance further. Thus, it was deemed important to not only acknowledge, but also to reflect on the challenges experienced over the course of the study and subsequently make refinements to the data collection protocol where appropriate.

An overview of the key challenges experienced, along with the researcher's reflections on these and the subsequent refinements made are detailed below.

Challenge: Despite adopting an inclusive approach to recruitment, only 30 (20% of eligible residents, 14% those screened) residents were recruited and agreed to wear a hip-worn accelerometer.

Reflection: Whilst there were few instances of residents or PCs explicitly stating that they did not want to wear an accelerometer, it may be surmised that the acceptability of the accelerometer was likely a key consideration for both residents and PCs approached for the study, particularly as they were unlikely to be familiar with them. It is also worth noting that 29% of the PCs approached did not respond. This finding, coupled with the fact that NCs were not used in the study as one of the care home managers objected to this approach, resulted in a loss of potential residents for recruitment.

Refinements:

- Care home managers will be encouraged to speak to as many relatives as possible in person about the study prior to sending out information.
- A concerted effort will be made to ensure the research team are approachable and available should relatives have any queries.
- Members of the research team will attended resident / relative meetings and meetings for staff to increase awareness of the research.
- Reassurance will be offered to care home managers regarding the process of consulting a NC.

Challenge: Accelerometer wear was variable

Reflection: In many cases participants were happy to wear the accelerometer when approached by a member of the research team. When asked why they were not wearing their accelerometers participants often reported that they had forgotten to put it on or that they were unable to fasten the belt. Evidently, enabling residents to wear monitors required greater support from care home staff than had been anticipated.

In addition, the practice of administering accelerometers as soon as possible once informed consent / assent had been attained, coupled with the recruitment methods employed (detailed in **Chapter 5**), meant that not all participants within a given home were wearing the accelerometer at the same time. As an example, in one of the care homes, accelerometers were administered to four participants on the Tuesday and two participants on the Thursday of the same week. An additional two accelerometers were then administered on the following Tuesday. It was surmised that this practice may have adversely affected wear compliance as the monitoring period for the "whole home" was protracted; hence the perceived burden of the research was likely greater.

Refinements:

- Participants were asked to continue wearing their accelerometer until between five and seven days of wear (not necessarily on a consecutive basis) were recorded on the activity log or when residents indicated that they no longer wanted to wear the accelerometer. [†]
- A member from the research team will visit or telephone the care home periodically (the frequency of visits will be based on perceived need) over the measurement period to prompt wear.
- Accelerometers will be administered more systematically (i.e. in batches) wherever possible.
- Written materials, namely a list of participants wearing an accelerometer and 'reminder posters' will be produced and care home staff will be encouraged to display these prominently within the care home.

[†] Refinement was made following the completion of data collection in the first home in Pilot Study 1 as during the "check in" visit at the first care home not all of the participants were wearing their accelerometer and the completion of the activity logs was variable. It was not clear therefore whether participants had been wearing their accelerometers.

Challenge: Completion of activity logs was poor and appeared onerous for staff.

Reflection: Whilst it was acknowledged that completion of activity logs may be viewed as burdensome by staff, correct identification of accelerometer wear time is imperative to ensure accelerometer data is interpreted and analysed correctly (Schrack et al., 2016). Thus, ensuring the time accelerometers are put on and taken off each day is captured was deemed necessary. Conversely, the collection of contextual information (i.e. the reason the accelerometer was removed and the time the monitor was taken off) were judged not be necessary.

Refinements:

- The activity logs will be administered in a way in which the research lead feels will be met with greatest success.
- Care home staff will be asked to record the times of administration and removal of the monitor and will be advised that recording reasons for removal are optional.
- The level of support offered by the research team will be increased such that a member of the research team will visit or phone the care home daily to prompt log completion.

Challenge: A number of activity logs were lost

Reflection: The sedentary profile of residents meant the identification of non-wear time was particularly difficult. The correct identification and removal of non-wear time is critical to ensure the conclusions derived from the data are accurate.

Refinements:

- Duplicate logs will be maintained by the researcher in an attempt to minimise the loss of data
- During their visits to the homes to prompt accelerometer wear and log completion the researcher will ask to review the activity logs and transcribe any information recorded on the activity logs onto their copy.

7.4.4 Pilot Study 2: Results

7.4.4.1 Quantitative findings

Participant recruitment

One hundred and seventy-six residents across four care homes were screened for eligibility between December 2014 and April 2015. Of these, 146 (83%) were eligible and 61 consented / had consultee agreement (42% of eligible residents; 35% of those screened) to take part in the REACH research programme. Only those participants (n = 51, 35% of eligible residents, 29% of those screened) who agreed to wear a hip-worn accelerometer were recruited to take part in the current study.

Regarding those eligible reisdents who were deemed to have capacity (n = 62), 14 (23%) were deemed ineligible; 32 (51%) consented and 16 (26%) refused. The majority of residents did not provide a reason for declining consent, with three residents actually refusing to speak to a member of the research team. Explicit reasons provided for non-consent included: not wanting to be involved in research (n = 7) and they did not think their participation would be useful (n = 1).

Seventy-three residents were deemed to lack the capacity to consent; however, a PC could not be identified for one of these residents. Thus, PCs of 72 potential participants were sent a letter requesting their agreement for their relative / friend to participate in the study. Eleven (15%) of these PCs agreed for the resident to take part in the study; 14 (19%) declined and ambiguous responses were received from three (4%). Reasons for non-agreement are provided in Table 7.7. The remaining 44 (61%) PCs did not respond.

As per the recruitment procedures (**Chapter 5, section 5.2.3**), in cases where a resident did not have a PC (n = 1) and the PC did not respond (n = 44), the research lead in each of the care homes was approached and asked to identify an appropriate NC for each resident. However, one home withdrew from the study before an appropriate NC could be identified for three residents, one resident died and three residents were identified as no longer being eligible (three were acutely unwell). Thus, a NC was approached to consider the participation of 38 potential participants across three of the care homes. Of these, NC agreement was attained for 18 residents (44% of those approached). Reasons for non-agreement are provided in Table 7.7. Notably, all of the residents recruited via NC agreement were from two care homes.

Table 7.7 Reasons for PC and NC consultee non-agreement.

Reason	**PC** (n = 14)	**NC** (n = 20)
	N (%)	
Relative / friend would not choose to participate	6 (35%)	8 (40%)
Resident not well enough	7 (41%)	4 (20%)
Resident's lack of comprehension (dementia)	0 (0%)	2 (10%)
Resident's anxiety / worry / agitation / confusion	2 (12%)	2 (10%)
Unable to comply to protocol	0 (0%)	4 (20%)
No reason given	2 (12%)	0 (0%)

Note: some PCs provided more than one reason.

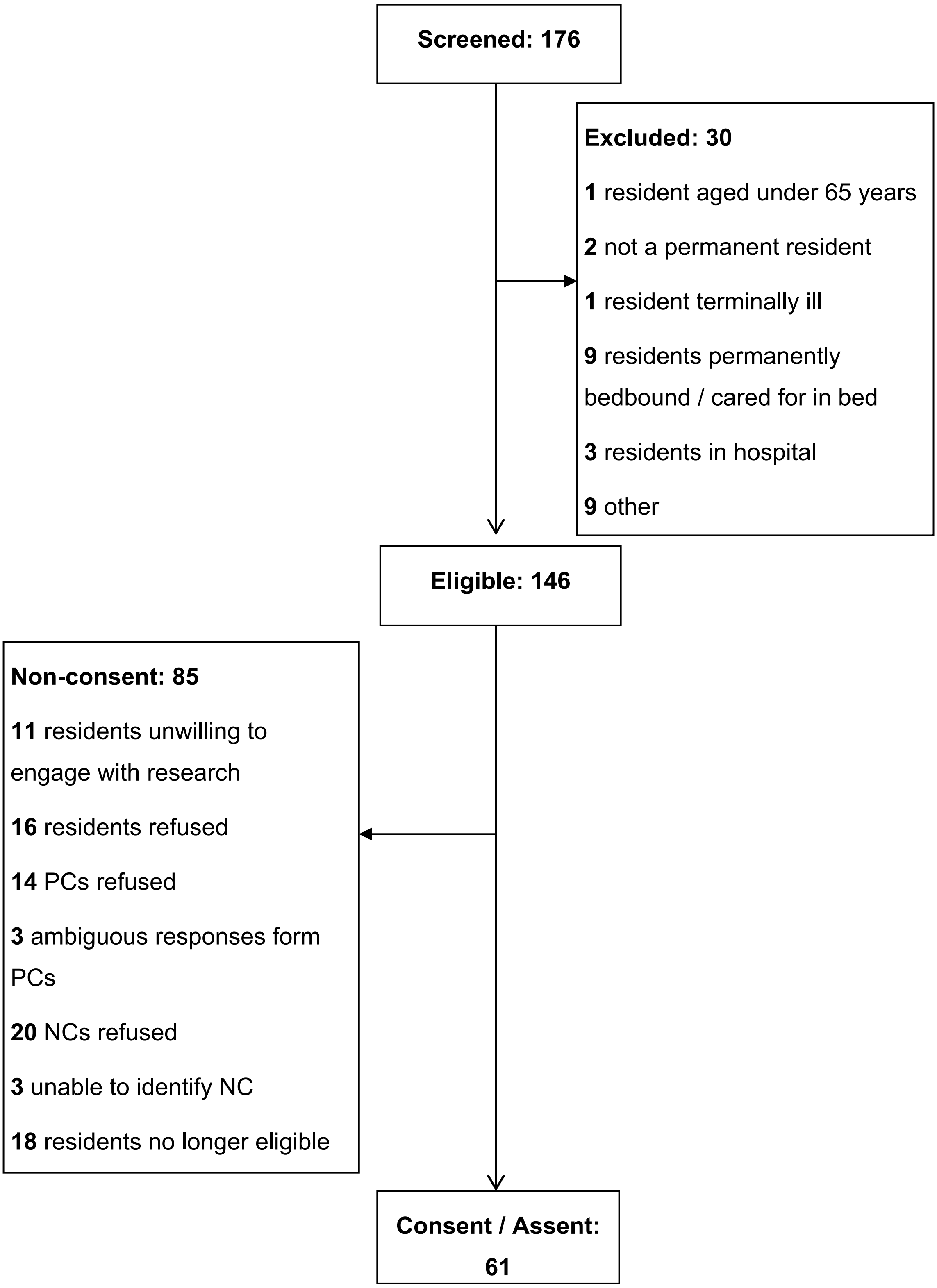


Figure 7.6 Consort diagram demonstrating the recruitment of participants between December 2014 and April 2015 across four care homes participating in the study.

Participant characteristics

To provide context, the characteristics and physical function and mobility assessment scores of recruited participants (n = 61) are provided in Table 7.8 and Table 7.9. Participants had resided in a care home for an average (median [IQR]) of 1 year 2 months [2 years 1 month]; however, there was a wide range in length of residence (4 months – 12 years 4 months). A considerable proportion of participants were females and over half were aged over 85 years. Just under half of participants recruited (n = 29, 48%) were deemed to not to have the capacity to consent themselves therefore it may be inferred that they had some degree of cognitive impairment. Further, the majority of participants had more than one comorbidity (n = 30, 61%).

With regards to physical function, over half of participants (n = 35, 57%) were judged to be 'dependent' based on their BI score. Still, based on the FAC, a considerable proportion of participants (n = 32, 64%) were categorised as being ambulatory independent on level surfaces, with some being independent on non-level surfaces.

Table 7.8 Participant characteristics (n = 61). Number of participants (n) is not equal to the total number of residents recruited due to missing data.

	n	N (%) or Mean ± SD
Gender (male)	61	22 (36%)
Age (y)	50	84 ± 8
Age group	50	
< 85 y		21 (42%)
≥ 85 y		29 (58%)
Height (cm)	47	162.1 ± 10.8
Weight (kg)	50	64.1 ± 15.7
Capacity to consent (yes)	61	32 (53%)
Number of comorbidities*:	49	
None		1 (2%)
1 - 2		33 (67%)
≥ 3		15 (31%)

*based on the CCI

Table 7.9 Scores of physical function and mobility assessments (n = 61).

	N (%) or Mean ± SD
BI score (score on a 21-point scale; 0-20)	11 ± 5
BI score ≤ 11 (dependent)	35 (57%)
BI score > 11 (independent)	26 (43%)
FAC*	
Level 0 (non-functional ambulation)	7 (14%)
Level 1 (ambulatory-dependent for physical assistance, level II)	5 (10%)
Level 2 (ambulatory-dependent for physical assistance, level I)	5 (10%)
Level 3 (ambulatory-dependent for supervision)	1 (2%)
Level 4 (ambulatory-independent on level surfaces)	21 (42%)
Level 5 (ambulatory-independent)	11 (22%)

*Data only available for 50 participants

Accelerometer wear

Across the four care homes, 50 (82%) of the 61 recruited residents agreed to wear a hip-worn accelerometer (Figure 7.7). An accelerometer was not administered to the other eleven participants for the following reasons: resident was ill during data collection (n = 1); consultee deemed it inappropriate (n = 3) and resident wore a wrist accelerometer (n = 7). There were no differences in the personal characteristics of those residents to whom a hip-worn accelerometer was administered (n = 50) and those who did not receive one (n = 11) ($p > 0.05$).

Of the 50 accelerometers administered, 47 (94%) were collected; however, three were never recovered. All three of the accelerometers lost were worn by residents who were judged to lack capacity to consent and subsequently entered into the study on the advice of a NC.

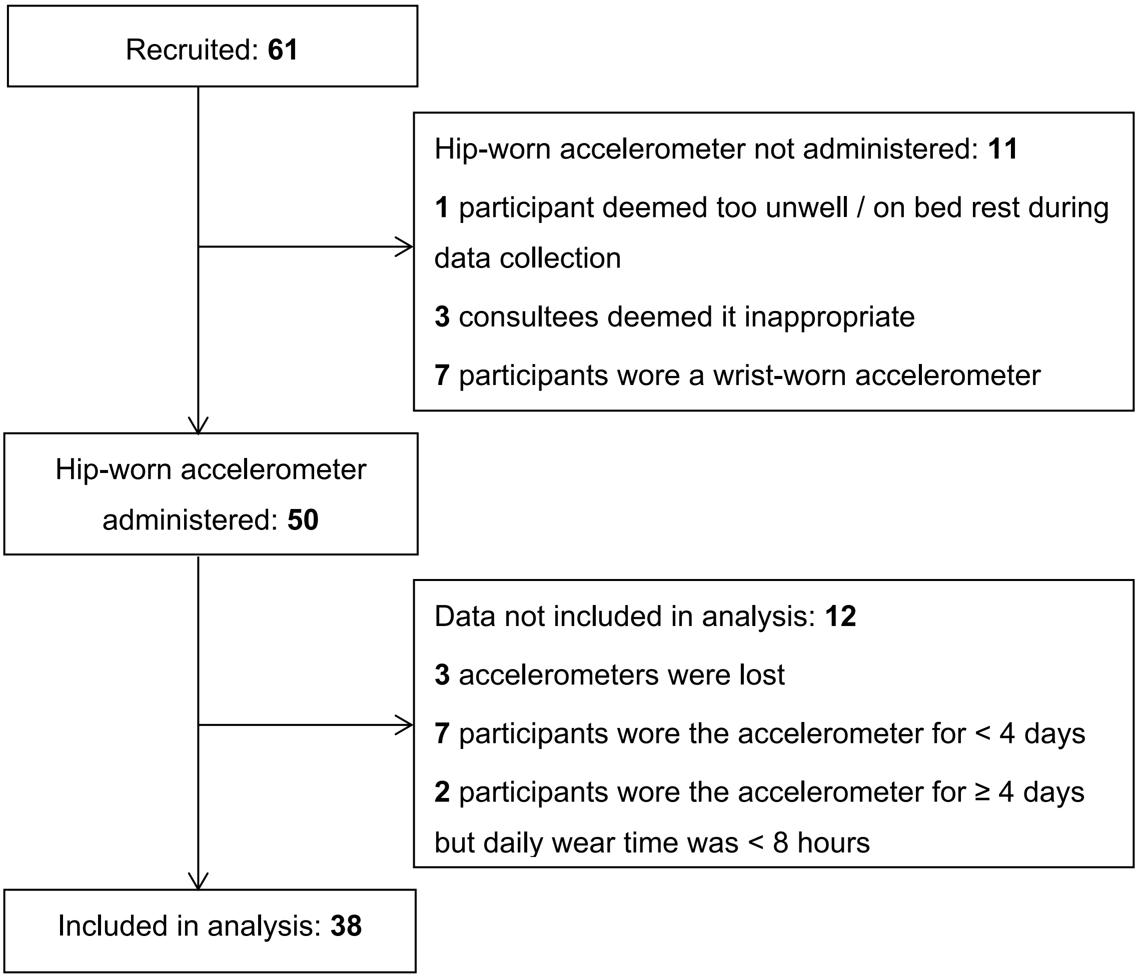


Figure 7.7 Consort diagram demonstrating the flow of recruited participants in Pilot Study 2 to those meeting the accelerometer wear time requirements to be included in analysis.

Data was successfully downloaded from all of the accelerometers collected (n = 47). A review of this data revealed that 81% (n = 38) of participants met the criteria for valid wear time (Figure 7.7), with 48% (n = 24) providing seven valid days of data (Table 7.10). With regards to those who did not meet the valid wear time criteria: one participant provided three valid days; two provided two valid days; one provided one valid day and the remaining five participants did not provide any valid days of data (Table 7.10). No differences in the personal characteristics (based on the items measured) or the physical function and mobility assessment scores of those participants who met the criteria for valid accelerometer data (n = 38) and those who did not (n = 12) were observed ($p > 0.05$).

Table 7.10 Number of valid days of accelerometer wear among participants to whom an accelerometer was administered to in *Pilot Study 2*.

Number of valid days (defined as ≥ 8 hours)	N (%) of participants
Monitor lost	3 (6%)
0	5 (10%)
1	1 (2%)
2	2 (4%)
3	1 (2%)
4	6 (12%)
5	3 (6%)
6	5 (10%)
7	24 (48%)

Activity log completion

Although three accelerometers were never returned, two of the three associated activity logs were. Thus, a total 49 (98%) of the activity logs administered were collected. Still, log completion was inconsistent. The number of log entries per log ranged from 1 to 24 (median [IQR] = 9 [11]). It is also worth noting that 39% of days had no log entry at all (i.e. no on or off time). Furthermore, only two activity logs (4%) were completed in their entirety. A closer inspection of the activity logs revealed that entries were predominately made by care home staff (57%) or a member of the research team (24%) rather than participants themselves (19%) (Table 7.11).

Accelerometers were “with” participants for an average of 10 days (IQR = 0, range: 3 - 12 days); yet the number of days the accelerometer was worn (as indicated by a single daily log entry) was lower (median [IQR] = 6 [6]; range: 1-11). What is more, the documented times the accelerometer was put on and taken off suggest the number of valid days of data obtained (defined as ≥ 8 hours) was lower again and varied considerable across participants (median [IQR] = 2 [5], range: 0 - 11).

Table 7.11 Details regarding activity log completion in *Pilot Study 2* (n = 50).

Percentage (%) of total log entries made by:	
Participant	19%
Care home staff	57%
Researcher	24%

7.4.4.2 Qualitative findings

As was the case in ***Pilot Study 1***, a considerable amount of qualitative data was collected over the course of this study. Similar factors and social processes were identified as being important in determining how the accelerometer data collection protocol was implemented in practice.

In order to avoid repetition, the focus of the following discussion is on those factors and social processes deemed to be most important and findings which were novel. These included:

- the organisation, management and delivery of care;
- awareness and understanding of the research project;
- engagement with the study;
- perception of the role of the care assistant;
- resident profile

Organisation, management and delivery of care

Much like ***Pilot Study 1***, whilst the care routine in each of the care homes was structured around regenerative work, differences in how care was delivered in each of the homes were observed. In three of the four care homes, how the care home was 'presented' to others seemed to be very important, therefore the ethos of care was predominantly paternalistic in nature. Although there were discussions of resident choice and promoting independence in all of these homes, there was little evidence that residents were enabled to make decisions and / or encouraged to be independent in practice. The emphasis appeared to be on 'caring for' residents which often resulted in 'doing-for' residents. The practice of 'doing for' residents also appeared to be the 'norm' at Care Home 7. However, in this home, the practice of 'doing-for' appeared to be a direct result of the emphasis placed on procedures and documentation rather than an effort to portray the home in a certain way.

Interestingly, it became apparent over the course of the observations that the wider organisational context exerted considerable influence over the day-to-day running of all of the participating care homes' and by extension, the homes involvement in the study. For example, in Care Home 10 there was a sense that the manager, although 'interested and keen to see how the research' works, had little input in the decision to take part in the research project. The researcher got the feeling that the 'organisation' had 'pushed' the home into participating in the research as they perceived it to be a 'good thing'. Similarly, at Care Home 9 it became apparent that the care home manager had little personal interest in the study but it was loosely aligned with some of the policy initiatives being championed by the wider organisation; hence why she agreed for the care home to take part. It was therefore unsurprising that once the study commenced, it was met with some resistance. There was a general sense across all of the homes that staff were "stretched enough" as it was and that they did not have scope to support the accelerometer data collection. Indeed, one of the few residents in Care Home 7 deemed to have strong cognitive abilities expressed her reluctance to ask for assistance with putting her accelerometer on. She remarked that the "girls" (care staff) are 'pushed' and have no time to do anything.

It was notable that in all of the participating homes, a task-focused approach to the delivery of care was adopted by a significant proportion of care staff, irrespective of the philosophy of care promoted by the wider organisation and / or the care home manager. In Care Homes 7 and 10 in particular, depleted staffing levels was a significant factor in the adoption of this approach. Further, in all of the homes, the importance attributed to maintaining the care home routine and ensuring relevant paperwork was completed meant staff were under a time pressure to get 'tasks' done (e.g. ensuring everyone was seated at the dining table for lunch by a given time).

It became clear over the course of the observations that upholding an ethos of encouraging independence under circumstances such as those described was extremely difficult. Indeed, an almost "fire-fighting" approach to delivering care was evident at times:

> *I got the sense that the care home was barely functioning today. Amy and the two other carers (Cedric and Laura) were the only staff visible. Cedric sat in the lounge writing up notes. He was asked by Laura to help get one of the residents up. He told her that he needed a few more minutes to*

> *complete the notes. I asked him how he was. "This is supposed to be my day off! But I got called in yesterday. You can get called in at any time. Last week I worked 50 hours".*
>
> *(Extract, researcher field-notes, Care Home 7)*

Thus, it was unsurprising that care staff were not always proactive in terms of supporting the accelerometer data collection. It was not uncommon for the researcher to visit the care home and to find that residents were not wearing their accelerometers and / or the activity logs had not been completed. Nevertheless, in three of the four care homes, staff were, in the main, very accommodating when the researcher visited. For example, when asked by the researcher, staff were generally happy to support residents with putting on their accelerometers and / or looking for missing activity logs.

Awareness and understanding of the project

During initial meetings to discuss participation in the REACH study, most of the care home managers conveyed the general belief that PA and keeping active was positive for residents in that it would promote well-being and facilitate social engagement. Hence, their interest in taking part in the study. Nevertheless, once the study commenced, they delegated all responsibility for it to other staff. Not all of the homes had an activities coordinator in post but in those that did, the responsibility for the accelerometer data collection was often delegated to them. This suggests that, whilst managers could see the benefit of encouraging residents to engage in more PA they struggled with the concept that routine activities such as getting dressed constituted PA and were instead focused on increasing organised activity. This had implications in terms of how the accelerometer data collection was perceived by care staff and ultimately how the data collection protocol was implemented in practice.

Engagement with the study

One of the main factors influencing accelerometer wear compliance in the current study was the fluctuation in residents' willingness to wear the accelerometers across and even within single days. Accordingly, when communicating with residents, an awareness of, and sensitivity to, observational cues and an individual's expressed emotion was crucial in encouraging wear. The following extracts, taken from the same day of the researcher's field-notes, highlights this:

I knocked on June's door, she came to it. I asked her how she was feeling today and she remarked, "fed-up". She (June) did not appear to be her usual 'chirpy' self. I tentatively asked if she would help me out and put her monitor (accelerometer) on. She apologised and said she didn't want to. I told her this was fine and hoped she felt better soon.

(Extract, researcher field-notes, Care Home 8)

I saw June sat of the bench by the entrance to the floor. I went and sat by her. We chatted for a while; she appeared to be in better spirits than earlier that morning. She (June) enquired about what I was doing so I mentioned the accelerometers. It was evident June did not remember our earlier exchange. I asked if she would mind helping me to which she replied "Not at all, it's nice to do something." I put June's accelerometer on her.

(Extract, researcher field-notes, Care Home 8)

As the above example demonstrates, though it is ultimately the decision of the resident as to whether they wear the accelerometer, it is important to recognise that much onus is on care home staff to encourage residents to wear the accelerometer and also offer support where necessary, in order to ensure high-quality PA data is collected.

There was, however, considerable variability in terms of staff engagement in the study which had implications in terms of the amount of encouragement and support offered to residents with regards to accelerometer wear. Some staff used their familiarity and rapport with residents to encourage them to wear their accelerometer whereas other did not. This inconsistency amongst staff may be attributable, at least in part, to staff knowledge of the research and in turn the value they attached to it. For example, in Care Home 9 it became evident that the manager, despite her initial enthusiasm, distanced herself from the study and had delegated all responsibility for it to her deputy manager and the activities co-ordinator. However, it became clear that neither the deputy manager nor the activities co-ordinator had the legitimacy to secure the engagement of the wider staff group and ultimately "steer" data collection.

Perception of staff roles

If the care home manager was agreeable, an effort was made to attend staff meetings in all of the homes. During these meetings staff were provided with a brief overview of the study as a whole (including background to the study and progress to date) and information on what the care homes involvement in the study would mean for them. Specifically, the accelerometer data collection protocols were explained and the importance of staff support with this (e.g. assisting residents to put their accelerometer on in a morning and / or take off before bed and complete the activity log) was emphasised. However, it became apparent over time that the research project, and in particular, supporting the accelerometer data collection was not deemed to be the responsibility of any particular group of staff. For that reason, the perceived role of the care assistant and activities co-ordinator (if in post) appeared pivotal in shaping how staff engaged with and supported the research project.

Conversations with care staff confirmed that they viewed their role primarily in terms of providing care and that they deemed the organisation of social and leisure activities to be the responsibility of an activities co-ordinator. Thus, the fact that assisting with data collection was not ‘usual’ care work meant that many care staff did not perceive it to be part of their job. Still, by the same token, assisting residents to put on the accelerometer was not really a social or leisure activity either. This proved to be a significant challenge in terms of the accelerometer data collection.

It was particularly evident in Care Home 9 and Care Home 10 that ‘care’ and ‘activities’ were perceived as separate, distinct entities and this was mirrored in how they were delivered. In general, across both of these homes, low priority was afforded to activities and the responsibility for delivering them fell solely on the activities co-ordinator. Thus, the fact that the managers in both of these homes had delegated responsibility for the accelerometer data collection to the activities co-ordinator meant care staff were reluctant to help with this. This was problematic given the activities co-ordinators’ shift patterns and “access” to residents meant that, compared to care staff, they had relatively little contact with residents. Consequently, supporting accelerometer wear in a meaningful way (for example administering an accelerometer while assisting a resident to get dressed on a morning or completing the activity log when the accelerometer was put on and / or taken off) was difficult for them.

Resident profile

Based on the observational data, there was considerable variation in the physical and cognitive capabilities of residents within all of the participating homes. In terms of residents’ physical capabilities there was a broad range, with some residents being able to ambulate independently whilst others were unable to ambulate at all and required a hoist to transfer from chair to bed for example. Similarly, residents’ cognitive abilities varied. Although some residents were very cognitively able; it was evident that others were in the later stages of dementia with some struggling to speak and / or make themselves understood. Notwithstanding this variation, many of the residents were physically weak and experienced some degree of cognitive impairment which impacted their memory. Consequently, much of the onus for ensuring compliance was on care staff, rather than residents themselves.

Interestingly, in Care Home 8 where residents' accommodation was spread across three floors, compliance with data collection was better on the floor where the clinical demand was perceived to be greater. It may be surmised that the superior staff-resident ratio, seemingly better communication between staff and the fact staff were more accustomed to providing residents with a high level of support meant that staff were able to adapt / "deal" with the additional task of assisting with data collection.

Care home staff were, understandably, protective of residents. This, coupled with a lack of appreciation of the importance of accurately measuring PA behaviour in this population, meant some residents were not actively encouraged or, in some cases, given the opportunity to participate. For example, in Care Home 10, none of the 11 eligible residents deemed to lack capacity were recruited to the study as NC agreement was not attained.

7.4.4.3 Summary of the key challenges to the collection of high-quality accelerometer data and refinements made to the data collection protocol

Challenge: Lack of shared responsibility for data collection

Reflection: The delegation of responsibility for the study to the activities coordinator suggests that, despite the efforts of the researcher to explain that any movement constituted PA, care home managers perceived PA in terms of organised activities such as exercise classes. This had implications in terms of how accelerometer data collection was perceived by care staff and ultimately how the data collection protocol was implemented in practice.

Refinements:

- When discussing the research project the terminology will be changed to emphasise 'movement'. It is hoped this subtle change in language will help foster a shared responsibility of data collection amongst the wider staff group.
- Members of the research team will strive to speak to as many care staff as possible and highlight the importance of their role in the accelerometer data collection.
- Wherever possible a member of care staff, rather than the activities co-ordinator (if in post) will be identified as the 'accelerometer lead' within the care home.

Challenge: Ensuring continuance of accelerometer wear

Reflection: The need for more support from the research team than was originally proposed was acknowledged in this study and a member from the research team visited or telephoned each of the care homes periodically over the measurement period. This regular contact from the researcher appeared to be important to ensure compliance. However, these visits were predominantly done on an 'ad hoc basis', as the frequency was based on perceived need. There is a need to be mindful of what is replicable in a larger RCT and also of the burden on both care homes and the researcher. It was felt that a more systematic approach to the provision of this support would be needed for a larger trial.

Refinements:

- Implement a structured prompting schedule. Specifically, a researcher would make a visit or telephone call to the care home two to three times over the measurement period. Flexibility would be afforded over when these prompts were made with the exception that all homes would receive a prompt on day two of the measurement period.

- Provide the research lead with a list of residents wearing the accelerometers and request this is displayed prominently in the care home.
- Provide care home staff with an “activity monitor how-to-guide” (which includes contact details for the research team).

Challenge: Ensuring participants meet the minimum daily wear criteria to be included in analysis.

Reflection: Many participants required support to put their accelerometer on and take it off. Hence, once they wearing their monitor it was uncommon for participants to remove them again before getting ready for bed. Having said this, some residents when to bed early therefore there were instances of residents not meeting the valid daily wear time criteria despite not taking the accelerometer off.

Refinements:

- Wherever possible accelerometers will be administered to all participants within each of the care homes between 09:00 and 11:00.
- All prompts (visits or phone calls) provided by the research team will also made between 09:00 and 11:00 to ensure that if participants are prompted to wear their accelerometer the chance of them having sufficient wear time that day will be increased.

Challenge: Notwithstanding the refinements made following ***Pilot Study 1***, completion of activity logs remained poor.

Reflection: Although the total number of log entries was similar in both pilot studies, the proportion of entries made by care home staff was considerably higher in ***Pilot Study 2*** (57%) compared to ***Pilot Study 1*** (31%).

This suggests that refinements made to the data collection protocol following ***Pilot Study 1*** did have a positive effect and that care home staff were more engaged with the research project in ***Pilot Study 2***. However, it was hoped further refinements would improve the completion of the logs further

Refinements:

Amendments were made to the activity log in an attempt to make it less burdensome to complete and ensure information regarding the time a participant's accelerometer was put on and taken off each day were collected. Specifically, an A3 activity monitor poster was created (**Appendix N**). This was printed in colour and displayed in a prominent position in participants' rooms (typically either on the back of the door or on a wardrobe door).

7.5 Chapter summary

The purpose of the current chapter was to explore the practical issues associated with using accelerometers in field-based research with older care home residents and ultimately, develop an accelerometer data collection protocol which is context-sensitive and appropriate to the population. In order to do this, a phased, iterative approach was adopted.

In the current study, **Phase 1** (also referred to as the conceptualisation phase), focused on the development of a provisional data collection protocol. Whilst the key components of the initial accelerometer data collection protocol were informed by published literature, few peer-review articles describe the accelerometer data collection protocols employed in sufficient detail to facilitate replication. Thus, previous experiences of using accelerometers in field-based research and the views of colleagues within the AUECR who had previous experience of collecting outcome data in older care home residents were also drawn upon.

Having developed a provisional data collection protocol, the focus of **Phase 2** (also referred to as the optimisation phase) was on testing the protocol in “real life” and refining it where appropriate. In order to do this, two pilot studies (***Pilot Study 1*** and ***Pilot Study 2***) were conducted sequentially with a period of reflection following each. These periods of reflection were key as they provided an opportunity to consider the extensive amount of data (both quantitative and qualitative) collected in each of the studies and ensured any refinements to the protocol were made based on evidence of what worked and what did not.

The integration of the quantitative and qualitative findings was central to the refinement of the protocol. Whilst the quantitative data investigated the efficacy of the protocol in terms of the number of residents wearing the accelerometers and providing valid data; the qualitative work conducted provided insight into the context within which the accelerometer data collection took place. It was only in considering these findings together that a more nuanced and comprehensive understanding of the feasibility and acceptability of the accelerometer data collection protocol was achieved. It may be surmised that without this understanding it would not of been possible to optimise the data collection protocol.

7.6 Conclusions and future work

In conclusion, the current chapter contributes much to the field of PA and sedentary behaviour measurement as peer-review articles rarely describe the data collection protocols employed in sufficient detail to facilitate replication in other studies. Moreover, the current study is significant as it is the first to utilise published frameworks (typically used to guide the development of health interventions) to guide the systematic development of an optimised accelerometer data collection protocol. This contribution is timely given the increased interest in using accelerometer to measure PA and sedentary behaviour in older care home residents.

Having developed and further refined a data collection protocol through the conceptualisation and optimisation work presented, the next step is to evaluate this protocol in a larger, independent sample of care home residents. Accordingly, the next chapter will evaluate the refined data collection protocol within the context of cRCT.

Chapter 8 Evaluation of a protocol to collect accelerometer data within the context of a feasibility cluster randomised control trial

8.1 Chapter overview

As stated previously (**Chapter 7**) a phased, iterative approach was adopted in order to develop a tailored accelerometer data collection protocol for use in field-based research with care home residents. An overview of this approach, which consists of three phases, is provided in the previous chapter, **section 7.2**. The previous chapter (**Chapter 7**) also reported on the first two phases of work conducted. Thus, the focus of this chapter is on Phase 3 (Figure 8.1). Specifically, the chapter will provide a comprehensive description of the evaluation of the accelerometer data collection protocol, developed and refined in the previous chapter, within the context of a cRCT.

Phase 1: Conceptualisation	Phase 2: Optimisation	Phase 3: Evaluation
First iteration of the data collection protocols based on a review of published literature and previous experience.	Cyclical process of testing and refinement of the data collection protocols through two pilot studies.	Testing of the refined data collection protocols in a cRCT.

Figure 8.1 Overview of the phases of work conducted in the development of the accelerometer data collection procedures.

8.2 Context: the REACH feasibility cluster randomised control trial

The ultimate aim of the REACH programme was to work with care home staff and residents to develop and preliminary test strategies to increase the time residents spend engaging in PA with the ultimate intention of improving their physical, psychological and social well-being (**Chapter 1, section 1.5.1**). The programme was delivered through five WSs (previously described). The focus here is on the fifth and final WS, the REACH feasibility cRCT with embedded process evaluation, designed to explore the practicality and acceptability of implementing a large scale cRCT comparing the REACH intervention (MoveMore) plus usual care to usual care alone in UK care homes (Forster et al., 2017).

Intervention and implementation process

MoveMore is a complex, whole home intervention and implementation process designed to assist care home staff to make changes in their approach to working with residents such that they encourage and support the movement of residents (i.e. increase PA) (Forster et al., 2017). The intervention focuses on change in four domains of daily routines that embrace:

- independent / supervised movement to get about;
- introducing movement into organised social and leisure activities;
- providing opportunities for residents to engage in ‘meaningful’ activities;
- encouraging them to do as much of their own self-care and instrumental activities of daily living as possible (Forster et al., 2017).

The implementation process itself comprised a cyclical process of change, guidance and tools for care home staff to:

- review current practice (observation);
- identify goals and action plans to effect change (reflection and action planning);
- act (pursue action plans) and
- review progress (evaluate what has been achieved) (Forster et al., 2017).

Whilst the aim was that care home staff would lead the implementation of the intervention, support and guidance was provided by the research team. An intervention manual which included observation tools, action plans, review sheets and an ideas bank of resources was provided. Staff were also required to attend three interactive workshops. The purpose of the workshops were to provide both understanding of the change process and to facilitate practice of the tools employed (Forster et al., 2017).

Randomisation and blinding

Care homes were randomised on a 1:1 basis to either MoveMore plus usual care or to usual care alone following the completion of baseline data collection. Stratified randomisation was used to ensure the two arms were balanced in terms of size of the care home and whether or not an activity co-ordinator was in post as these characteristics were expected to be correlated with intervention implementation and outcome evaluation (Forster et al., 2017). Researchers involved in data collection were not informed of care home allocation and a concerted effort was made to ensure they remained 'blind' throughout the trial. Care homes were asked not to disclose their allocation to these researchers and when in the office, 'blinded' and 'unblinded' researchers were based in separate offices (Forster et al., 2017).

Trial data collection

As stated above, MoveMore is a whole-home intervention; hence, the intention was that it would become embedded within those care homes randomised to receive it. In order to assess the impact of the intervention on the 'whole home', data were collected at the level of the care home (including staff), as well as from individual participants at four time-points: baseline (prior to randomisation), three, six and nine months post-randomisation (Forster et al., 2017). A summary of the data collected at each time-point is provided in **Appendix O**.

Given the ultimate aim of MoveMore was to encourage and support residents to engage in more PA, accelerometers were identified as a potential primary outcome measure for a full trial (and a focus of progression criteria). Thus, the detailed accelerometer data collection protocol developed in the previous chapter was followed in an effort to ensure the collection of high quality data. Participants were approached to wear an accelerometer once an attempt had been made to complete all other assessments with all of the participants in a given home. Data collection was completed in this order to ensure accelerometer wear did not influence completion of the other outcome assessments (Forster et al., 2017).

Process evaluation

A detailed overview of the process evaluation conducted alongside the REACH cRCT is provided in Forster et al (2017). Briefly, the purpose of the embedded process evaluation was to collect data on:

- the 'how' of the intervention and implementation process (the 'theory of change' or assumptions underpinning the programme);
- the process and content of MoveMore implementation as it evolved over time (Century et al., 2012);
- how implementation impacted on, and was shaped by, the organisational and interactional environment of the care home (Hawe et al., 2009).

Thus, a multiple-method, comparative case study design was adopted. A dedicated process evaluation researcher collected data across all 12 trial homes. Analysis was based on the principles of grounded theory (Charmaz, 2014).

8.3 Methods

8.3.1 Setting and participants

A full description of care home and participant recruitment procedures, including details regarding screening and the process of obtaining consent is provided in **Chapter 5, section 5.2**. All care homes were screened and recruited by a researcher based within the AUECR. The care homes recruited varied in terms of size, setting and ownership (Table 8.1).

As was the case in **Chapter 7**, following care home agreement to participate, all residents were screened and recruited by researchers from the AUECR with experience of working with older people. An assessment of the mental capacity of all eligible residents was undertaken prior to taking consent and for those eligible residents deemed to lack capacity, PC or NC agreement was sought.

Table 8.1 Characteristics of the participating care homes (n = 12)

Care home	Number of beds*	Location	Local authority	Ownership	Care provision*
50084	12	Suburban	Bradford	Local authority	Residential; dementia;
50085	29	Semi-rural	Bradford	Independent	Residential
50086	16	Suburban	Bradford	Independent	Residential
50090	44	Suburban	Calderdale	Not-for-profit	Residential
50091	21	Urban	Wakefield	Independent	Residential
50092	35	Suburban	Calderdale	Chain	Residential; nursing
50095	35	Urban	Calderdale	Chain	Residential; dementia
50097	30	Suburban	Leeds	Independent	Residential
50098	18	Rural	North Yorkshire	Chain	Residential; dementia
50099	28	Semi-rural	North Yorkshire	Not-for-profit	Residential
50100	18	Semi-rural	North Yorkshire	Independent	Residential
10716	40	Suburban	Leeds	Not-for-profit	Residential

* in the unit involved if whole care home not recruited

8.3.2 Data collection

Data for this chapter were collected in the context of the REACH cRCT (**Chapter 1, section 1.5.1**). As stated above, the collection of objective PA data using accelerometers was one of a battery of assessments completed. Both participants themselves and an appropriate member of care home staff were asked to complete a range of outcome measures (**Appendix P)**. However, only the data collection related to the evaluation of the accelerometer data collection procedures is detailed here.

Quantitative data

A full description of the quantitative data collected is provided in the previous chapter (**Chapter 7, section 7.4.2.2**). Briefly, data surrounding resident recruitment; accelerometer wear; activity log completion; and contact from the research team were collected.

Qualitative data

As was the case in the previous chapter, the predominant data collection method employed in this study was quantitative. However, in order to gain further insight into the acceptability of the proposed data collection procedures different sources and types of qualitative data were again drawn upon including: ethnographic observations; informal conversations; and formal qualitative interviews.

A full description of the methods employed and data collected via ethnographic observations and informal conversations is provided in the previous chapter therefore will not be replicated here (**Chapter 7, section 7.4.2.2**). Observations undertaken during the optimisation work discussed in the **previous chapter** identified several preliminary hypotheses therefore these were used to guide the observations in the current study. In addition, as the informal conversations between researchers and key stakeholders (i.e. residents and care home staff) had proved to be particularly informative in the optimisation work (**Chapter 7**), all researchers involved with trial data collection were asked to write these up as part of field notes.

In the current study, formal audio-recorded interviews were also conducted with at least one senior member of staff in each of the twelve participating care homes. These were completed by the dedicated process evaluation researcher at the end of the trial. Interviews were conducted, where possible, in a quiet private area and adopted an open, flexible style using a topic guide as an aide memoire (Rubin and Rubin, 2012; Mishler, 1986). This allowed the researcher to draw on observations to inform the interviews and ensured they were as inclusive as possible. Over the course of these interviews, interviewees were asked about how they felt data collection had gone and whether there were any aspects of this that had been particularly difficult. These questions were guided by observations undertaken by myself.

8.3.3 Data reduction and analysis

Quantitative data

Treatment of the quantitative data in preparation for statistical analysis is detailed in **Chapter 5, section 5.3**.

A full description of the data reduction and analysis are presented in the previous chapter (**Chapter 7, section 7.4.2.2**). Briefly, descriptive statistics were used to summarise participant recruitment, accelerometer wear and activity log completion. In addition, data collected on participation and accelerometer wear were also summarised by care home.

Qualitative data

As was the case with the quantitative data, details regarding the reduction and analysis of the ethnographic observations and informal conversations are provided in the previous chapter (**section 7.4.2.2**). Formal interviews were fully transcribed and (as was the case with the ethnographic observations and informal conversations) pseudonyms were used throughout and efforts were made to remove any identifiable information.

A pragmatic approach to the analysis of all the qualitative data (ethnographic observations, informal conversations and formal interviews) was adopted, drawing on the principles of thematic analysis (Braun et al., 2016; Green and Thorogood, 2014). The analysis was discussed with colleagues regularly throughout this process to ensure they were relevant to the research question, appeared ‘reasonable’ and were not misrepresenting the data (Braun et al., 2016).

8.4 Results

8.4.1 Quantitative findings

Participant recruitment

Three hundred residents across the twelve care homes were screened for participation. Of these, 278 (93%) were eligible, 159 consented / had consultee agreement (57% of eligible; 53% of those screened) and 153 were registered to take part in the REACH cRCT (55% of eligible; 96% of those consenting / consultee agreement) (Figure 8.2).

Regarding those eligible reisdents who were deemed to have capacity (n = 72, 24% of those screened), 43 (60%) agreed to particpate, 28 (39%) declined and one (1%) asked for a NC to be consulted (the resident did not have a PC). The most common reason given by residents for not wanting to participate was that they did not want to be involved in research (n = 10). Other reasons given are detailed in Table 8.2.

Of the 203 residents without or doubtful mental capacity, 187 (92%) had a potental PC while 16 (8%) did not. One hundred and twenty-six PCs (67% of those approached) agreed to act; however the remaining 61 (33%) either did not agree to act or did not respond to letters requesting their advice. In summary, 73 (58%) of the residents for whom the PC agreed to act were recruited, 52 (41%) were not and the PC of one (1%) resident was uncertain about making the decision. In the case where the PC was unsure, a NC was approached. Over half (60%) of PCs did not provide a reason for objecting to their relative / friends' participation in the study. An overview of the reasons provided for declining agreement are shown in Table 8.2.

A NC was approached to consider the participation of 79 residents (16 residents without a PC; 61 residents with a PC who did not agree to act or did not respond to letters; one resident with mental capacity who asked for the NC to be consulted; and one resident whose PC was uncertain over whether the resident should be recruited). The NC approached agreed to act for 76 (96%) of these 79 residents. Of these 76 residents, NC agreement was attained for 43 (57%) residents to take part in the trial; 32 (42%) declined and the remaining resident (1%) was no longer eligible for the trial. The reasons provided by the NC for declining agreement are shown in Table 8.2.

Table 8.2 Reasons for non-consent, PC assent and NC assent.

Reason	Resident	PC	NC
	N (%)		
Ill health / not well enough (including because of dementia, poor eyesight, hearing)	3 (11%)	14 (27%)	2 (6%)
Did not want to take part / would have been unwilling to take part	10 (36%)	2 (4%)	4 (13%)
Too much going on already	4 (14%)	0 (0%)	0 (0%)
Feeling too upset / would cause distress	1 (4%)	1 (2%)	2 (6%)
Unsuited to study	0 (0%)	0 (0%)	4 (13%)
Does not want to be bothered, wants to be left alone	2 (7%)	1 (2%)	0 (0%)
Project a waste of time	1 (4%)	0 (0%)	1 (3%)
Not appropriate	0 (0%)	3 (6%)	0 (0%)
Worried would do something wrong / wouldn’t be able to comply	1 (4%)	0 (0%)	1 (3%)
Problems wearing accelerometer belt	0 (0%)	0 (0%)	2 (6%)
Family object to this sort of thing	0 (0%)	0 (0%	1 (3%)
Dislike of authority (previous medical history)	0 (0%)	0 (0%)	1 (3%)
Did not want to take part and does not see the point (active already)	1 (4%)	0 (0%)	0 (0%)
Too much going on already and ill health	1 (4%)	0 (0%)	0 (0%)
No reason given	4 (14%)	31 (60%)	14 (44%)

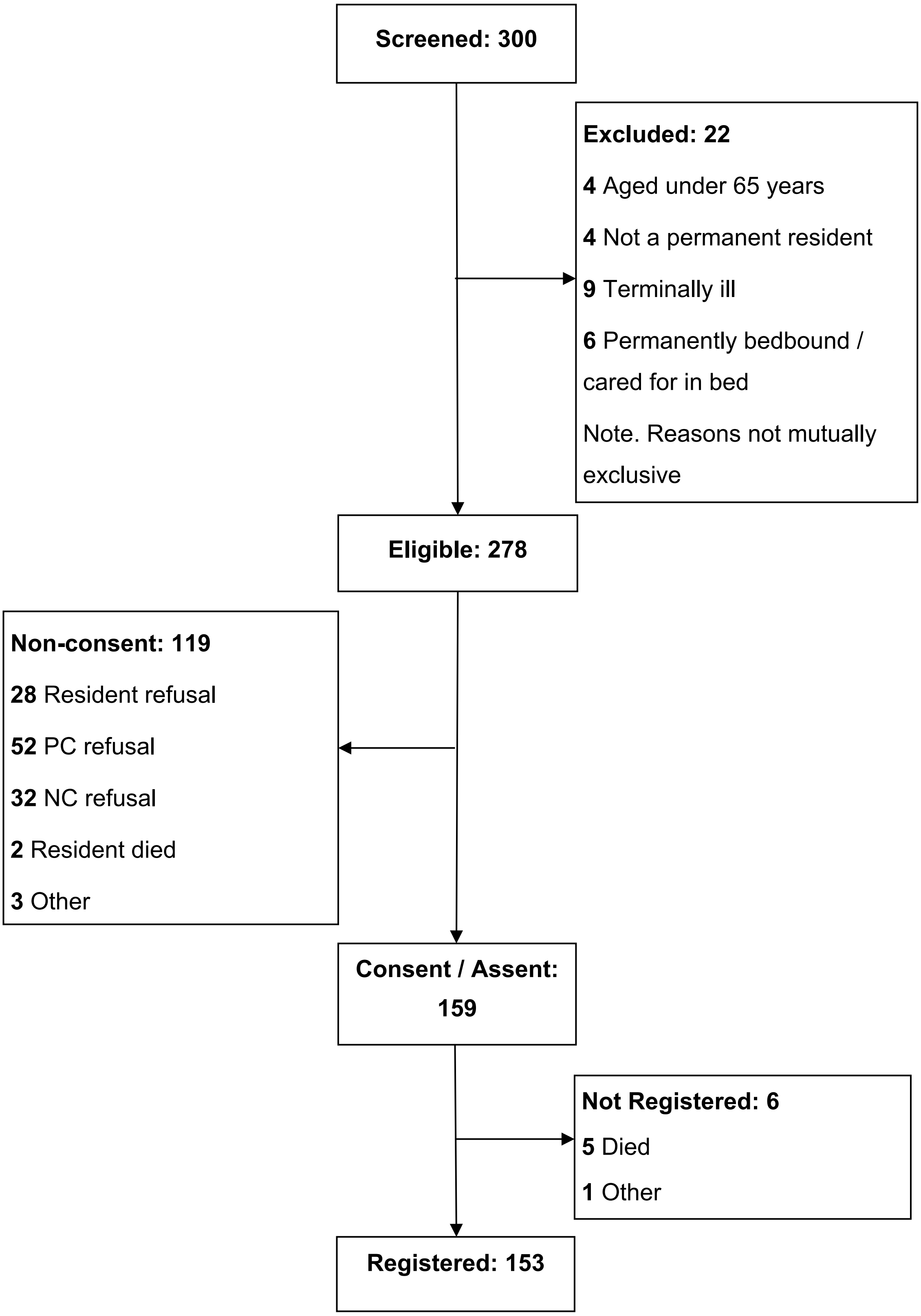


Figure 8.2 Consort diagram demonstrating the recruitment of participants between October 2015 and August 2016 across 12 care homes participating in the study.

Participant characteristics

To provide context, the personal characteristics and physical function and mobility assessment scores of participants (n = 153) are provided in Table 8.3 and Table 8.4. Participants had resided in a care home for an average of 1 year 5 months (IQR = 2 years 11 months); however, there was a wide range in length of residence (< 1 month – 17 years). A large proportion of the participants were female and over half of the participants were aged over 85 years. Almost three quarters (73%) of participants were deemed not to have the capacity to consent themselves. It may be inferred therefore, that they have some form of cognitive impairment. Almost all (n = 136, 90%) of the participants had at least one co-morbidity. Having said this, a number of participants were judged to be physically able with 48% (n = 74) considered independent in ADLs based on their BI score and 52% (n = 79) of participants being able to ambulate independently on level surfaces (i.e. FAC level of 4 or 5).

Table 8.3 Participant characteristics (n = 153). Number of participants (n) is not equal to the total number of residents recruited due to missing data.

	n	N (%) or Mean ± SD
Gender (male)	153	31 (20%)
Age (y)	153	86 ± 7
Age group		
< 85 y		59 (39%)
≥ 85 y		94 (61%)
Height (cm)	135	159.9 ± 10.4
Weight (kg)	147	64.5 ± 14.6
Capacity to consent (yes)	153	42 (27%)
Number of comorbidities*:	151	
None		15 (10%)
1 - 2		104 (69%)
≥ 3		32 (21%)

* based on the CCI.

Table 8.4: Scores of physical function and mobility assessments (n = 153).

	N (%) or Mean ± SD
BI score (score on a 21-point scale; 0-20)	11 ± 6
BI score ≤ 11 (dependent)	79 (52%)
BI score > 11 (independent)	74 (48%)
FAC *	
Level 0 (non-functional ambulation)	32 (21%)
Level 1 (ambulatory-dependent for physical assistance, level II)	11 (7%)
Level 2 (ambulatory-dependent for physical assistance, level I)	15 (10%)
Level 3 (ambulatory-dependent for supervision)	15 (10%)
Level 4 (ambulatory-independent on level surfaces)	44 (29%)
Level 5 (ambulatory-independent)	35 (23%)

* Data available for 152 participants

Accelerometer wear

An accelerometer was administered to 145 (95%) of the 153 residents recruited to the trial. Accelerometers were not administered for the following reasons: participant refused to wear (n = 3), participant was in hospital (n = 3) or the participant was deemed too unwell or on bed-rest at the time of data collection (n = 2) (Figure 8.3). There were no differences in the personal characteristics (based on the items measured) or the physical function and mobility assessment scores between those to whom a hip-worn accelerometer was not administered to and those who did receive one ($p > 0.05$). Thus, those participants wearing an accelerometer can be considered a representative sample.

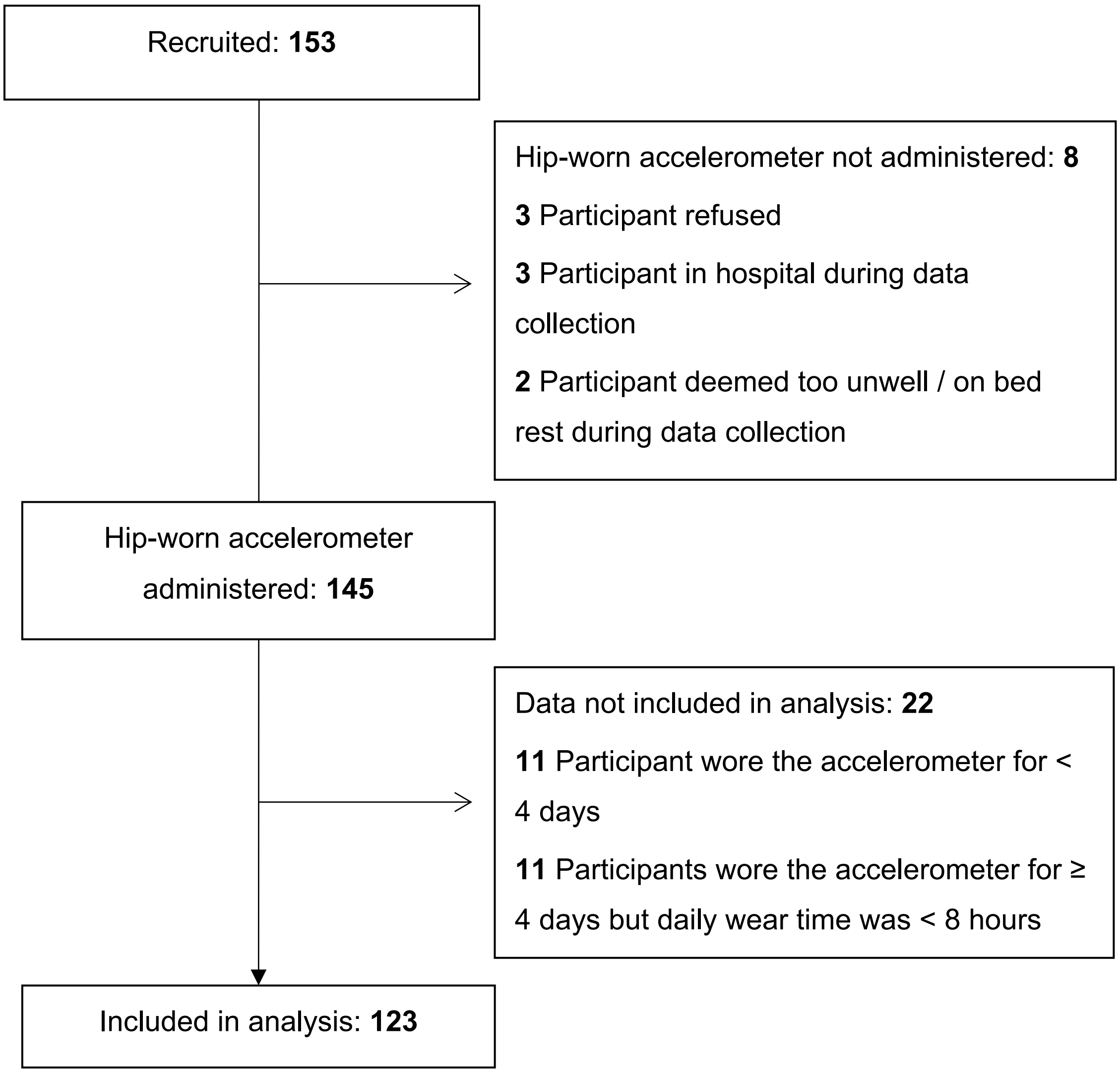


Figure 8.3: Consort diagram demonstrating the flow of recruited participants in to those meeting the accelerometer wear time requirements to be included in analysis

All of the accelerometers administered were collected and data were successfully downloaded. A review of the accelerometer data revealed that overall, 85% (n = 123) of the participants to whom an accelerometer was administered met the criterion for valid wear time (i.e. ≥ 8 hours of data on ≥ 4 days) (Figure 8.3), with 32% (n = 39) of participants providing seven valid days (Table 8.5). Differences in accelerometer wear were observed between the homes with the proportion of participants providing useable data ranging between 50% and100% (Table 8.6). Potential reasons for these differences are discussed below in **section 8.4.2**.

With regards to those who did not meet the valid wear time criteria, eleven participants provided three valid days, six participants provided two valid days, two participants provided one valid day; and three participants did not provide any valid data (Table 8.5).

There were no differences in the personal characteristics (based on the items measured) or the physical function and mobility assessment scores of those participants who met the criteria for valid accelerometer data and those who did not ($p > 0.05$). This suggests those participants providing valid data were representative of the population; therefore any conclusions drawn from the data are likely to be generalisable.

Table 8.5: Number of valid days of accelerometer wear among participants to whom an accelerometer was administered to (n = 145).

Number of valid days (defined as ≥ eight hours)	**N (%) of participants**
0	3 (2%)
1	2 (1%)
2	6 (4%)
3	11 (8%)
4	16 (11%)
5	26 (18%)
6	42 (29%)
7	39 (27%)

Table 8.6: Number (%) of participants at each of the care homes meeting the minimal wear time requirements

	Care Home											
	50084	**50085**	**50086**	**50090**	**50091**	**50092**	**50095**	**50097**	**50098**	**50099**	**50100**	**10716**
N (%) of participants:												
Fitted with an accelerometer	6 (100%)	10 (91%)	8 (100%)	17 (94%)	11 (92%)	15 (100%)	21 (95%)	11 (92%)	5 (86%)	18 (100%)	9 (90%)	14 (93%)
Meeting the minimum wear requirements for valid data*	6 (100%)	6 (55%)	8 (100%)	14 (78%)	11 (92%)	11 (73%)	17 (77%)	7 (58%)	3 (50%)	14 (78%)	8 (80%)	12 (80%)

* Minimum wear is classified as ≥ 8 hours per day on ≥ 4 days of the week (can be non-consecutive days and does not need to include a weekend).

Activity log completion

The majority of the activity monitor posters were collected at the end of the monitoring period and on the whole, these were fairly well completed (median [IQR] number of log entries = 12 [6]). Still, there was considerable variation across participants with the number of entries ranging from 2 to 26. It is also important to note that approximately a third (33%) of monitoring days were without a log entry (i.e. no on or off time).

A review of the activity monitor posters revealed that a considerable proportion of the entries were attributable to a member care home staff (84%) rather than participants themselves (3%) (Table 8.7). This was unsurprising given the high levels of dependency amongst the sample. It is also worth noting that in some of the homes, staff frequently provided contextual information in addition to just stating whether or not the participant was wearing the accelerometer and the time it was put on and / or taken off. Additional information provided included things such as:

> *"taken belt off, time unknown"*
>
> *(comment, activity monitor poster, Care Home 50099)*
>
> and
>
> *"found Marys pedometer in dining room 3:30pm. Refused to keep it on"*
>
> *(comment, activity monitor poster, Care Home 50099)*

Table 8.7: Details regarding activity log completion (n = 145)

Percentage (%) of total log entries made by:	
Participant	3%
Care home staff	84%
Researcher	13%

Contact from research team

Following accelerometer administration all twelve of the care homes were prompted at least twice by a researcher (either in person or vis telephone) over the monitoring period (Table 8.8). As per the protocol, flexibility was afforded over when these prompts were made with the exception that all of the homes received a prompt on day two of the measurement period. For ten of the homes this prompt was delivered in person during researcher visit, while the other two homes were contacted by telephone.

Table 8.8 Summary of researcher contact with each of the care homes over the accelerometer monitoring period

Care Home	Visits (n)	Phone calls (n)
50084	3	0
50085	2	1
50086	2	1
50090	1	2
50091	2	1
50092	2	1
50095	2	2
50097	2	0
50098*	2	1
50099*	2	1
50100*	2	1
10716	2	1

*Visits were undertaken by clinical research network (CRN) staff

8.4.2 Qualitative findings

The ethnographic work undertaken enabled an understanding of how the accelerometer data collection procedures were implemented across the different care homes, within the context of the cRCT. As well as highlighting factors which may have hindered data collection, it also allowed for an understanding of ways in which data collection may be optimised given the characteristics of residents' physical and mental health, as well as the processes by which care is delivered within a care home setting.

Many of the factors and social process identified in **Chapter 7** as being key in determining how the accelerometer data collection protocol was implemented in practice were again recognised as important. The following are discussed in more detail below:

- organisation, management and delivery of care;
- awareness and understanding of the research project;
- staff perception of, and attitude towards the research project;
- engagement with the study;
- perception of staff roles;
- staff knowledge of residents;
- resident profile.

Organisation, management and delivery of care

As discussed in the **previous chapter**, how care is delivered within the organisational routine characteristic of a care home setting (i.e. around regenerative work) is largely dependent on the philosophy of care adopted. In the current study, the philosophy of care in the participating care homes appeared to be shaped by three main factors: the wider political-economy of care; the policies of the organisation (where appropriate) and the managerial team. As a result, there were nuances and differences in the care environment in each of the homes. Having said this, drawing upon the observational and interview data, it appeared the provision of care in all of the homes could be broadly described as being either predominately task- or person-centred in nature.

As the extract below highlights, in those homes where the emphasis was on completing care tasks and documentation in a timely manner, the staff-resident interactions observed were predominately focused on the task (e.g. transferring a resident from an armchair to a wheelchair), with little or no attention on the resident as a person:

I noticed two carers using a hoist. At first I thought that they were putting it away because I could not see from where I was seated the residents who sat in this area, and because the carers were talking over the hoist to each other…However, as the hoist was raised, I saw a female resident sat in it. One carer looked at her (the resident) and remarked 'don't be so grumpy'. The resident's facial expression to me was one of distress. The carers continued to talk amongst themselves whilst they lowered the woman into a chair. They then moved the hoist out of the lounge area…

(Extract from researcher field-notes, Care Home 50092)

It may be surmised that the absence of personally meaningful interaction likely impacted upon residents' emotional well-being which in turn may explain why some residents were less receptive to wearing an accelerometer. In contrast, in those homes where a more person-centred approach to care was adopted, staff were encouraged to engage with residents in a more meaningfully way and were therefore given "permission" to spend time talking with residents. Unsurprisingly, a genuine rapport between staff and residents was observed in many of these homes. Thus, if staff made it known to residents that they were "on-board" with the study and willing to assist them with putting on the accelerometers and completing the activity log, residents appeared to be more amenable to taking part.

Notwithstanding the observed differences observed in terms of the provision of care, it appeared that the existence (or not) of a shared understanding amongst staff of how care should be delivery had a large impact upon the culture within the home, which in turn had implications in terms of how the accelerometer data collection protocol was implemented. For example, in Care Home 50084 all staff appeared to be committed to providing care which was both holistic and meaningful. There was a sense of collaborative working and staff morale was high. This helped to foster a relaxed atmosphere in the home. Indeed both staff and residents appeared comfortable with each other and their surroundings.

In contrast, in Care Home 10716, it became apparent over the course of observations that staff were not united in their approach to care delivery. The care home manager was relatively new in post and there appeared to be some tensions between her and a group of care staff. Staff demeanour suggested morale was low and there appeared to be a general feeling that staff did not feel they had the capacity to do anything over and above what they were already doing. Hence, the fact that the manager's enthusiasm for the study was not mirrored by the wider staff group was not unexpected.

Awareness and understanding of the research project

Efforts were made to promote the research; to be "up front" about the procedures and speak to as many staff as possible in all of the homes prior to the beginning of the study. Nevertheless, shift patterns; absence due to holidays and / or sickness and staff turnover made this difficult. It was requested that written information, provided in the form of information sheets was circulated widely. However, conversations with staff suggested this did not always happen. For example, during her end of study interview, the unit manager at Care Home 50098 explained how at the start of the study the unit manager left and that she was one of three seniors tasked with leading the unit. She went on to say how they did not get very much information from the deputy manager of the home about the study; therefore she was not clear what the purpose of the research was:

> *"… when it started I was just told REACH team were coming in to do some research."*
>
> *(Unit manager, Care Home 50098)*

It was therefore unsurprising that there was limited engagement with the study. Having said this, even in care homes where the manager / research lead had been employed by the care home for a number of years and appeared proactive in terms of 'driving' the research, some staff appeared to know little about the research:

> *I realised when she (staff member) started talking to me that she was confused. I explained who I was and that I was hoping to spend some time that afternoon getting to know the care home and residents – she did not seem to know much about the project and asked me to wait in the office next to the front door whilst she went away to check with the manager*
>
> *(Extract, researcher field-notes, Care Home 10716)*

There were even instances over the course of the observations of staff claiming to be unaware of the REACH project. This suggests communication regarding the project was limited in some of the homes. Moreover, it was noted that, in some of the homes, the posters provided to promote the project and ensure that staff, residents and relatives were aware of the homes involvement in the research were not displayed.

It also became apparent over the course of the observations that, in some cases, there was a lack of understanding about the necessity of wearing accelerometers;

particularly for those residents who were immobile. Some staff appeared frustrated with the task of putting on monitors for some residents:

> *I asked about Alan (a resident) and the staff member tetchily told me that he rarely walked and is transported in a wheelchair. I explained that we were aware of this and that we would still be grateful if staff would help him to wear a monitor and complete the recording sheet.*
>
> *(Extract from researcher field-notes, Care Home 50084)*

Staff perception of, and attitude towards the research project

There was a general feeling amongst care staff that the care home's participation in the research project, and the accelerometer data collection in particular, added to their workload. Whilst some staff were accepting of this, others were resentful as they did not feel they had scope to support the accelerometer data collection within the constraints of the tasks required of them.

It became clear that if staff perceived the research as worthwhile and appreciated the importance of measuring the PA and sedentary behaviour of residents, they were more likely to do what they could to support and encourage accelerometer wear. The quotes below, taken from the end of trial interviews, show how staff adopted different approaches to encourage and facilitate accelerometer wear:

> *"…because Bill had moved on we'd got a spare pedometer (accelerometer), I wore a pedometer (accelerometer) when I was putting them on, to show them look, I've got mine on as well I'm doing it for the National Health Service, and it really made quite a difference, so that, just a visual aid for them, I mean it is again a visual aid, isn't it, really?"*
>
> *(Activities coordinator, Care Home 50099)*

> *"… we've found at one point it was easier to leave them all in the staff room on a night so it reminds them to put them on a morning because sometimes a resident can put them somewhere else as well so they're not easy to find the next morning, so."*
>
> *(Care assistant, Care Home 50100)*

In contrast, if staff did not see the value in conducting the research, they tended to view the study as an inconvenience and were less willing to offer support the activities associated with it, including recruitment and data collection.

Engagement with the study

Whilst it was unsurprising given what has already been discussed (i.e. differences in attitudes towards the research etc.), it is important to acknowledge that there was also considerable variability in terms of care staff engagement in the study which in turn had implications with regards to the amount of encouragement and support offered to residents with regards to accelerometer wear.

The extract below shows how some care assistants were particularly conscientious with regards to supporting the accelerometer data collection:

> *Diane seemed very pleasant and obliging. I followed her into the lounge / dining room. I explained that I had a list of residents who had agreed to wear an activity monitor and that I had come to administer them this morning. I said how I hadn't met any of the residents before so would be grateful if someone could introduce me to them. She asked how long they had to wear the monitors for; how to put them on etc (genuinely seemed interested and wrote it all down on a notepad). I explained that we wanted residents to wear them for 7 days, put them on first thing on a morning and take them off on an evening (staff support necessary), completing the activity log poster (I showed her this). She went and got another carer as she said she typically did night shift so got residents up. I went over things briefly again and demonstrated how the monitor should be worn. We then administered a monitor to Anna whilst they were both stood with me. The second carer asked Diane to make sure everything was written down in the communication log. I explained that I had some info sheets about the monitors which I could leave too. The second carer went to "see to" residents.*
>
> *(Extract, researcher field-notes, Care Home 50091)*

However, there were staff who clearly did not wish to be involved in the research project. Whilst few staff were deliberately obstructive, some (like Julie in the extract below) offered very little support to the researcher:

> *Julie did not appear very enthusiastic about the project (especially in comparison to other staff within the home) and was almost dismissive of us.*

She voiced her opinion that she does not feel the residents will want to wear them (the accelerometers). She provided us with an example of a resident who gets distressed when they provide personal care. I gently reiterated that we have gone through the process of speaking to relatives and that we want to be as inclusive as possible. I explained that we will "check" capacity each time we interact with the residents and that if they do not wish to answer any questions / wear an accelerometer we will respect this. I also explained that we are 'testing' the monitors to see what types of movement they record. Julie (reluctantly) agreed that we could speak to the residents downstairs but was averse to introducing us to residents – she indicated where people were sitting but did not accompany us.

(Extract, research field-notes, Care Home 50095)

As was the case with staff, residents engaged with the accelerometer data collection to different extents. Whilst the majority of participants did not appear to be burdened by wearing the accelerometer and some expressed their willingness to wear it again, there were some who refused to wear their monitor. For example, one participant chose not to wear her accelerometer on two days over the monitoring period as she was going out. This particular participant told researchers she was afraid she would damage the monitor. Other reasons for non-wear included discomfort and a view that "there was no point" in wearing the accelerometer. However, on many occasions participants did not provide an explicit reason for not wanting to wear their accelerometer.

Perception of staff roles

As was the case in **Chapter 7**, the perceived role of the care assistant and activities coordinator (if in post) appeared to be important in shaping how staff engaged with and supported the research project. In general, care assistants seemed reluctant to engage in anything they perceived to be outside of their role:

"… I didn't appreciate how hard it was going to be to do the pedometers, because everybody's focused on their own job, they haven't got the time and they haven't got the inclination to do it because it's not part of their job spec."

(Activities co-ordinator, Care Home 50099)

Across all of the homes, staff perception of their role appeared to be closely aligned with the philosophy of care adopted by the home. For example, in those homes where the emphasis was on procedures, documentation and a task-focused approach to care delivery, care staff were generally better at ensuring residents were wearing their accelerometers and completing the activity monitor posters. However, even in these homes staff spoke about the difficulties of managing their workload and acknowledged that other ‘tasks’ took priority over the supporting the research:

> *“Yeah, and then remembering the time and you know you have got it wrong but you have got to put a time. Because you have been busy and you have had to go and do another job, but remembering the time of taking someone’s belt off sometimes isn’t a priority when you see something else what needs doing.”*
>
> *(Team leader, Care Home 50100)*

In contrast, in those homes where the provision of care was more holistic and enabling, residents were encouraged to do certain things for themselves (e.g. getting dressed) and staff viewed their role as being to support residents where necessary not to ‘do to them’. Thus, if residents did not ask for help with putting their accelerometer on or with completing the activity log then staff, understandably given their workload, were not always proactive in ensuring residents were wearing their accelerometer and checking the activity log was completed.

Staff knowledge of residents

Across all of the participating homes there was a sense that, as a group, staff were genuinely fond of the residents under their care. In general, those interactions observed between residents and staff were friendly, respectful and responsive. Further, in the majority of homes, staff demonstrated meaningful knowledge of residents such that they were not only aware of residents’ care needs but also had an awareness of aspects of residents’ lives prior to admission into the care home; their likes and their dislikes. As was the case in **Chapter 7**, some staff were particularly adept in drawing on this knowledge when met with resistance when attempting to encourage and support residents to wear their accelerometers.

How staff communicated with residents, particularly those in the latter stages of dementia who were largely inert, also appeared to be important when assisting them with putting on the accelerometer. In two of the care homes in particular (one of which was the local authority managed dementia facility), the assignment of staff to a fixed unit / floor within the home meant residents became familiar with staff which in turn seemed to facilitate the development of relationships between staff and residents. It became apparent over the course of the observations that staff had awareness of and were sensitive to individuals' expressed emotion. As a result, residents, who may have been classed as "resistant", were more receptive to putting the accelerometer on:

> *Jack initially declined to wear one (an accelerometer) - he seemed confused and guarded. We (researchers) were at the point of leaving him with the intention of returning later when Lorraine approached and agreed that we needed to stop. At this point, Vaughan (care assistant) offered to help. Vaughan encouraged Jack to go with him to be changed, Jack was obliging. When he (Jack) returned he is wearing the belt.*
>
> *(Extract, researcher field-notes, Care Home 50095)*

Resident profile

Interestingly, whilst many residents had multiple physical co-morbidities, the high levels of dementia amongst residents was perceived to be the biggest challenge to the collection of high-quality PA data by care home staff. As the extract below demonstrates, some staff were open in their scepticism about residents with dementia wearing an accelerometer:

> *Jessica (team leader) immediately expressed negative views of the project; stating that most of the residents have dementia and are unlikely to tolerate wearing the monitors. I explained to her that we have worked in a number of care homes in which people who have dementia live and that many have tolerated wearing the belts well.*
>
> *(Extract, researcher field-notes, Care Home 10716)*

Still, the majority of staff were on-board with the inclusivity of the research and were more accepting of the challenges posed by residents with dementia and pragmatic in terms of addressing these:

> *"A lot of looking around for, you know, the different pedometers (accelerometers) and checking rooms and handbags and finding it in someone else's room and then, so there's been quite a bit of that. But that was again going to be par for the course really."*
>
> *(Deputy manager, Care Home 50099)*

Whilst it was understandably frustrating for staff when residents repeatedly removed their accelerometers themselves and they had to spend time looking for them the majority of staff spoken to recalled these instances with warmth and humour.

"The only issues we had were with the belts for a few of them [laughs], the ones with dementia they kept missing them. <u>They kept what?</u> Losing them. And they're the ones that are quite active you know and they wander about all day, and then… So they could be anywhere. Yeah they took them off and you'd be hunting for them."

(Care home manager, Care Home 50086)

8.5 Discussion

The current chapter evaluated the efficacy of an accelerometer data collection protocol, purposively developed in an effort to ensure the collection of high-quality PA and sedentary behaviour data in a care home population, within the context of the REACH cRCT. The findings (discussed in more detail below), contribute to a cumulative body of knowledge regarding the use of accelerometers in field-based research with older care home residents.

The recruitment rate of eligible residents was 57% (159 / 278), consistent with rates of 32% to 84% quoted in other studies conducted in care home setting (Siddiqi et al., 2016; Underwood et al., 2013). Whilst these figures are pleasing (the acceptability of the accelerometer was likely a key consideration for both residents and consultees approached for the study) what is particularly encouraging within the context of this thesis is that 95% (148 / 153) of participants recruited agreed to wear a hip-worn accelerometer. Moreover it was notable that in the majority of cases where accelerometers were not administered, this was due to reasons outside of the research (e.g. resident was unwell or in hospital at the time of data collection) rather than residents declining to wear the accelerometer. Indeed only, three participants actually declined to wear an accelerometer. This corroborates previous findings that, when given the opportunity, care home residents are willing to be involved in research (Wood et al., 2013; Hall et al., 2009).

Whilst it is encouraging that such a high proportion of participants agreed to wear a hip-worn accelerometer, as discussed previously, it is imperative that participants comply with the data collection protocol and wear the accelerometer for long enough to ensure estimates of PA and sedentary behaviour are reliable (Matthews et al., 2012; Ridgers and Fairclough, 2011). In the current study high rates of compliance (85%) were apparent when assessing whether the pre-determined minimum wear time criteria of ≥ eight hours ≥ four days was met (**Chapter 6, Study 3**). Critically, compared to the two pilot studies conducted in **Chapter 7**, a higher proportion of participants in the current study met the minimum wear time criteria and thus provided valid accelerometer data (Pilot Study 1: 73%, Pilot Study 2: 76% and the current study: 85%). This suggests the refined data collection protocol was effective in maximising accelerometer wear, particularly given the participants in the current study were comparatively frailer than those in both Pilot Study 1 and Pilot Study 2.

It is also worth noting that compliance in the current study compares favourably to recent studies conducted in LTC settings which have employed similar criteria to define valid wear time (Leung et al., 2017; Marmeleira et al., 2017; Corcoran et al., 2016). Having said this, caution is warranted when making direct comparisons between studies as the definition and method of identifying non-wear time varies across studies (**Chapter 3**). The non-wear time criterion used impacts upon wear time estimates and thus, has the potential to effect compliance estimates, even when the criteria for valid wear time is consistent (Hutto et al., 2013; Winkler et al., 2012; Mâsse et al., 2005). For example, Keadle and colleagues found that in their large sample of older women (n = 7,650, mean age: 71 y ± 5 y) estimates of compliance with a minimum wear criteria of ≥ ten hours on ≥ four days were lower when non-wear time was defined as 60 minutes of consecutive zero's with allowance for up to two minutes of non-zeros during this time (Troiano et al., 2008); compared to 90 minutes of consecutive zeros with an interruption of two minutes of activity if the 30 minutes preceding and following this 90-minute period consists of consecutive zeros (Choi et al., 2012).

Despite the overall compliance rate being high (85%), the proportion of participants providing valid data did vary across the twelve participating homes. Similarly, although the activity log completion was (on the whole) better than what was reported in the pilot studies conducted in **Chapter 7**, there was considerable variation across participants. Whilst it was not possible to say with certainty why these differences existed, it may be surmised based on the qualitative data collected, that the disparity between the care homes may be attributable to whether or not 'buy-in' was achieved at both an individual and a collective level. That is, in those homes where compliance rates were highest, key stakeholders (i.e. residents and staff) perceived the research as worthwhile and appreciated the importance of objectively measuring residents PA and sedentary behaviour. Moreover, it was apparent from the outset that there was shared understanding of how the data collection protocol was to be delivered and everyone was clear about their responsibility with regards to this. Conversely, in those homes where compliance was poorer there appeared to be more uncertainty around value of the research project and by extension the need to measure residents PA and sedentary behaviour. In addition, the accelerometer data collection was generally assumed to primarily be the responsibility of a single member staff. Whilst this in of itself was not necessarily a problem, this staff member was often the activities co-ordinator and they rarely had the legitimacy to secure the support from the wider staff group. Moreover, activities co-ordinators' shift patterns and "access" to residents made supporting accelerometer wear (for example administering an accelerometer while assisting a resident to get dressed on a morning or completing the activity log when the accelerometer was put on and / or taken off) was more difficult for them compared to care staff. It may be surmised that it was the lack of shared responsibility which undermined efforts to maximise data compliance as it is not possible for a single person to support accelerometer wear in a meaningful way consistently over the entirety of the monitoring period.

Given the intended flexibility and multicomponent nature of the accelerometer data collection protocol it is perhaps most appropriate to say that it was the combination of the chosen components which led to the data collection protocol being successful. However, on reflecting on both the findings of the current study and those reported in **Chapter 7**, it may be surmised that increasing the amount of support provided by the research team was a key factor contributing to the high compliance rate achieved in the REACH cRCT. This increased support was predominantly provided by means of the structured prompting scheduled implemented. Whilst this method appeared to be effective in the REACH cRCT, it is important to recognise that there are cost (both in terms of resource and time) implications associated with this. This is an important consideration in determining whether the protocol is replicable in larger trials. Still, given there is a degree of flexibility afforded within the prompting schedule in terms of the days on which the prompts are delivered and how the prompts are delivered (by phone or in person), implementing this on a larger scale would be possible.

8.5.1 Strengths and limitations

The current study has several important strengths. Of these, the holistic approach adopted in terms of evaluating the data collection protocol is arguably the most important given the dynamic nature of the care home environment. The integration of different sources of data, both quantitative and qualitative ensured a thorough, nuanced and critical understanding of the feasibility and acceptability of the data collection protocol. This understanding is imperative given the increased interest in using an accelerometer to measure PA and sedentary behaviour in older care home residents. Another notable strength of the current study was that a range of care homes were recruited in terms of size, location, ownership and provision. In addition, the broad eligibility criteria and comprehensive approach to resident recruitment ensured participants were representative of the wider care home population. There was considerable heterogeneity in terms of the demographic characteristics, physical function and level of cognitive impairment of those recruited. Accordingly, it may be surmised that the results of the current study are likely generalisable. In addition, the fact that the method used to identify non-wear time was based on empirical evidence is an important advantage of the current study as it increases confidence that estimates of compliance are accurate.

Nonetheless, the study was not without limitations and it is important to acknowledge these when reflecting on the findings presented. First, although the accelerometer data collection protocol was evaluated within the context of a cRCT, the trial was not designed to determine the efficacy of the data collection protocol. Rather inferences were made regarding the ‘success’ of the data collection protocol by comparing estimates of compliance to those reported in the pilot studies presented in **Chapter 7**. Second, although a considerable amount of participant data was collected, including information about physical function and level of cognitive impairment, there may be characteristics associated with compliance to the data collection protocol that were not assessed. For example, participants’ level of education or socio-economic status. Finally, whilst the qualitative work conducted provided important insight into how the data collection was implemented in practice across the different care homes, it is probable that many of the interactions between care staff and participants surrounding accelerometer wear (for example assisting with putting the monitor on during dressing) were not directly observed given observations were only conducted in the communal areas of the participating care homes. Moreover, due to time constraints, the interpretation of the qualitative data collected was done independently therefore there is potential for researcher bias.

8.6 Conclusion

In conclusion, the current study builds on existing evidence which suggests it is feasible to use accelerometers to measure PA and sedentary behaviour in field-based research with older care home residents. Specifically, it appears that a tailored data collection protocol, alongside robust data collection procedures are key to maximising participant compliance and ensuring high quality data on PA and sedentary behaviour are collected in this population. As is the case with any research processes, ‘buy-in’ from key stakeholders (i.e. residents and staff) within the care home also appear to be vital.

Chapter 9 Levels and patterns of physical activity and sedentary behaviour, as measured by an ActiGraph accelerometer, in older care home residents

Aspects of this chapter were presented at the following conferences / academic meetings:

- American College of Sports Medicine (ACSM) Annual Meeting, Boston, USA, June 2016 – Poster Presentation
- Annual Faculty of Biological Sciences Postgraduate Symposium, University of Leeds, England, UK, July 2016 – Oral presentation (Awarded 2nd prize)
- Bradford Institute for Health Research Conference: “Research that changes a city”, Bradford, UK, October 2016 – Poster presentation
- 14th Congress of the European Forum from Research in Rehabilitation (EFRR), Glasgow, Scotland, UK, May 2017 – Oral presentation
- School of Healthcare Education and Debate Talk: “Promoting a relevant evidence-base for care homes – Spotlight on care home research”, University of Leeds, England, UK, February 2019 - Invited oral presentation

And published in:

- Medicine and Science in Sports and Exercise (2016). 48(5S): S2100, p.591

9.i Preface

Given the dearth of information regarding the levels and patterns of PA and sedentary behaviour in older adults residing in care homes, the collection of accelerometer data in **Chapters 6 – 8** presented a considerable opportunity. In order to pursue this opportunity, the decision was taken to pool this data to form a larger cross- sectional data set.

9.1 Introduction

The systematic review presented in **Chapter 3** demonstrated that the use of accelerometers to objectively measure PA and sedentary behaviour in older care adults residing in care homes is increasing. Yet, only five of the 18 studies included employed a hip-worn ActiGraph accelerometer and reported estimates of time spent engaging in different intensities of PA and sedentary behaviour. Whilst these studies provide some insight into the levels of PA and sedentary behaviour in care home residents, it seems premature to draw definitive conclusions regarding the profile of PA behaviour of care home residents based on so few studies, particularly given their heterogeneity.

Of the five studies which reported estimates of time spent engaging in different intensities of PA and sedentary behaviour, three were conducted in AL facilities (Park et al., 2017; Leung et al., 2017; Corcoran et al., 2016), one was conducted in residential homes (Barber et al., 2015) and one in nursing homes (Marmeleira et al., 2017). Although all of these facilities fell under the definition of a 'care home' used in **Chapter 3**, it is important to recognise that traditionally these facilities were considered separate entities, distinguishable from one another in terms of the care provided (Luff et al., 2011; Froggatt et al., 2009). For example, in the UK, AL facilities are often viewed as being at one end of a "continuum of care provision" (Figure 9.1) as they tend only to provide 'assistance' with ADLs, whereas nursing homes are viewed as being at the opposite end of this "continuum", as they provide both personal and on-site nursing care (Sanford et al., 2015; Zimmerman et al., 2003). Whilst more ambiguity surrounds the 'location' of residential homes along this continuum, they primarily provide personal care and can therefore be considered an intermediary between AL facilities and nursing homes (Szczepura, 2011; Rothera et al., 2003).

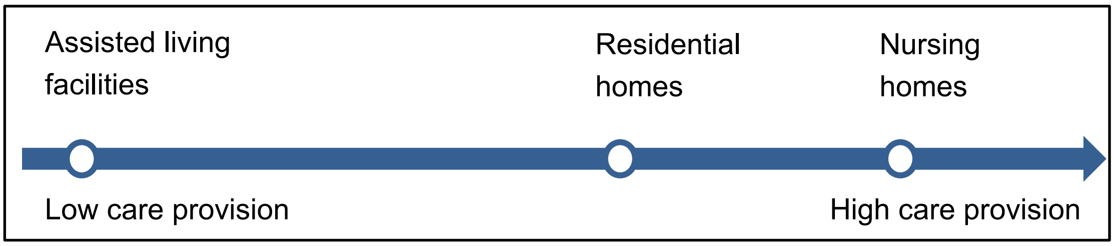


Figure 9.1 Continuum of care provision

Accordingly, the needs of residents in each of these facilities are likely to differ with the level of dependency being lowest in AL facilities and highest in nursing homes (Gordon et al., 2014; Rothera et al., 2003). It is notable however, that studies are increasingly reporting that there is an overlap in the needs and dependency of residents in residential and nursing homes (Gordon et al., 2014, Bebbington et al, 2001). Still, it would seem reasonable to assume that older adults residing in AL facilities are more likely to engage in more PA and spend less time sedentary compared to their counterparts living in residential or nursing homes. Thus, it may be that the results are not generalisable across care settings. However, as the number of studies conducted in different settings to date is so small it is not possible to make any meaningful comparisons across the different facilities.

Irrespective of the care setting (i.e. AL facility, residential home or nursing home), many, if not most of the residents in these facilities will have complex health needs (Szczepura, 2011, Bebbington et al., 2001). There is increasing recognition that older adults residing in care homes are the frailest segment of the population, distinguishable from community-dwelling older adults of the same age because of their physical disability, multi-morbidity, dependency on others and cognitive impairment (Gordon et al., 2014; Rothera et al., 2003). It is notable therefore, that all five of the studies conducted to date which reported on estimates of time spent engaging in different intensities of PA and sedentary behaviour, stated some inclusion / exclusion criteria relating to either residents' mobility and / or cognitive function. As a result, it is unclear whether the residents included in these studies are representative of the wider population residing in care homes. This is particularly problematic in terms of being able to comment on the generalisability of results as the sample sizes in these studies have generally been small (three of the five studies reviewed included fewer than 100 participants). In addition, the variability in the inclusion / exclusion criteria employed across studies hampers comparability across studies.

Whilst there are concerns regarding generalisability, the findings from the studies reviewed, coupled with findings from observational research, suggest care home residents spend a considerable proportion of their time sedentary. It is therefore important to acknowledge recent evidence which proposes that how sedentary time is accumulated (i.e. the pattern) may have important consequences in terms of health-related outcomes (Sardinha et al., 2015; Healy et al., 2008). It may be that encouraging residents to engage in short bouts of PA more regularly in order to interrupt prolonged periods of sedentary time may be a more feasible target for interventions in this population (Fuzeki et al., 2017). Nevertheless, no studies conducted to date have examined the patterns of PA and sedentary behaviour in this population. This represents a significant gap in our knowledge as an understanding of the patterns of PA and sedentary behaviour typical in this population is needed in order to guide the development of appropriate interventions.

Thus, in this study, the accelerometer-determined levels and patterns of PA and sedentary behaviour in older adults, including those with limited mobility and cognitive impairment, residing in care homes in the UK is described. Based on the review presented in **Chapter 3**, it was hypothesised that levels of PA would be low and that residents would spend the majority of their time sedentary. It was further postulated that the patterns of PA and sedentary behaviour would likely reflect the care home routine. That is, any PA residents engage in would be around mealtimes and / or relate to ADLs and that they would spend a considerable amount of time engaging in prolonged bouts of sedentary behaviour.

A secondary aim was to explore the effect of personal characteristics on the levels and patterns of PA and sedentary behaviour. In light of previous research, it was hypothesised that levels of PA would be higher and sedentary time lower in those residents who were younger and had better physical and cognitive function (Leung et al., 2017; Barber et al., 2015). Whilst there is little information regarding the influence of personal characteristics on the patterns of PA and sedentary behaviour it was further hypothesised that older age, male gender, poorer physical function and severe cognitive impairment would be associated with the accumulation of sedentary time in prolonged, uninterrupted bouts (Hartman et al., 2018; Leung et al., 2017; Bellettiere et al., 2015).

9.2 Methods

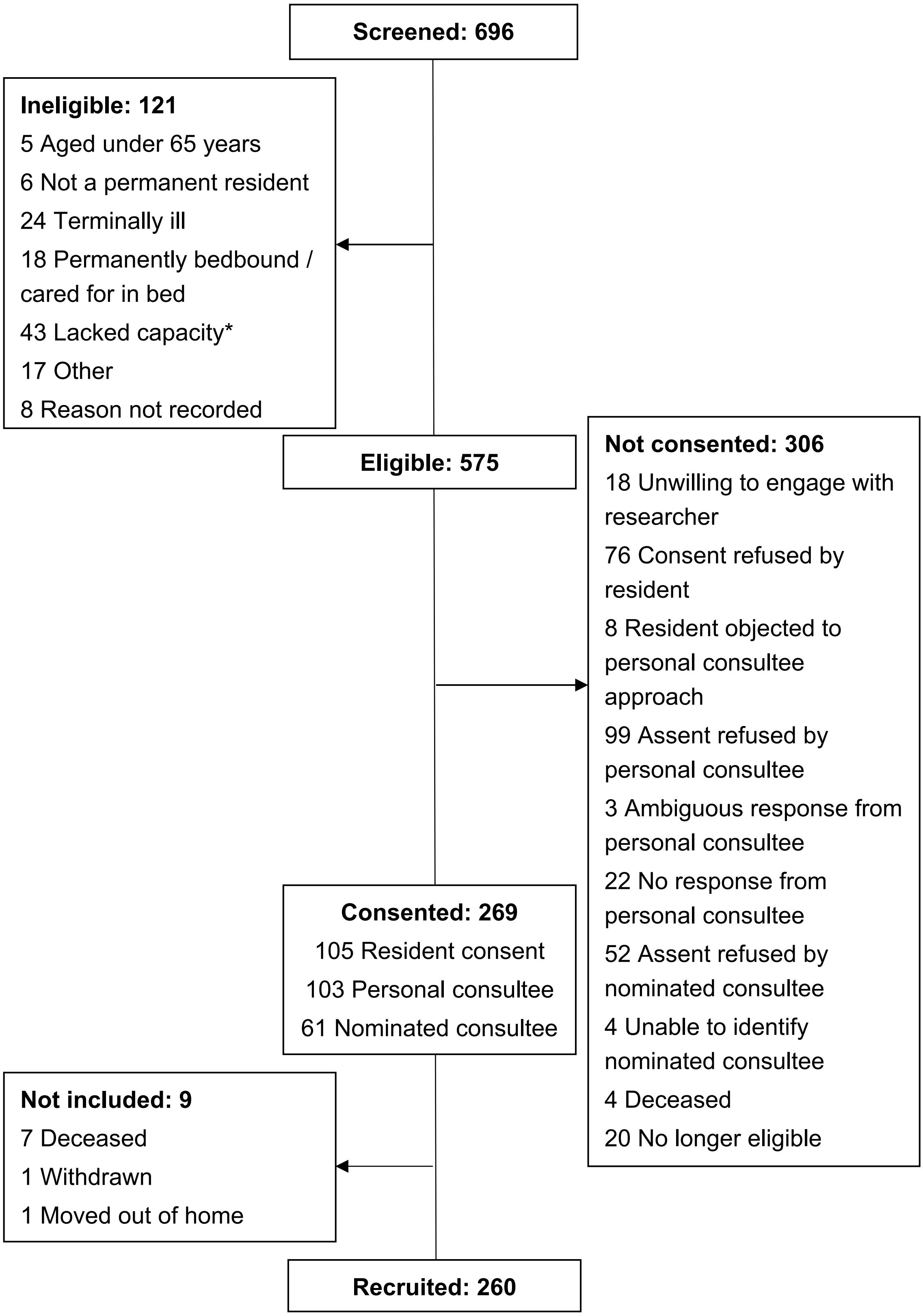
9.2.1 Study design

As the accelerometer data collection and processing methods (i.e. accelerometer wear location, sampling frequency etc.) employed in Chapters 7 and 8 were the same, the decision was taken to pool the data collected to form a larger data set. Having said this, for transparency, it is important to acknowledge that different strategies were employed in each of the studies in an effort to improve compliance with the data collection protocol. For example, in the study presented in **Chapter 8** a structured prompting schedule was implemented whereas prompts were delivered in an 'ad hoc' manner in the studies presented in **Chapter 7**.

Thus, this study was an exploratory cross-sectional analysis of data collected in Chapter 7 and Chapter 8.

9.2.2 Setting and participants

A full description of the care home and participant recruitment procedures, including details regarding screening and the process of obtaining consent are provided in **Chapter 5, section 5.2.2**. Briefly, as stated above, participants for the current study were drawn from the two pilot studies presented in Chapter 7 (n = 107) and the cRCT discussed in Chapter 8 (n = 153). More details regarding participant recruitment (e.g. number of residents screened and consented) are therefore provided in Chapter 7 and Chapter 8. However, for context and clarity, an overview of participant recruitment is provided in Figure 9.2.



*Having capacity was an eligibility criteria in one of the homes

Figure 9.2 Consort diagram demonstrating the recruitment of residents between June 2013 and August 2016 across 22 care homes

9.2.3 Data Reduction

9.2.3.1 Accelerometer count data

Based on the analysis presented in **Chapter 6**, raw activity count data were processed with the normal filter and aggregated over 60 second epochs. VM activity counts were used for analysis.

Daily wear time was determined as per the procedures described in **Chapter 6, section 6.3.2.3**. Valid accelerometer wear time for this sample was defined as ≥ 8 hours on ≥ 4 days of the week (Chapter 6).

Total activity counts per day (counts.day^{-1}) and activity cpm were recorded to represent the total volume of PA and to facilitate comparison with existing literature (Bassett et al., 2015). Next, a published cut-point was applied to the activity cpm to identify time spent engaging in PA (≥ 200 cpm) and sedentary behaviours (< 200 cpm) (Aguilar-Farias et al., 2014). The total time spent engaging in PA and sedentary behaviour was also converted into a percentage of daily wear time to account for intra- and inter-individual differences in daily wear time (Aadland and Ylvisåker, 2015; Hinkley et al., 2012). Further, as a single cut-point was used to distinguish between PA and sedentary behaviour, the intensity distribution of activity was considered as a continuous construct (Berkemeyer et al., 2016). That is, the median (IQR) time spent in eleven zones of activity counts was calculated and displayed graphically.

In order to facilitate discussion around the patterns of PA and sedentary behaviour, the number and length of 'bouts' of PA and sedentary behaviour were calculated. Specifically, bouts of five - nine minutes and at least ten minutes were calculated for PA and bouts of 30 – 59 minutes and at least 60 minutes were calculated for sedentary behaviour. For each bout length (i.e. 5 - 9 min, ≥10 min, 30 - 59 min and ≥ 60 min), a bout was defined as the equivalent amount (or more) of consecutive minutes of either PA (≥ 200 cpm) or sedentary behaviour (< 200 cpm). The total amount of PA and sedentary time accumulated in bouts was also calculated for each bout length.

Finally, PA and sedentary behaviour data were reduced into days of the week (Monday - Sunday) and hours of the day (8am – 8pm) summaries. In order to produce the hours of the day summary, partial hours (defined as hours with less than 60 minutes of accelerometer wear) were excluded (Huisingh-Scheetz et al., 2017) and a pragmatic approach was adopted to identify the core waking hours of the sample (Bellettiere et al., 2015).

9.2.4 Statistical Analysis

Treatment of the data in preparation for statistical analysis is detailed in the **general methods chapter, section 5.6**. Differences in the demographic characteristics and physical function of the following groups of participants were compared using a series of one-way ANOVAs (Welch's F is reported in cases where sample sizes were unequal and the assumption of homogeneity was violated) or Kruskal-Wallis tests as appropriate. Firstly, those residents who agreed to wear a hip worn accelerometer were compared to those who did not. Next, for those participants who wore a hip worn accelerometer, their demographic characteristics and physical function data were examined to see whether those who did and did not provide valid accelerometer data differed.

Descriptive statistics (median, IQR and range) were utilised to describe the levels and patterns of PA and sedentary behaviour. Next, linear mixed effect models were conducted to examine the effect of: a) day of the week (Monday – Sunday) and b) time of day (morning, afternoon, evening) on PA and sedentary behaviour. Each model included a random intercept for participants. The models examining the effect of day of the week on PA and sedentary behaviour were also adjusted for daily wear time.

In order to explore the effect of personal characteristics on the levels and patterns of PA and sedentary behaviour, participants were grouped according to age (< 85 y or ≥ 85 y), gender (male or female), mental capacity (deemed to have capacity or not) and physical function (BI score ≤ 11, dependent or > 11, independent). Differences between the groups were assessed using a series of one-way ANOVAs (as above, Welch's F is reported in cases where sample sizes were unequal and the assumption of homogeneity was violated) or Kruskal-Wallis tests as appropriate.

9.3 Results

9.3.1 Participant characteristics

Demographic characteristics and physical function and mobility assessment scores of recruited participants (n = 260), stratified according to whether a hip or wrist accelerometer was administered to them, are presented in Table 9.1 and Table 9.2. Participants had resided in a care home for 2 years 4 months ± 2 years 9 months; however, there was a wide range in length of residence (< 1 month – 17 years). A considerable proportion of participants were females (74%) and over half were aged ≥85 years (60%). A large proportion of participants recruited (n = 157, 60%) were deemed to not to have the capacity to consent themselves therefore it may be inferred that they had some form of cognitive impairment. It was also notable that 43% (n = 111) of participants had more than one comorbidity. Nevertheless, just under half the participants were judged to be independent in ADLs based on their BI score and 56% (n= 138) of participants were able to ambulate independently on level surfaces (i.e. FAC level of 4 or 5).

Table 9.1 Characteristics of all participants and those to whom a hip- worn accelerometer was and was not administered. Number of participants (*n*) is not equal to the total number of residents recruited due to missing data.

	All participants (n = 260)		Participants to whom a hip-worn accelerometer was administered (n = 225)		Participants to whom a hip-worn accelerometer was not administered (n = 35)	
	n	N (%) or Mean ± SD	*n*	N (%) or Mean ± SD	*n*	N (%) or Mean ± SD
Gender (male)	260	67 (26%)	225	59 (26%)	35	10 (29%)
Age (y)	247	86 ± 7	216	86 ± 7	31	84 ± 8
Age Group	247		216		31	
< 85 y		100 (40%)		85 (39%)		15 (48%)
≥ 85 y		147 (60%)		131 (61%)		16 (52%)
Height (cm)	217	161.2 ± 10.5	187	160.7 ± 10.7	30	163.9 ± 8.6
Weight (kg)	242	65.1 ± 14.5	211	64.9 ± 14.6	31	66.3 ± 14.1
Capacity to consent (yes)	260	103 (40%)	225	89 (40%)	35	14 (40%)
Number of comorbidities*:	237		206		31	
None		17 (7%)		17 (8%)		0 (0%)
1 – 2		167 (71%)		142 (69%)		25 (81%)
≥ 3		53 (22%)		47 (23%)		6 (19%)

*based on the CCI (Charlson et al., 1987)

Table 9.2 Scores of physical function and mobility assessments of all participants and those to whom a hip- worn accelerometer was and was not administered. Number of participants (*n*) is not equal to the total number of residents recruited due to missing data

	All participants (n = 260)	**Participants to whom a hip-worn accelerometer was administered (*n* = 225)**	**Participants to whom a hip-worn accelerometer was not administered (*n* = 35)**
	N (%) or Mean ± SD		
BI score (21 point scale; 0-20)	10.8 ± 5.5	10.9 ± 5.5	11.1 ± 6.1
BI score ≤ 11 (dependent)	133 (51%)	115 (51%)	18 (51%)
BI score > 11 (independent)	127 (49%)	110 (49%)	17 (49%)
FAC*:			
Level 0 (non-functional ambulation)	50 (20%)	40 (18.4%)	10 (32.2%)
Level 1 (ambulatory-dependent for physical assistance – level II)	22 (9%)	19 (8.8%)	3 (9.7%)
Level 2 (ambulatory-dependent for physical assistance – level I)	20 (8%)	19 (8.8%)	1 (3.2%)
Level 3 (ambulatory-dependent for supervision)	18 (7%)	16 (7.4%)	2 (6.5%)
Level 4 (ambulatory-independent on level surfaces)	79 (32%)	72 (33.2%)	7 (22.6%)
Level 5 (ambulatory-independent)	59 (24%)	51 (23.5%)	8 (25.8%)

* Data only available for 248 participants: 217 of those to whom a hip-worn accelerometer was administered and 31 of those to whom a hip-worn accelerometer was not administered.

9.3.2 Accelerometer wear

A hip-worn accelerometer was administered to 225 (87%) participants. An accelerometer was not administered to the other participants for the following reasons: participant refused to wear (n = 4); consultee deemed it inappropriate (n = 4); participant was in hospital during data collection (n = 3); participant was deemed too unwell during data collection (n = 6); participant wore a wrist accelerometer (n = 17); participant wore a commercially available device (n = 1).

There were no differences in the personal characteristics (Gender: $X_2(1) = 0.086$, $p = 0.770$; Age: $F(1,245) = 1.097$, $p = 0.296$; Height: $F(1,215) = -2.483$, $p = 0.117$; Weight: $F(1,240) = 0.262$, $p = 0.609$; Capacity to consent: $X_2(1) = 0.003$, $p = 0.960$; Number of comorbidities: $X_2(1) = 0.011$, $p = 0.916$); physical function score ($F(1,248) = 0.022$, $p = 0.882$) or mobility assessment score ($X_2(1) = 0.839$ $p = 0.360$) of those participants to whom a hip-worn accelerometer was administered (n = 225) and those who did not receive one (n = 35) (Table 9.1 and Table 9.2).

Of those participants to whom a hip worn accelerometer was administered, 42 (19%) did not meet the criteria for valid wear time (Figure 9.3). Twenty-two participants wore the monitor for less than four days and 15 participants completed four days of monitoring, however daily wear time was less than eight hours. The accelerometers for five participants were lost. There were no differences in the demographic characteristics (Gender: $X_2(1) = 0.063$, $p = 0.801$; Age: $F(1, 214) = 0.084$, $p = 0.772$; Height: $X_2(1) = 0.037$, $p = 0.848$; Weight: $F(1,209) = 0.001$, $p = 0.979$; Capacity to consent: $X_2(1) = 0.836$, $p = 0.360$; Number of comorbidities: $X_2(1) = 0.032$, $p = 0.858$); physical function score ($X_2(1) = 0.079$, $p = 0.779$) or mobility assessment score ($X_2(1) = 0.100$, $p = 0.752$) of those participants who met the criteria for valid accelerometer data (n = 183) and those who did not (n = 42). Data from these participants was not included in the final analysis. Thus 183 data sets were included.

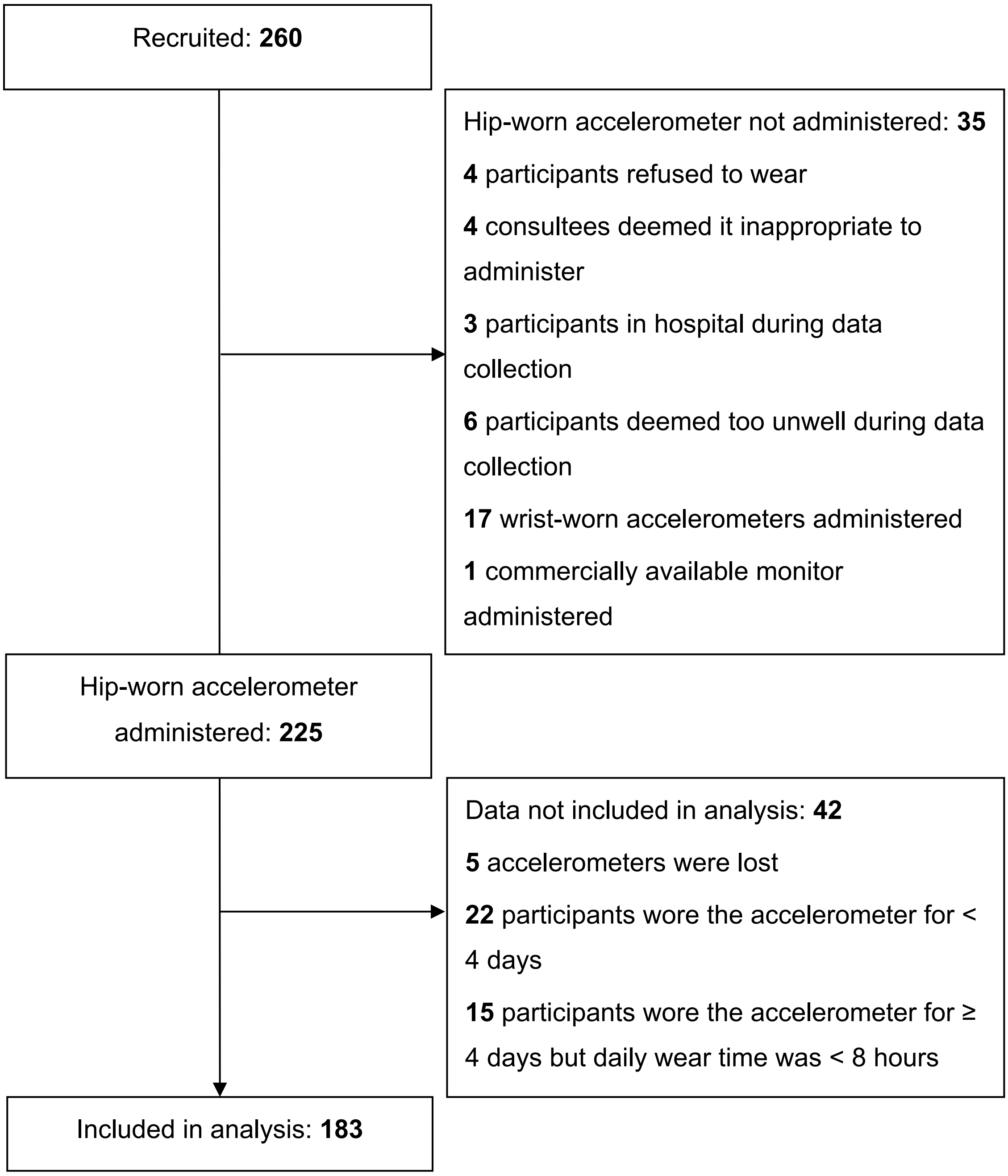


Figure 9.3 Flow diagram demonstrating the flow of recruited participants to those meeting the accelerometer wear time requirements to be included in analysis.

9.3.3 Levels of physical activity and sedentary behaviour

Of the participants with valid accelerometer data (n = 183), 70 (38%), 50 (27%), 33 (18%) and 30 (16%) had seven, six, five and four valid days respectively. Median daily wear time was 12 hours 6 minutes (IQR: 3 h 45 min).

With regards to engagement in PA, median accelerometer counts.day^{-1} and cpm were 68,920 counts.day^{-1} (IQR: 90,536 counts.day^{-1}) and 89 cpm (IQR: 130 cpm) respectively. Median daily time spent engaging in PA was 1 hour and 32 minutes (IQR: 2 h and 18 min). This corresponded to between 0 and 76% (median: 13%) of daily wear time. Still, as can be seen from Figure 9.4, the vast majority of the PA participants engaged in was of very light intensity: between 200 and 500 cpm (median: 6%, IQR: 7). Further, participants spent a considerable portion of time engaging in sedentary behaviours (median: 87%, range: 24 – 100%). Median daily sedentary time was 10 hours 10 minutes (IQR: 3 h 19 min).

There were no differences in levels of PA or sedentary behaviour across days of the week ($F(6, 894.698) = 0.947$, $p = 0.461$ and $F(6, 894.698) = 0.947$, $p = 0.461$ respectively, Figure 9.5). However, there was a significant main effect of time of day (i.e. morning, afternoon or evening) on both the level of PA and sedentary behaviour ($F(2, 10912.838) = 84.115$, $p = 0.000$ and $F(2,10912.903) = 84.115$, $p = 0.000$ respectively Figure 9.6). As can be seen from Figure 9.6 the proportion of time residents spent engaging in PA was lowest in the morning (13%) and increased throughout the day (16% and 19% in the afternoon and evening respectively; $F(2, 10912.819) = 83.880$, $p = 0.000$). Conversely, sedentary time decreased from 87% during the morning hours to 84% and 81% in the afternoon and evening ($F(2, 10912.819) = 83.880$, $p = 0.000$,).

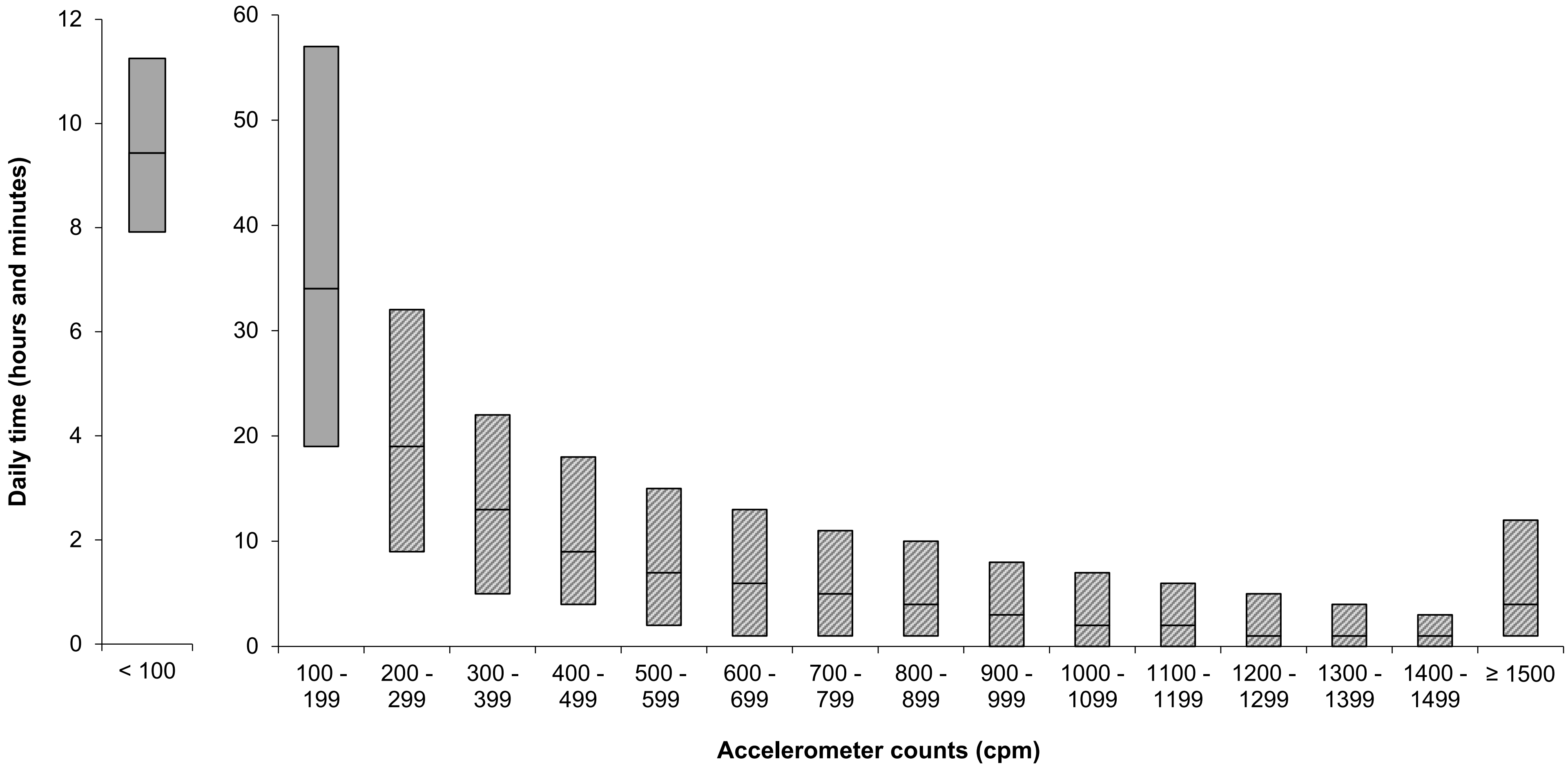


Figure 9.4 The distribution of time (median and IQR) spent engaging in sedentary behaviour (< 200 cpm) and physical activity (≥ 200 cpm).

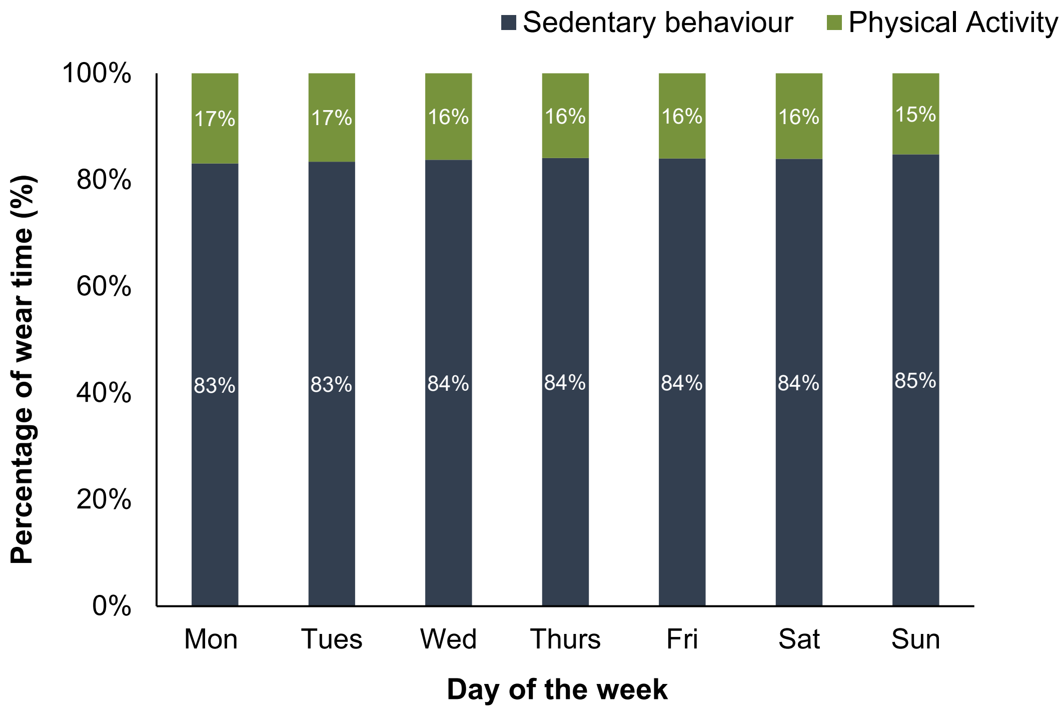


Figure 9.5 Percentage of time spent engaging in PA and sedentary behaviour across days of the week. Data presented as mean ± SD.

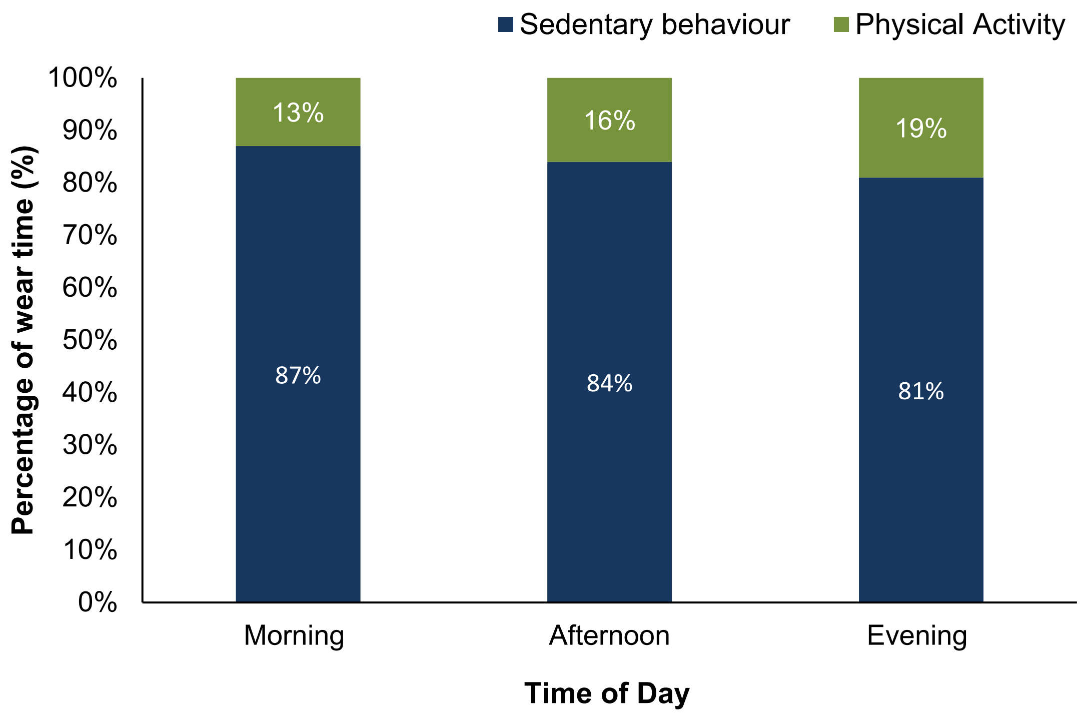


Figure 9.6 Percentage of time spent engaging in PA and sedentary behaviour across three periods of the day: morning (8:00-11:59), afternoon (12:00-16:59) and evening (17:00-20:00).

9.3.4 Pattern of physical activity and sedentary behaviour

Eighty-eight percent of the time participants spent engaging in PA was accumulated in bouts lasting either 5-9 min (32%) or at least ten minutes (56%). The contribution of these PA bouts to the total time spent engaging in PA was similar across the day (Figure 9.7).

One hundred and seventy-nine (98%) of participants engaged in at least one five – nine minute bout of PA over the course of the measurement period and 135 (74%) participants actually engaged in at least one bout daily. One hundred and fifty-five (85%) participants performed at least one bout (≥ 10 min) of PA over the course of the measurement period, with 80 (44%) performing at least one PA bout daily. Furthermore, 118 (65%) participants accumulated 30 min of PA daily over the course of the monitoring period and 48 (26%) participants actually accumulated this time in bouts of ≥ 10 min as per the current PA guidelines.

A considerable proportion of the time spent engaging in sedentary behaviour was accumulated in bouts of 30 – 59 min (21%) and ≥ 60 min (47%) respectively. As can been seen from Figure 9.8, the contribution of 30 – 59 min and ≥ 60 min sedentary bouts to total sedentary time varies across the day with the contribution from these bouts decreasing from 94% in the morning to 67% in the afternoon and 51% in the evening.

All but one resident (n = 182) engaged in at least one sedentary bout (30 – 59 min) over the course of the measurement period, with 96% (n = 176) of participants engaging in at least one bout daily. The median number of daily sedentary bouts (30 - 59 min) was three (IQR: 3, range: 0 - 11) and each bout lasted on average (median) 41 minutes (IQR: 14 min). One hundred and seventy-eight (97%) participants engaged in at least one bout (≥ 60 min) of sedentary behaviour over the course of the measurement period. Moreover, 112 (61%) participants engaged in at least one sedentary bout (≥ 60 min) daily. The median number of daily sedentary bouts (≥ 60 min) was two (IQR: 3, range: 0 - 7) and median bout length was 1 h and 33 min (IQR: 1 h and 3 min).

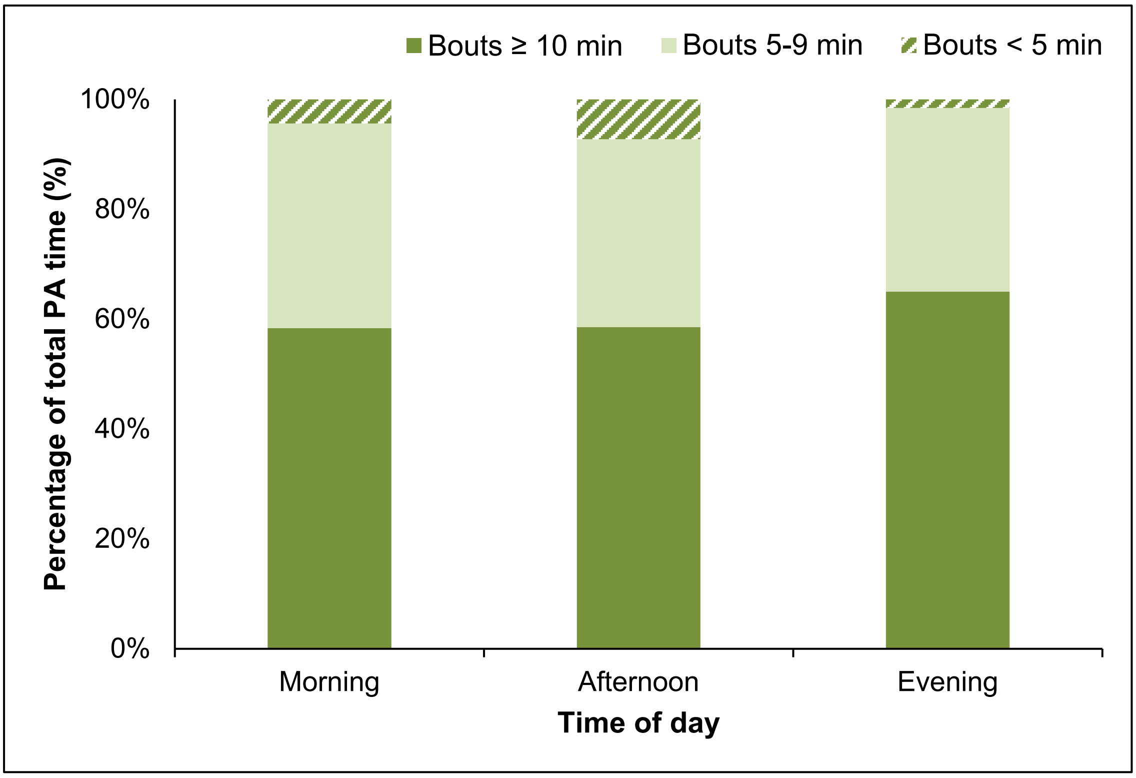


Figure 9.7 Contribution of PA bouts of three different lengths to total PA time across three periods of the day. Morning (08:00-11:59), afternoon (12:00 -16:59) and evening (17:00-20:59).

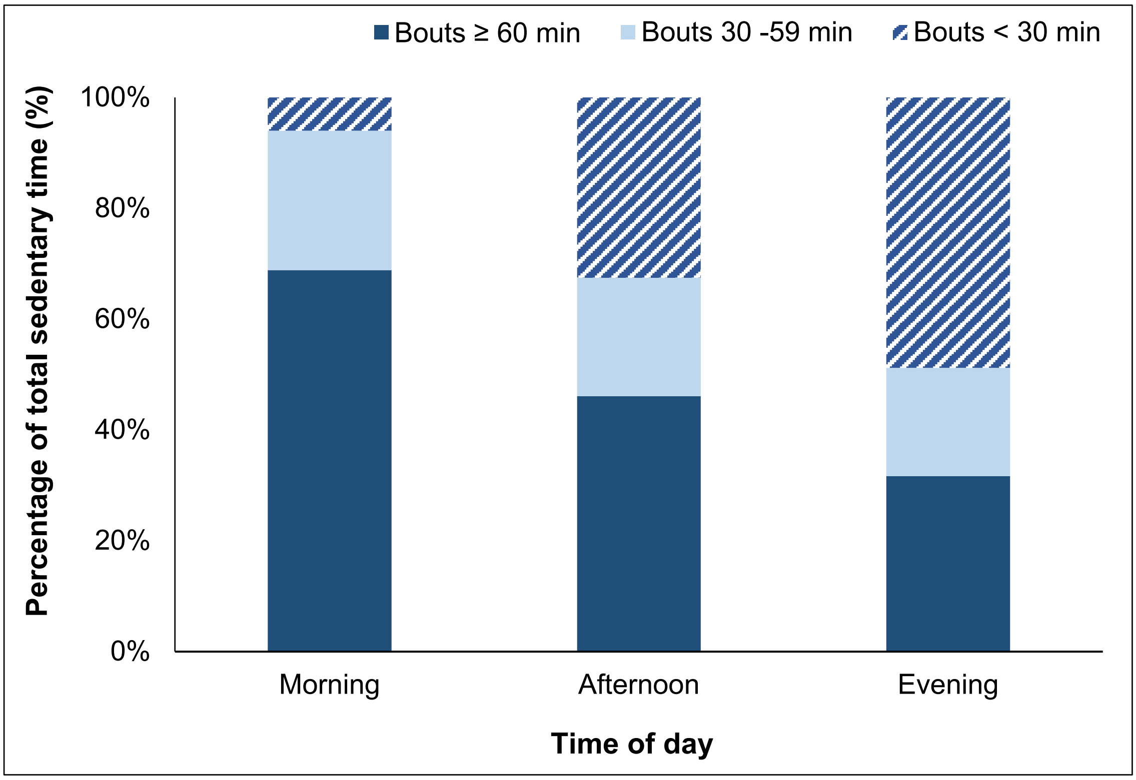


Figure 9.8 Contribution of sedentary behaviour bouts of three different lengths to total sedentary time across three periods of the day. Morning (08:00-11:59), afternoon (12:00 -16:59) and evening (17:00-20:59).

As discussed above residents engaged in very little PA and spent the majority of their time sedentary. Figure 9.9 provides further information on the patterns of PA and sedentary behaviour across a ‘typical day’. The exemplar plots shown detail the pattern of PA and sedentary behaviour of two participants: one from the most active quartile of the sample and one from the least active quartile (quartiles were based on average activity counts$\cdot$day^{-1}).

As can be seen in Figure 9.9, the patterns of the two participants were notably different. The more active participant engaged in PA throughout the day and actually engaged in a number of 10-minute bouts across the day. Conversely, the less active participant spent the majority of their time sedentary and the little PA that they did engage in appeared to be associated with ADLs (i.e. getting out of bed and dressing in the morning and getting ready for bed in the evening).

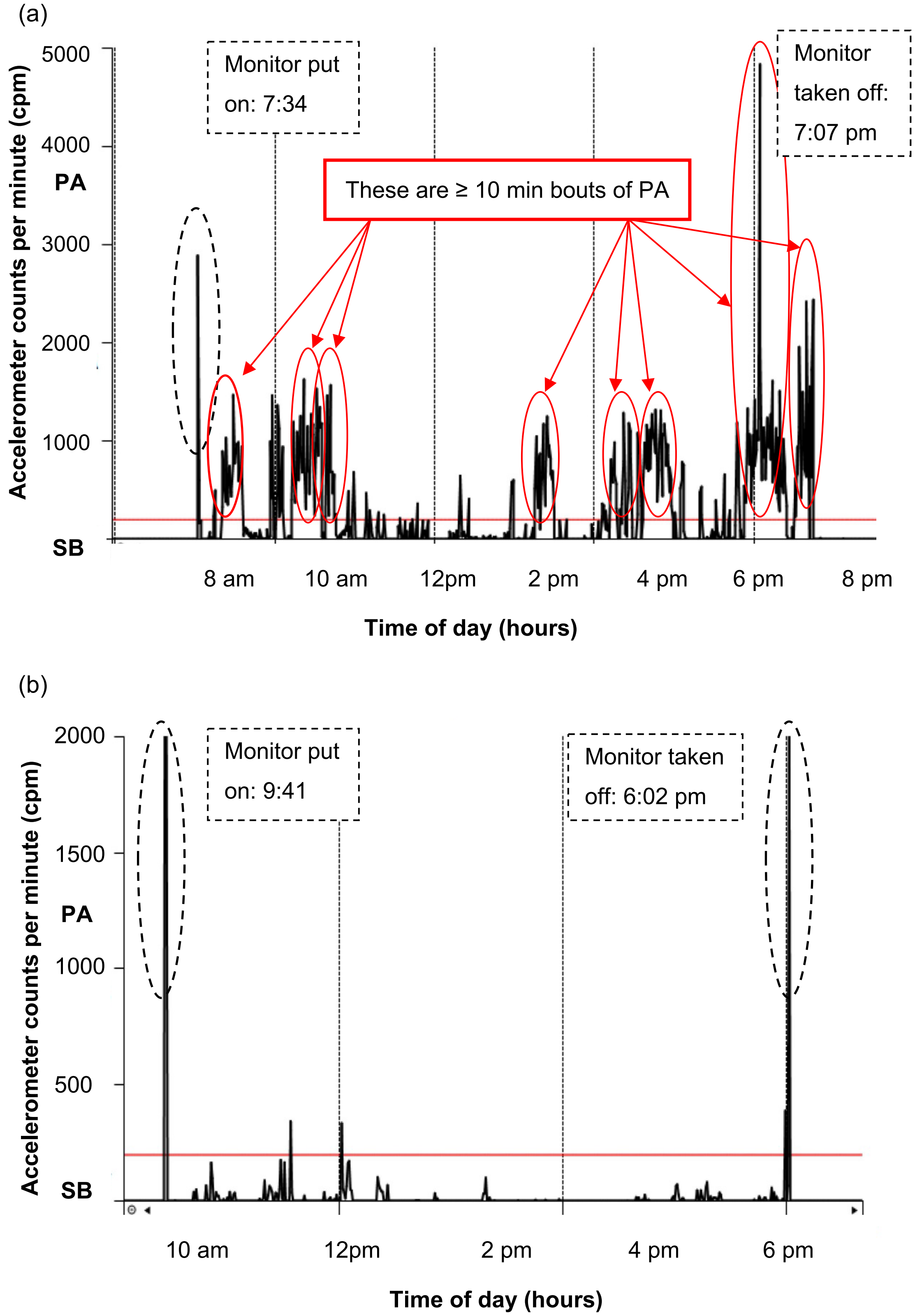


Figure 9.9 Examples of the pattern of PA and sedentary behaviour as indicated by activity counts for a participant in the (a) most active and (b) least active quartile. Red line represents the cut – point to distinguish between PA and sedentary behaviour (SB).

9.3.5 Personal characteristics related to levels and patterns of physical activity and sedentary behaviour

The differences in levels and patterns of PA and sedentary behaviour between different groups of participants are detailed in Table 9.3 and Table 9.4. Whilst the daily time spent engaging in PA was similar between participants aged < 85 y and those aged ≥ 85 y, the older group spent significantly more time sedentary ($F(1,176) = 4.327$, $p = 0.039$, Table 9.3). This reflects the strong negative association between age and daily PA time ($r = -0.214$, $p = 0.004$) and the positive association observed between age and daily sedentary time ($r = 0.156$, $p = 0.037$). Despite the difference in the levels of sedentary behaviour between the age groups, no difference in the pattern of this behaviour (as indicated by the time accumulated in bouts of 30 – 59 minutes and ≥ 60 minutes) was observed ($X_2(1) = 0.294$, $p = 0.588$; $X_2(1) = 1.520$, $p =$ 218, respectively, Table 9.4).

As can be seen in Table 9.3, male participants' daily sedentary time was significantly higher than their female counterparts ($F(1,181) = 7.627$, $p = 0.006$). However, this difference likely reflects the fact that male participants wore their accelerometer, on average, 56 minutes longer (95% CI: 19 min, 1 h and 32 min) per day. This is supported by the finding that the percentage of wear time spent engaging in PA and sedentary behaviour was similar between genders ($X_2(1) = 0.270$, $p = 0.603$ and $X_2(1) = 0.270$, $p = 0.603$ respectively), as were accelerometer counts.day^{-1} ($F(1,181) = 0.061$, $p = 0.806$) and accelerometer cpm ($F(1,181) = 0.044$, $p = 0.834$, Table 9.3). Furthermore, no differences were observed in the pattern of PA (as indicated by the time accumulated in bouts of 5 – 9 minutes ($X_2(1) = 0.984$, $p = 0.321$) and ≥ 10 minutes ($X_2(1) = 2.512$, $p = 0.113$) respectively) or sedentary behaviour (as indicated by the time accumulated in bouts of 30 – 59 min ($X_2(1) = 0.294$, $p = 0.588$) and ≥ 60 min bouts ($X_2(1) = 1.520$, $p = 0.218$) respectively) (Table 9.4).

Although there were no differences in the levels of PA and sedentary behaviour between those participants deemed to have capacity and those who did not ($X_2(1) =$ 0.1.334, $p = 0.248$ and $F(1,181) = 0.038$, $p = 0.847$ respectively , Table 9.3), a difference in the pattern of sedentary behaviour was observed (Table 9.4). Indeed, participants deemed to lack capacity spent more time in prolonged periods of sedentary behaviour (as indicated by the total time accumulated in 30 – 59 min and ≥ 60 min bouts) compared to those participants deemed to have capacity ($X_2(1) = 5.567$, $p = 0.018$ and $X_2(1) = 8.617$, $p = 0.003$, respectively). In addition, those participants deemed to lack capacity accumulated significantly less time in PA in bouts of five to nine minutes in duration ($X_2(1) = 10.245$, $p = 0.001$, Table 9.4).

Both the levels and pattern of PA and sedentary behaviour differed significantly dependent on participants' physical function (Table 9.3). Participants with better physical function spent significantly more time engaging in PA ($F(1, 169.277) = 44.605$, $p = 0.000$); recorded significantly more accelerometer counts.day^{-1} (Welch's $F(1, 179.216) = 41.754$, $p = 0.000$) and accelerometer cpm (Welch's $F(1,178.259) = 44.859$, $p = 0.000$) compared to those participants with poorer function (Table 9.3). These participants also spent less time sedentary (Welch's $F(1, 176.177) = 13.868$, $p = 0.000$,Table 9.3). Furthermore, participants with better physical function accumulated more time in PA bouts of 5 – 9 minutes and ≥ 10 minutes respectively ($X_2(1) = 42.959$, $p = 0.000$ and $X_2(1) = 29.998$, $p = 0.000$) and also accumulated less time in sedentary bouts of 30 – 59 minutes and ≥ 60 minutes ($X_2(1) = 10.025$, $p = 0.002$ and $X_2(1) = 42.831$, $p = 0.000$, respectively, Table 9.4).

Table 9.3 Differences in levels of PA and sedentary behaviour between participants grouped according to age, gender, whether or not they were deemed to have capacity and physical function†. Data are presented as median (IQR).

	Age		Gender		Capacity		Physical function†	
	< 85 y (n = 71)	**≥ 85 y (n = 107)**	**Male (n = 47)**	**Female (n = 136)**	**Yes (n = 75)**	**No (n = 108)**	**Dependent (n = 96)**	**Independent (n = 87)**
Accelerometer counts.day^{-1}	86,424 (117,730)*	57,648 (76,104)*	60,857 (109,307)	70,784 (79,635)	73,429 (101,490)	66,076 (81,,851)	37455 (72,205)**	90,,345 (111850)**
Accelerometer cpm	123 cpm (138 cpm)*	89 cpm (97 cpm)*	76 cpm (145 cpm)	98 cpm (110 cpm)	98 cpm (105 cpm)	84 cpm (119 cpm)	55 cpm (85 cpm)**	128 cpm (122 cpm)**
Daily PA time (hours and minutes)	1 h 48 min (2 h 7 min)	1 h 28 min (1 h 55 min)	1h 38 min (2 h 41min)	1h 39min (2 h 3 min)	1h 42min (2 h 10 min)	1 h 33 min (2 h 10 min)	53 min (1 h 38 min)**	2 h 7 min (2 h 32 min)**
Percentage total PA (%)	15% (16%)	12% (15%)	11% (18%)	15% (18%)	15% (14%)	12% (16%)	7% (13%)**	18% (16%)**
Daily sedentary time (hours and minutes)	9 h 49 min (2h 35 min)*	10 h 25 min (2 h 39 min)*	11 h 15 min (2h 22 min)**	10 h 1min (2 h 37min)**	10 h 1min (2 h 42 min)	10 h 19 min (2 h 46 min)	10 h 56 min (2h 14min)**	9 h 41 min (2 h 17 min)**
Percentage Sedentary (%)	85% (16%)	88% (15%)	89% (18%)	85% (15%)	85% (14%)	88% (16%)	93% (13%)**	82% (16%)**

Significant differences are highlighted with * ($p < 0.05$) or ** ($p < 0.01$).

† Physical function as assessed using the BI. A cut-off of > 11 was used to define independence.

Table 9.4 Differences in patterns of and PA and sedentary behaviour between participants grouped according to age, gender, whether or not they were deemed to have capacity and physical function†. Data are presented as median (IQR).

	Age		**Gender**		**Capacity**		**Physical function†**	
	< 85 y (n = 71)	**≥ 85 y (n = 107)**	**Male (n = 47)**	**Female (n = 136)**	**Yes (n = 75)**	**No (n = 108)**	**Dependent (n = 96)**	**Independent (n = 87)**
Time accumulated in PA bouts:								
5 - 9 min	39 min (29 min)	33 min (40 min)	37 min (57 min)	34 min (38 min)	44 min (47 min)**	30 min (37 min)**	21 min (32 min)**	47 min (34 min)**
≥ 10min	45 min (1h 56 min)	34 min (1h 6 min)	37 min (1h 21 min)	34 min (1h 22min)	36 min (1h 15 min)	35 min (1h 32 min)	7 min (53 min)**	57 min (1h 52 min)**
Time accumulated in sedentary bouts:								
30 – 59 min	2 h 1min (1h 50 min)	2 h 18min (1h 52 min)	2h 1 min (2h 10min)	2h 12min (1h 46min)	2 h 28 min (1h 33min)*	1 h 52 min (1 h 52 min)*	1 h 41 min (2 h 2 min)**	2 h 32 min (1 h 35 min)**
≥ 60 min	4 h 3 min (4 h 42min)	4 h 23 min (6 h 7min)	5 h 40 min (6h 26 min)	4 h 4 min (5h 24min)	3 h 3 min (4h 55 min)**	4 h 56 min (5h 56 min)**	7 h 1 min (5h 10 min)**	2h 20 min (3h 17 min)**

Significant differences are highlighted with * ($p < 0.05$) or ** ($p < 0.01$)

† Physical function as assessed using the BI. A cut-off of > 11 was used to define independence.

9.4 Discussion

9.4.1 Levels and patterns of physical activity and sedentary behaviour

The primary aim of the current study was to describe the accelerometer-determined levels and patterns of PA and sedentary behaviour in a representative sample of older care home residents. In accordance with previous studies conducted in a care home setting (Leung et al., 2017; Corcoran et al., 2016; Barber et al., 2015), the findings of this study suggest that in general, older care home residents engage in very little PA and spend the majority of their time sedentary. Moreover, the PA residents did engage in was predominantly of low intensity.

Having said this, the heterogeneity of care homes was highlighted in the introduction (**section 9.1**) therefore caution is warranted when making comparisons with existing studies. Arguably, only the study by Barber and colleagues was conducted in a comparable setting (i.e. UK care homes). Compared with residents in Barber's study, those in the current study engaged in a lower volume of PA (mean ± SD: 98,246 counts·day^{-1} ± 104,861 counts·day^{-1} compared to 113,477 ± 88,012 counts·day^{-1}) and spent a greater proportion of their waking time sedentary (87% compared to 79%). The difference in findings reported may be attributable to the difference in the characteristics of the residents included in each of the studies. For example, residents who provided valid accelerometer data in Barber's study were younger (82 y ± 9 y compared to 86 y ± 7 y) and had better physical function (as indicated by scores on the BI: 14 ± 5 compared to 11 ± 5) compared to those in this study.

Although it was anticipated given there was no effect of monitoring day on PA behaviour (**Chapter 6, section 6.3.3.2**), it is important to acknowledge that neither levels of PA nor sedentary behaviour differed across days of the week. It is also worth noting that this finding is in accordance with previous studies conducted in a care home setting (Barber et al., 2015). It may be inferred that the variability in PA across days is likely reduced in care home residents given the functional impairments characteristic of this population and the lack of daily variation in routines for the care home residents (Hawkins et al., 2017; Gordon et al., 2014). However, levels of PA and sedentary behaviour did differ according to time of day. The proportion of time residents spent engaging in PA was lowest in the morning (13%) and increased throughout the day (16% and 19% in the afternoon and evening respectively). Conversely, sedentary time decreased from 87% during the morning hours to 84% and 81% in the afternoon and evening. Whilst it is not entirely clear why there was a difference in levels of PA and sedentary behaviour according to time of day, intra-day variations have been reported previously in studies conducted in a care home setting (van Alphen et al., 2016; Reid et al., 2013). In the current study it may be surmised that the higher levels of PA observed in the afternoon and evening periods may be attributed to peaks in PA typically observed around mealtimes (Breakfast: ≈ 9.30am; Lunch: ≈ 12 pm – 2pm and Dinner: ≈ 4.30 pm – 6 pm) and the fact that organised activities in the care homes involved often took place in the afternoons (typically around 2 pm). Another potential explanation is that residents, particularly those with dementia, became more agitated later in the day and therefore engaged in more PA.

No studies to date have explored the pattern of either PA or sedentary behaviour in a care home population. Hence, one of the novel findings from the current study is that participants spent a considerable amount of time engaging in prolonged periods of sedentary behaviour. Specifically, 21% and 47% of total sedentary time was accumulated in bouts of 30 – 59 min and ≥ 60 min respectively. It is also interesting to note that the contribution of prolonged bouts of sedentary time decreased over the course of the day. For example, 69% of total sedentary time was accumulated in bouts of ≥ 60 min during the morning; however, the contribution of these prolonged bouts decreased to 46% and 32% during the afternoon and evening respectively. These findings are particularly important given emerging evidence suggests that how sedentary time is accumulated may have important consequences in terms of health (Dunstan et al., 2012). Indeed, a recent study found that “breaking up” prolonged periods of sedentary behaviour is associated with better physical functioning in older adults (Sardinha et al., 2015). Whilst further work is warranted to understand why the patterns of sedentary behaviour vary across the day; these findings have important implications in terms of the development of interventions which aim to reduce sedentary behaviour in a care home setting.

One of the most encouraging findings of the present study was that 87% of the time participants spent engaging in PA was accumulated in bouts lasting either 5-9 min (32%) or at least ten minutes (56%). This suggests that one potential strategy for PA interventions in a care home setting could be to encourage residents to increase both the intensity and duration of the PA bouts they are already engaging in with a view to meeting the current recommendations that PA should be of moderate intensity and accumulated in bouts of at least ten minutes in order to accrue health benefits. However, there is a concern that this population group may be fearful of engaging in moderate intensity PA and / or struggle to engage in prolonged bouts of PA (Brawley et al., 2003). Thus, it may be that simply encouraging residents to engage in short bouts of PA of any intensity more regularly in order to interrupt their prolonged periods of sedentary time may be more achievable starting point (Fuzeki et al., 2017). This recommendation is corroborated by a recent cohort study conducted in older men (n = 1,274, mean age: 78 y ± 5 y) which found that engagement in PA, defined as being of at least light intensity, was associated with decreased mortality (Jefferis et al., 2018). Moreover, the authors report that it was simply the total volume of PA rather than the pattern of accrual, which was important in terms of the beneficial association with mortality (Jefferis et al., 2018).

9.4.2 Personal characteristics related to levels and patterns of physical activity and sedentary behaviour

It is important to recognise that older adults, particularly those residing in care homes, are not a homogenous population. It is therefore important to consider the influence of personal factors on PA behaviour. Whilst there was no significant difference in the proportion of waking time spent engaging in PA or sedentary behaviours between those participants aged < 85 y and ≥ 85 y, there was a strong association between age and both PA and sedentary behaviour. This is in accordance with a considerable body of literature which suggests increasing age is accompanied by a decrease in PA and an increase in sedentary time (Arnardottir et al., 2013; Troiano et al., 2008).

In community-dwelling older adults, significant differences in the time spent engaging in PA and sedentary behaviours between men and women have been reported (Aoyagi and Shephard, 2013; Davis et al., 2011). However, this finding was not replicated in the current study. The lack of a difference in PA behaviour between men and women has been reported in care home populations previously (Barber et al., 2015) and may be explained by the culture within care homes. That is, outside of the care home setting men tend to engage in physical tasks of a higher intensity compared to those completed by women; however, in a care home setting daily tasks are not typically part of residents' daily routine.

Not surprisingly, participants who had poorer physical function (as indicated by their scores on the BI) spent less time engaging in PA and more time sedentary compared to their counterparts with superior physical function and better mobility. Perhaps more interesting, particularly given previous studies have reported that individuals with dementia are more sedentary than those without dementia (Marmeleira et al., 2017; van Alphen et al., 2016), was the finding that there was no difference in the levels of PA or sedentary behaviour between those participants considered capacious and those judged as not having the capacity. Having said this, those participants deemed to lack capacity accumulated more of their sedentary time in prolonged bouts (i.e. 30 – 59 min and ≥ 60 min) compared to those with capacity. It may be inferred that those residents who were deemed to lack capacity were those individuals with more severe cognitive impairment and that the higher time spent in prolonged sedentary time may be a consequence of lack of stimulation. However, further work is needed to examine whether this difference is replicated in other samples and if so, to understand why this difference occurs.

9.4.3 Strengths and limitations

The current study has several important strengths. Firstly, and perhaps most importantly is that this study investigates an important health behaviour in a sub-group of the population which is often neglected in research terms because of difficulties surrounding recruitment and 'access' (Kalinowski et al., 2012; Zermansky et al., 2007). The large sample size and minimal missing data is an important advantage over previous studies conducted in a care home setting. Studies presented in this thesis (**Chapter 6**), supported by previous research (Chomistek et al., 2017; Keadle et al., 2014), suggest the validity of estimates of PA and sedentary behaviour are better when derived from triaxial (i.e. VM counts) compared to uniaxial data (i.e. VA counts). Thus, the use of triaxial accelerometer data to derive estimates of PA and sedentary behaviour in the current study is an additional strength. Lastly, the current study builds on existing literature and provides important information regarding the pattern of PA and sedentary behaviour which is invaluable when developing interventions for this population.

Nevertheless, the study was not without limitations and these should be considered when interpreting the results. Whilst accelerometers have emerged as the preferred method of assessing PA and sedentary behaviour in field-based research there are unique challenges associated with their use in a care home population. A substantial amount of work around the methodological issues and practical feasibility of using accelerometers with a care home population was conducted in the studies presented in Chapters 6 - 8 of this thesis. Whilst this work ultimately informed and enhanced the use of the accelerometers in this study, some challenges still persist.

As discussed previously (**Chapter 6, Study 2**), the use of cut-points to quantify PA and sedentary behaviour has become commonplace yet they fail to take into account posture, which is fundamental in the definition of sedentary behaviour (**Chapter 2, section 2.1.2.3**). Furthermore, the position of the accelerometer on the hip means upper body activities and the altered gait pattern characteristic of many care home residents may not be captured as it is likely that the counts recorded fall under the cut-point for sedentary time (i.e. 100 cpm). As a result, it is possible that in the current study estimates of the time participants spent engaging in PA may have been underestimated while sedentary time may have been inflated. Another potential weakness of the present study is the lack of information regarding the time spent engaging in differing intensities of PA. However, in the absence of cut-points deemed appropriate to identify differing intensities of PA in this population and a shift in emphasis towards both reducing the total volume and interrupting prolonged bouts of sedentary behaviour, alternative outcomes (i.e. patterns of PA and sedentary behaviour) were thought to be more relevant.

9.5 Conclusions

The results of this study highlight the fact that as a group, care home residents spend the majority of their time sedentary and the little PA they do engage in is typically of low intensity. Moreover, a considerable proportion of the time participants spent sedentary was accumulated in prolonged bouts of at least 30 minutes, further highlighting the need for interventions targeting PA behaviour in a care home population. Still, it was encouraging that almost three quarters (65%) of the sample did manage to engage in at least 30 minutes of PA daily. Furthermore, the vast majority (87%) of the PA that participants did engage in was accumulated in bouts of at least five minutes which suggests care home residents are capable of engaging in more sustained bouts of PA. Taken together these findings have important implications for the development of interventions in this population group. Nevertheless, it is important to note that care home residents are a particularly heterogeneous group and the levels and patterns of PA and sedentary behaviour were influenced by participants' characteristics and physical function. Consequently, any intervention developed may need to be tailored to specific populations (for example those suffering from cognitive impairment) in order to ensure they are appropriate and effective.

Chapter 10 General Discussion

10.1 Chapter overview

The overarching aim of this doctoral work was to identify an appropriate method of assessing PA and sedentary behaviour in older adults residing in care homes. In order to achieve this aim, seven objectives were outlined:

i. To review a sample of PA and sedentary behaviour assessment methods (identified through a scoping review of the literature, as having potential application in a care home population) in order to determine which method is most appropriate for simultaneously assessing both PA and sedentary behaviour in a care home population (**Chapter 2**).
ii. To synthesise current literature detailing accelerometer use in older adults residing in care homes to gauge what literature already exists and identify gaps in the knowledge base (**Chapter 3**).
iii. To review existing research investigating methodological issues associated with accelerometer use, with a specific focus on studies involving older adults (**Chapter 4**).
iv. To explore the impact of key methodological decisions on accelerometer-determined estimates of PA and sedentary behaviour in older care home residents (**Chapter 6**).
v. To explore the practical issues associated with using accelerometers to measure PA behaviour in field-based research with older care home residents and develop a data collection protocol which is both appropriate to the population and context-specific (**Chapter 7**).
vi. To evaluate the accelerometer data collection protocol developed in a larger, independent sample of care home residents within the context of a cRCT (**Chapter 8**).
vii. To describe the levels and patterns of PA and sedentary behaviour in older care home residents (**Chapter 9**).

Each objective was addressed in a separate chapter and can therefore be considered as distinct pieces of research. Hence, a thorough discussion of the findings, strengths and limitations of the work, along with some preliminary conclusions is provided in each chapter.

Thus, the purpose of this chapter is not to repeat what has already been said but rather to:

a) Summarise and reiterate the key findings from each of the studies within the context of existing research and comment on the implications of these;
b) Critically reflect on the process of conducting research within the context of a care home;
c) Review the overarching limitations of the research presented and provide recommendations for future work

10.2 Summary of key findings and their implications

In **Chapter 2**, a sample of assessment methods, identified through a scoping review of the literature as having potential application in a care home population were reviewed. Based on this review, accelerometers were deemed to be the most promising method. However, the use of accelerometers in field-based research is not as established as other methods (e.g. self-report questionnaires) and it was unclear to what extent these monitors are being used in care home setting. Thus, in **Chapter 3** a systematic review was conducted to identify and synthesise existing literature detailing accelerometer use in older adults residing in care homes.

Eighteen studies were included in the review presented in **Chapter 3**, highlighting that the use of accelerometers to measure PA and sedentary behaviour in older care home residents is increasing. However, it was not possible to draw definitive conclusions regarding the profile of PA behaviour in this group due to the methodological inconsistencies across the included studies. Whilst this might have been anticipated given that several key decisions pertaining to the data collection and processing methods need to be made, the lack of consensus makes it difficult for researchers opting to use accelerometers to make the “correct” decisions (Migueles et al., 2017; Trost et al., 2005). Accordingly, the purpose of **Chapter 4** was to review existing literature regarding the key methodological decisions associated with the use of accelerometers in order to ascertain whether there was any empirical evidence to support particular decisions in older care home residents.

The principal finding from **Chapter 4** was that there is a paucity of high-quality methodological research involving older adults, with no such studies conducted specifically with care home residents. Whilst this goes some way to explaining the absence of a consensus on the “correct” methodological decisions in this population, it was concerning given the literature reviewed suggested the decisions made can have a large impact on the interpretation of the data collected and ultimately on the validity of results (Mâsse et al., 2005). Consequently, **Chapter 6** sought to explore the impact of some of these key methodological decisions on estimates of PA and sedentary behaviour in older adults (including those residing in a care home), with the intention of providing empirical evidence to support their use in the remaining studies presented within this thesis.

The key finding from **Chapter 6** was that the methodological decisions pertaining to the processing, reduction and analysis of accelerometer data do have an impact on the validity and reliability of estimates of PA and sedentary behaviour in older adults, including those residing in care home. This finding has important implications for future studies opting to use accelerometers to measure PA and sedentary behaviour in older care home residents. For example, whilst many studies are increasingly using wrist-worn accelerometers in light of claims of improved compliance, the results from ***Study 1*** demonstrate that in a population of community-dwelling older adults, the validity of estimates of EE derived from activity count data were better when the accelerometer was worn on the hip compared to the wrist. The question therefore is whether more value is attributed to the volume or quality of the data collected. Observations conducted in care homes over the course of this doctoral work suggest that amongst care home residents, compliance may actually be worse with a wrist-worn accelerometer. Residents were often observed fiddling / removing the wrist-worn monitor; whereas residents tended to forget they were wearing a hip-worn monitor, particularly if it was worn underneath clothing. This finding, coupled with the paucity of data on PA and sedentary behaviour in care home residents, suggests greater emphasis should be placed on ensuring high-quality data is being collected in this population. Hence, participants in the remaining studies presented within this thesis were asked to wear a hip-worn accelerometer.

In addition to accelerometer wear location, the effect of the filter used to process the raw accelerometer data (normal vs. LFE) and the activity count value used for analysis (VA vs. VM) were also explored in ***Study 1***. Although both filter and axis had a significant effect on the MET values derived from activity counts recorded by the hip-worn accelerometer, there was little difference in the validity of EE estimates. This finding has two important implications. Frist, the premise underpinning the development of the LFE was that it would be useful when measuring PA in older adults who tend to move slowly as more of the acceleration data is retained (ActiGraph Corporation, 2012). Yet this was not the case in ***Study 1***. In the absence of a substantial improvement in the validity of EE estimates following the application of the LFE filter, the use of the normal filter to process raw accelerometer data was used in the remaining studies presented within this thesis to enable comparison with a wider body of literature. Second, although EE estimates derived from VM counts showed only marginally better agreement with the criterion measure (compared to estimates based on VA counts), this finding adds to the small but increasing body of evidence which supports the recommendation that VM counts (i.e. triaxial data) should be used. Nevertheless, it was felt further work was warranted to corroborate this finding before opting to use VM counts as many studies continue to use uniaxial monitors due to economic reasons. As a result, findings based on VM counts would not (at present) be directly comparable to a considerable body of literature.

Recognising that outcomes other than EE may be more relevant to older care home residents, ***Study 2*** explored the impact of the activity count used for analysis (VA or VM) and epoch length (15 s or 60 s) on the criterion validity of estimates of PA and sedentary time in a sample of care home residents. The key finding from this study was that VM counts showed better agreement than VA counts for the classification of both PA and sedentary behaviour. Whilst this finding was not unexpected given the PA typical of care home residents (e.g. ADL's) likely necessitates more antero-posterior and medio-lateral movements which would only be accounted for by the VM count (Sasaki et al., 2011), it is notable given all of the studies with care home residents conducted to date have used VA counts to derive estimates of PA and / or sedentary behaviour. The other key finding from this study was that there was little difference in the agreement with the criterion measure between the two epoch lengths (15 s and 60 s). This finding was more surprising as it was hypothesised that the use of a shorter epoch would improve the validity of estimates of PA and sedentary time. Having said this, the results are in accordance with the findings of a similar study conducted recently with community-dwelling older adults (Koster et al., 2016). Based on these results, raw activity count data collected in the remaining studies presented in this thesis were aggregated over 60 s epochs and VM counts were used for all analyses.

In adopting a pragmatic approach, ***Study 3*** demonstrated that the minimum accelerometer wear time criteria of eight hours on any four days (not necessarily on a consecutive basis) was sufficient to achieve reliable estimates of key PA outcomes (i.e. counts·minute^{-1}, counts.day^{-1},PA time and sedentary time) in a care home population. The identification of a population-specific minimum wear time criterion has several important implications. First, whilst many studies opt for a seven-day monitoring period with the hope of collecting valid data over seven consecutive days, there is increasing recognition that various factors can impact upon data collection and in many cases, participants are not fully compliant with the data collection protocol . Hence, studies typically apply a minimum wear time criterion. However, the application of a minimum wear time criterion derived from studies involving different populations may result in data being needlessly excluded from analysis which can ultimately effect conclusions made. Thus, determining a population specific minimum wear time criterion is beneficial as it maximises the sample size and subsequently the volume of useful accelerometer data retained in cases where a substantial proportion of participants do not present seven days' worth of data.

Secondly, reducing participant burden is a particularly pertinent consideration in studies with older care home residents given the fragility of the population. With this in mind, a shorter monitoring period may be desirable. Fewer days of monitoring would also decrease the costs associated with data processing as the storage capacity and processing time necessitated would be reduced. This is likely an important consideration for large-scale studies. Having said this, it is important to acknowledge concerns that reducing the monitoring period may lead to inaccurate estimates of PA behaviour if there is considerable variation between days. The pragmatic approach adopted in this study addressed these concerns and ensured a balance between measurement reliability and sample size was achieved. Future studies opting to use accelerometers to measure the PA and / or sedentary behaviour in care home residents can use this wear time criterion and have confidence in the PA outcomes reported.

The studies presented in **Chapter 6** demonstrated that a hip-worn accelerometer could be used to collect valid and reliable data relating to PA and sedentary behaviour in older adults residing in a care home setting. Still, in order to be confident in promoting the use of accelerometers in field-based research with older care home residents, further work to determine the most effective means of maximising accelerometer wear and thus ensure high-quality data on PA and sedentary behaviour is collected in this population was deemed important.

Accordingly, **Chapter 7** adopted a phased, iterative approach, based on key components of the MOST and mHeath Development and Evaluation frameworks, in order to develop a tailored accelerometer data collection protocol for use in field-based research with care home residents. A key feature of this approach was that it provided an opportunity test the protocol in a care home setting therefore refinements made were based on empirical evidence. In addition, the integration of quantitative and qualitative findings ensured a nuanced and comprehensive understanding of the feasibility and acceptability of the accelerometer data collection protocol within the context of care homes was achieved.

The development of an accelerometer data collection protocol which is both context both appropriate to the population and context specific has important implications. In addition to the general challenges associated with the use of accelerometers in field-based research, there are extra challenges specific to a care home population which threaten to undermine the acquisition of data. Thus, a data collection protocol developed based on an awareness of these challenges is likely to optimise data collection. Every effort should be made to optimise accelerometer data collection (irrespective of the study population) as non-compliance is costly in terms of data quality and research budgets. However, this is particularly important in a care home setting given the fragility of the population

Having developed and further refined a data collection protocol through the conceptualisation and optimisation work presented in **Chapter 7**, the next step was to evaluate this protocol in a larger, independent sample of care home residents. Accordingly, **Chapter 8** evaluated the feasibility and acceptability of accelerometer data collection protocol developed within the context of the REACH cRCT.

The “take-home message” from **Chapter 8** was that it is feasible to use accelerometers to measure PA and sedentary behaviour in older care home residents, albeit with specific considerations. Specifically, it appears that a tailored data collection protocol, alongside robust data collection procedures are key to maximising participant compliance and ensuring high quality data on PA and sedentary behaviour are collected in this population. As is the case with any research processes, ‘buy-in’ from key stakeholders (i.e. residents and staff) within the care home also appear to be vital to the ‘successful’ collection of accelerometer data.

As became apparent in **Chapter 3**, few studies conducted with care home residents have reported estimates of time spent engaging in different intensities of PA and sedentary behaviour. In addition, no studies to date have explored the pattern of either PA or sedentary behaviour in a care home population. Thus, the collection of accelerometer data in Chapters 6 – 8 offered an opportunity to address this notable gap in the literature. The data were pooled in **Chapter 9** to form one of the largest accelerometer datasets for care home residents.

In accordance with previous studies, the results presented in **Chapter 9** highlight the fact that as a group, care home residents spend the majority of their time sedentary and the little PA they do engage in is typically of low intensity. Moreover, a considerable proportion of the time participants spent sedentary was accumulated in prolonged bouts of at least 30 minutes. Still, it was encouraging that almost three quarters (65%) of the sample did manage to engage in at least 30 minutes of PA daily. Furthermore, the vast majority (87%) of the PA that participants did engage in was accumulated in bouts of at least five minutes which suggests care home residents are capable of engaging in more sustained bouts of PA. The accelerometer data also provided valuable information on the patterns of PA and sedentary behaviour across a ‘typical day’. Much of the PA residents tended to engage in appeared to be associated with ADLs (i.e. getting out of bed and dressing in the morning and getting ready for bed in the evening) or around mealtimes (i.e. moving to and from the dining room). These findings could be used to prompt discussions with care home residents and staff around how to change the care environment to increase opportunities for PA. Use of commercially available technology (e.g. fitbit) may prompt similar discussion. Simple observation tools could also be used to encourage staff to take a step back and observe the level of PA and sedentary behaviour being undertaken by residents.

Chapter 9 also demonstrated that that care home residents are a particularly heterogeneous group and that the levels and patterns of PA and sedentary behaviour were influenced by participants’ characteristics and physical function. Taken together these findings have important implications for both the development of interventions and the refinement of PA and sedentary behaviour guidelines in this population group. There is unlikely to be one intervention or single recommendation which is appropriate for the ‘whole’ population. For example, one potential strategy for PA behaviour interventions in a care home setting would be to encourage residents to engage in short bouts of PA of any intensity more regularly in order to interrupt their prolonged periods of sedentary behaviour. Alternatively, for some residents it may be appropriate to encourage them to increase both the intensity and duration of the PA bouts they are already engaging in with a view to meeting the current PA recommendations.

10.3 Reflections on undertaking research within a care home setting

It is widely acknowledged that undertaking research in a care home setting poses unique challenges for researchers; yet there has been little discussion about the ‘process’ of conducting care home research within academic literature (Luff et al., 2015). It was therefore deemed important to reflect on the experience of undertaking this doctoral work and discuss some of the key issues pertinent to care home research.

My role and the location of this doctoral work within the REACH programme (**section 1.5, Chapter 1**), meant that I spent a considerable amount of time within the participating care homes over the course of the whole research process (i.e. care home recruitment, participant recruitment and data collection). This time was invaluable as it provided me with the opportunity to orientate myself within a setting often described as complex and to gain a better understanding of the organisation, management and delivery of care. It soon became apparent that whilst there was considerable variation between the care homes involved, the challenges posed by engagement in research and therefore warranting particular consideration were similar across all.

First, although the care home owners and / or managers had agreed to participate in the research, which in turn suggested they appreciated that there were some anticipated benefits of doing so; it was evident that not all care staff shared this view. Some staff articulated that they felt residents were too frail to take part in the research, while others commented that they did not feel the research was relevant to their home as they were already doing all they could to support movement. It also became clear that many staff viewed the researchers as “outsiders” who were out of touch with the realities of a care home setting. Members of the research team got the impression that staff were suspicious of their motives for being there and were fearful that their practices were being scrutinised.

Nonetheless, the research team were conscious that staff are a key feature of any care home and that their engagement was central to the success of the research, particularly given the high levels of dependency amongst residents (Gordon et al., 2014; Rothera et al., 2003). Thus, the researchers were tolerant of hostility and invested a considerable amount of effort in fostering positive relationships with staff. For example, members of the research team attended staff meetings where appropriate and were proactive in introducing themselves and speaking to staff, particularly those they did not recognise, during their visits to the homes. The research team also recognised that care staff were ‘experts’ with regards to things such as the organisational routines of the care home; whether or not something would be acceptable within the home and the needs and preferences of residents. Consequently, whilst mindful not to burden care staff, researchers actively sought their opinions over the course of the research and listened to what they had to say. Importantly, researchers were appreciative of staff input and expressed their gratitude for this both verbally and through “thank you” gestures such as providing biscuits. These “acts” ensured staff felt valued, helped make the researchers more personable and ultimately, meant care staff were more willing to support the research.

Second, it was notable that all of the care homes involved were under considerable pressure to ensure the complex care needs of residents were met. Care homes are regulated by the CQC and whilst the research team was aware of the importance of the CQC inspections, it became apparent that these inspections were a major source of concern for all of the homes involved. Given the implications of these inspections staff energies were often directed towards preparing for imminent or scheduled inspections; ensuring they were fulfilling their requirements and on occasions, addressing concerns expressed in a recently completed inspection. As a result, although the research team had been proactive from the outset in communicating with staff at all levels about the purpose of the research and what the care homes involvement would mean for them, there were times (in all of the homes) where the relevance of the research was, understandably, lost amidst the day-to-day struggle to provide high-quality care. During these times data collection was particularly challenging. Having said this, the researchers' ability to empathise with staff, patience and willingness to work flexibility (i.e. visiting the homes during evenings and at weekends) ensured data was collected in a timely manner with minimal disruption to care home routines and little additional work for care staff.

Third, although members of the research team were aware that care home residents are arguably the frailest segment of the population, the level of dependency, either because of physical or cognitive impairments, was greater than anticipated. It was also noted that in many cases residents were admitted to the care home following a 'crisis' such as a fall, hospital stay or bereavement of an informal caregiver. Nevertheless, recruitment to the REACH feasibility cRCT (**Chapter 8**) was comparable with what has been reported in similar studies (Siddiqi et al., 2016; Underwood et al., 2013). This may be attributed to the comprehensive recruitment strategy employed. Specifically, the recruitment strategy included seeking agreement from personal and nominated consultees; attending residents' and relatives meetings and being readily available to answer any questions residents or consultees had about the research. Whilst lengthy, this approach to recruitment was justified to strengthen both the generalisability and validity of the research given a considerable proportion of care homes residents are likely to experience some degree of cognitive impairment which would preclude them from providing informed consent (Stewart et al., 2014).

Finally, whilst not surprising given the care home setting has largely been neglected in research terms, it is important to reflect on the fact that the majority of care home staff (including managers) were unfamiliar with research processes (e.g. randomisation, 'blinding' of researchers etc). Moreover, the use of accelerometers to measure PA in this population group is novel. As a result, it soon became clear that more support from the research team than was originally proposed was necessary in order to ensure high-quality data was collected.

10.4 Limitations of the research presented in this thesis and recommendations for future work

As with any research this doctoral work is not without limitations. The first relates to the use of a fixed, absolute intensity cut-point to derive estimates of time spent engaging in PA and sedentary behaviours. Whilst this approach has been used almost exclusively in field-based research with older adults (Gorman et al., 2014); its applicability in a care home population may be questioned. Based on previous research, it may be surmised that the use of an absolute intensity cut-point may have resulted in estimates of PA time being underestimated while sedentary time estimates may have been inflated (Zisko et al., 2017; Evenson et al., 2012). This is because the absolute PA cut-point may have been unattainable for those residents with poorer physical function and lower CRF given the relative effort required to perform PA is higher for them (Ozemek et al., 2013; Miller et al., 2010).

Ideally, an individualised cut-point would allow for the most accurate estimates of PA and sedentary behaviour (Rejeski et al., 2016; Zisko et al., 2015; Pruitt et al., 2008). However, due to time constraints and the lack of the necessary equipment, this was not possible in the current thesis. Future studies with older care home residents could look to calibrate individually tailored cut-points. However, given the adoption of an individualised approach is unlikely to be feasible in large epidemiological studies due to the aforementioned issues, an evaluation of the validity of relative intensity thresholds (such as those recently developed by Zisjo and colleagues in an elderly population aged between 70 y and 77 y [n = 111]) in older care home residents may be more relevant.

As alluded to previously, another limitation associated with the use of a single cut-point to distinguish between PA and sedentary behaviour is that it prevented the classification of PA intensities (i.e. light or moderate). Given the increasing emphasis on the benefits of light intensity PA it could be argued that this is a notable drawback of this doctoral work. However, few calibration studies have been conducted using tri-axial accelerometers and none have been conducted specifically with older care home residents. In the absence of empirical evidence to support the superiority of a particular set of cut-points, the single cut-point used in this doctoral work was chosen as it was the first one calibrated for vector magnitude (VM) data in a sample of older adults and it has been used in other studies (Lee et al., 2018b; Chomistek et al., 2017; Aguilar-Farias et al., 2014). Having said this, more recent calibration studies have yielded VM cut-points for light and moderate intensity PA (notably those developed by Zisjo and colleagues referred to above) therefore future studies in care home residents could look to apply these if deemed to be valid in this population.

It is also important to acknowledge that sedentary behaviour was not measured in accordance with the conceptual definition outlined in **Chapter 2**. Having said this, a consensus regarding this definition has only recently emerged and capturing both components (EE and posture) represents a significant challenge (Tremblay et al., 2017; Biddle and Bennie, 2017; Kang and Rowe, 2015). Given the focus of the current thesis is on the measurement of PA, the use of an EE device (the ActiGraph) was deemed the most pragmatic option. However, given the profile of PA behaviour of care home residents it may be that the emphasis of future work should be on exploring the measurement of sedentary behaviour in this population.

In addition, although the pooled accelerometer data set represents one of the largest to date in this population, the variable and in some cases, small number of residents providing valid accelerometer data in each of the homes meant it was not possible to conduct sub-group analyses to investigate environmental and organisational factors relating to levels and patterns of PA and sedentary behaviour in this population. Further work to explore these relationships is needed as expanding current understanding of these relationships would help inform intervention development.

Finally, it is also important to recognise that this doctoral work was conceptualised in 2013 and inevitably the research agenda has progressed over time. Of particular note is the growing recognition that a lack of consensus about how best to define and assess validity and reliability has led to confusion within the field and in some cases, the selection of an inappropriate assessment method. In response, frameworks for establishing feasibility, validity and reliability of PA and sedentary behaviour assessment methods have emerged (Kelly et al., 2016; Keadle et al., 2019). One of these frameworks, The Edinburgh Framework put forward by Kelly and colleagues in 2016, is particularly pertinent to this doctoral work and is therefore presented for information in **Appendix Q**. The framework offers a structured and standardised way of considering the different aspects of measurement validity and reliability (Kelly et al., 2016). It may be surmised therefore, that future studies considering PA and sedentary behaviour assessment methods should consider adopting a methodological framework such as the Edinburgh Framework.

10.5 Concluding remarks

Undertaking research in care homes, whilst challenging, is extremely important as care homes will remain a key component of the services available to support older people going forward. As in any setting, engagement in research will help enhance the care setting. Notably, improvement in care may result from both the research procedures (for example, improving methods of collecting routine data in care homes) and the research outputs. Given the fragility of residents and complexity of the setting it is imperative that we continue to build on existing knowledge.

To summarise, the overarching aim of this doctoral work was to identify and evaluate an appropriate method of assessing PA and sedentary behaviour in older adults residing in care homes. Encouragingly, the studies presented within this thesis have demonstrated that a hip-worn accelerometer can be used to collect valid and reliable data relating to PA and sedentary behaviour in field-based research with older care home residents. In addition, the accelerometer data collated represents one of the largest datasets for care homes residents and thus provides unique insights into the levels and patterns of both PA and sedentary behaviour in this population.

Evidently, this doctoral work makes a significant contribution to the literature on measuring PA and sedentary behaviour in older care home residents. Notably, this work also had implications for community-dwelling older adults. However, research is still required in order to establish specific, standardised guidelines for collecting and processing accelerometer data in older adults, including those residing in care homes. Further work is also needed in order to determine how best to analyse and interpret the vast amount of data collected by accelerometers to ensure the outcomes most relevant to special populations such as care home residents are reported on. It is hoped that that this doctoral work represents an important starting point that can be used as an impetus for further research on a topic of great importance.

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Appendices

Appendix A: Extract from NIHR Programme Development Grant Final Report Form: Development and testing of strategies to enhance physical activity in care homes: a feasibility study (RP-DG-0709-10141)

CLARIFICATION OF MEASUREMENTS

We sought to clarify appropriate tools for the assessment of physical activity in a frail care home population.

Methods

Following a review of the literature and advice from an Expert Seminar (led by Mark Davis University of Bristol) we undertook preliminary assessment of instruments to measure physical activity (PA) and sedentary behaviour. The following were assessed.

1. Ambulatory monitors:
    - Two accelerometers (hip-mounted ActiGraph GTX-3; wrist-mounted ActiGraph GTX-3: Actigraph, Florida, USA)
    - Gyroscope (ActivPAL:PAL technologies Ltd Glasgow, UK)
    - Pedometer (NL-1000:New Lifestyles Inc Missouri, USA)
2. Physical activity scale for the elderly (PASE) questionnaire (Washburn et al., 1993)
3. 24-hour activity diary completed by the care home activity co-ordinator

All four ambulatory monitors were worn simultaneously by participants during a series of pre-selected fixed activities and over a two hour free living period. An independent researcher undertook direct observations as the criterion method. Fixed activities included sitting, a card game, clapping hands, throwing game and walking (20 minutes in total). In the free living condition participants were instructed to continue their usual routines. At the conclusion of the assessment period a structured proforma was completed by participants and staff to illicit views about observation and wearing the monitors. The best monitor in terms of validity and acceptability was then tested for feasibility over a 5-day period. The PASE was administered to residents in the form of an interview and the activity coordinator employed by the care home completed an activity diary for these residents.

In order to gain insight into the challenges of assessment tools in this population a sample of residents completed the Barthel index (BI) of daily living (Mahoney and Barthel, 1965), the EQ-5D) (3), the Short-Form 12 Health Survey (SF-12) (Ware Jr et al., 1996) and a timed Up and Go test (TUGT) (Podsiadlo and Richardson, 1991) to assess quality of life and functional ability respectively. The acceptability of these measures to residents' was determined using a structured proforma.

Management and analysis of data

The independent observer recorded steps taken, time spent upright and seated, number of transfers (sit to stand and stand to sit), types of activity and time spent in MET compendium (Ainsworth et al., 2011) evaluated categories of Physical Activity (PA) intensity (sedentary-moderate). The PAL, pedometer and

ActiGraphs recorded steps taken. The PAL also recorded time spent seated, or upright and number of transfers. The ActiGraph accelerometers recorded movement counts in 15 s epochs that were then converted to time spent sedentary (<100 counts per minute (cpm)), in low PA, (100-759 cpm (Hansen et al., 2012; Matthews et al., 2008; Healy et al., 2007)), light PA (760-2019 cpm (Hansen et al., 2012; Hagströmer et al., 2010; Matthews et al., 2008)) and in moderate PA (≥ 2020 cpm (Hansen et al., 2012; Troiano et al., 2008)). We have chosen to title counts of 760-2019 as light rather than lifestyle as previously described (Hansen et al., 2012) as this is more appropriate for care home residents who do not engage in lifestyle activities (e.g. grocery shopping, vacuuming and child care). Agreement, sensitivity and predictive value of each of the monitors were assessed in comparison to scores derived from the observation. Magnitude of agreement was evaluated using Bland Altman (Bland and Altman, 1986), whilst percentage of agreement was determined as the number of identical scores for observation and monitor * 100 / total number of scores. Sensitivity was the degree to which each observed PA (steps, postures, or activity intensities) was detected correctly by the monitor: number of identical scores for observation and monitor *100 / total number of observations. Predictive value was the degree to which each PA detected by the monitor agreed with the observed PA: number of identical scores for observation and monitor *100 / total number of samples of the PA from monitor (Grant et al., 2006).

The 5-day data from the hip-ActiGraph was assessed for valid wear time (>10 hours on 5 consecutive days wear or >10 hours on 6 random days (Hart et al., 2011b)) and acceptability were assessed using the structured proforma with participants and staff. A Spearman's correlation between PASE score and average daily time spent in PA determined by the 5-day monitoring was conducted. Activity diaries were compared to average daily time spent sedentary, in low, light and moderate PA determined by the 5-

day monitoring and mean differences, upper and lower limits of agreement were determined using the method of Bland Altman (Bland and Altman, 1986). The acceptability of the, BI, EQ-5D, SF-12 and the TUGT were determined by examining response rates for completion of the questionnaires, missing data and administration time. Pearson's correlations time spent in different activity intensities from the 5-day accelerometry data and the BI and TUGT were conducted.

Participants

Participants (aged 83.2 ± 8.5 years) were 17 female and 3 male care home residents and ranged from normal to severe dysfunction in ambulatory ability (Holden et al., 1984) and from normal to moderate dysfunction in cognitive function (Folstein et al., 1975). Residents were excluded if they had severe hearing impairment or lacked capacity to consent. Informed consent was obtained from all participants.

Results

Data are displayed in Tables 1-6 and Figure 1 in the Appendix. Ten residents participated in assessment of the ambulatory monitors. Staff and residents had no objections to the observations, but steps were difficult to count because of the shuffling gait pattern of residents. Observation was possible within the communal areas of the care home; however, for reasons of privacy, the observer did not record activity related to personal care. The NL-1000 could not be worn by 3 women as they were wearing dresses without waistbands. However, for the purpose of data collection, the NL-1000 was attached to the belt of the ActiGraph monitor and data was collected for these participants. During the free living condition, one participant removed the hip-ActiGraph and 2 removed the wrist-ActiGraph reporting they were uncomfortable and in the way. Three other participants were also observed fiddling with the wrist-ActiGraph. Care home staff were concerned about the method of attachment to the leg of the PAL and worried about irritation and damage to the skin of participants. One participant refused to wear the PAL. Once the PAL was attached participants did not fiddle with or remove them. There were no instances of damaged or irritated skin.

During the fixed activities, there were large discrepancies between steps counted by all of the ambulatory monitors and the observed steps counted. Monitors counted on average between 280 and 60 fewer steps during a 5 minute walk compared to observations (Table 1). Thus, the NL 1000 was eliminated as a candidate measure after the fixed activity condition and step count was not assessed during the two hour free living condition. Further to this, the wrist ActiGraph was also eliminated as a candidate measure as it had wide limits of agreement during both fixed and free living conditions and had lower % agreement, % sensitivity and % predictive compared to the PAL and hip ActiGraph (Table 2).

Throughout the fixed activity condition the PAL displayed the strongest agreement with observed time spent sedentary (mean difference compared to observation = 0, Table 3). It also had a high magnitude of agreement with observed time upright and transfers (mean difference compared to observation = -0.02 minutes and -0.05 times respectively, Table 3). The hip-ActiGraph also had a high magnitude of agreement for sedentary time (mean difference compared to observation = 0.49 minutes) and moderate magnitude of agreement with time spent in low intensity PA (mean difference compared to observation = -0.2 minutes; Table 4).

Overall, within the free living period the percentage of agreement between all observed scores and the hip-ActiGraph and PAL scores were similar and high (96% and 95% respectively). However, the magnitude of agreement with observed sedentary time was greater with the hip-ActiGraph compared to the PAL (mean difference = 0.46 and 2.76 minutes respectively). The % sensitivity and % predictive was high and similar for sedentary time between the hip-ActiGraph and the PAL; % sensitivity = 96% and 98% respectively, and % predictive = 97% and 109% respectively. The PAL had a high magnitude of agreement with observed time upright and transfers (mean difference = 0.04 minutes and -0.21 times respectively). Predictive value was high (77% and 110% respectively for upright time and transfers), however, sensitivity for upright time and transfers was only moderate (66% and 65% respectively). The hip-ActiGraph had a high magnitude of agreement with time spent in low PA (mean difference = -0.46 minutes) and the sensitivity and predictive value of the hip-ActiGraph for low PA was high (80% and 71% respectively). Two participants performed light intensity PA during the 2-hour free living period and the hip-ActiGraph accelerometry counts (760 – 2019) agreed with the observation.

The hip-ActiGraph was thus chosen as the monitor best suitable and most accurate for the 5-day feasibility study.

Seven residents participated in the 5-day feasibility study of the hip-ActiGraph. This revealed that mean daily time in sedentary behaviour was 13.7 ± 4.2 hours; in low intensity PA, 54.6 ± 41 minutes; in light PA, 9.32 ± 8.6 minutes; and in moderate-vigorous PA, 1.6 ± 1.1 minutes. When counts were plotted against time on each day for each individual, there was an emerging pattern of PA based around routines in the home (getting up, meal times and going to bed; Figure 1). Residents and care staff were able to follow the prescribed protocol for the 5 day data collection. Six out of seven participants had the sufficient wear time for valid data; one participant required a further day of data collection. All residents reported that once on, they forgot they were wearing the monitor.

The correlation between the PASE score and mean daily PA determined by the hip-ActiGraph was low (r = 0.22). Comparison of the activity diary to the hip-ActiGraph revealed wide limits of agreement for sedentary, low PA and light PA (Table 5).

Twenty residents agreed to complete the BI, EQ5-D and SF-12. Half of the participants required some assistance from a member of staff for completion of the BI, EQ5-D and SF-12 questionnaires. In the EQ5-D 28% of participants reported uncertainty in answering question 1 (mobility), and 11% reported uncertainty with question 5 (depression). Eighty three percent reported that questions 2 & 3 (moderate PA) of the SF-12 were inappropriate for care home residents. With support from a member of staff completion rates were high, fatigue was low and administration time was acceptable for the BI and EQ-5D (Table 6). The SF-12 was not feasible even with carer support (Table 6). Eight participants (40%) refused to complete the TUGT; reasons included lack of motivation, pain, and illness. Five participants were unable to complete the test as they required assistance. Time spent sedentary (from the 5-day accelerometer data) correlated with the BI ($r = -0.96$, $p < 0.01$). There were no other correlations between time spent in different activity intensities and BI or TUGT.

Appendix: Tables of results for the clarification of measures (section 7).

Table 1: Steps counted by activity monitors compared to observation in a "fixed activity" 5 minute walk.

	NL-1000	ActiGraph wrist	ActiGraph hip	PAL
Mean difference (steps)	- 280	- 233	- 299	- 60
Upper limit of Agreement (steps)	- 69	- 94	-127	90
Lower limit of Agreement (steps)	- 491	- 372	- 471	- 210
Pearson's correlation	0.27	0.62	0.27	0.9

Table 2: Magnitude and percentage agreement, sensitivity and predictive value for the wrist-ActiGraph during fixed and free living conditions

	Fixed activity	Free living
Mean difference sedentary time (mins)	-0.95	-3.26
Upper limit of agreement sedentary time (mins)	1.89	19.25
Lower limit of agreement sedentary time (mins)	-3.79	-25.77
Pearson's correlation sedentary time	0.61	0.74
Mean difference low time (mins)	3.12	-0.44
Upper limit of agreement low time (mins)	24.44	1.69
Lower limit of agreement low time (mins)	-18.11	-2.57
Pearson's correlation low time	0.5	0.65
% agreement		66
% sensitivity for sedentary time		52
% sensitivity for low time		51
% predictive value for sedentary time		73
% predictive value for low time		12

Table 3: Magnitude and percentage agreement, sensitivity and predictive value for the PAL during fixed and free living conditions

	Fixed activity	Free living
Mean difference sedentary time (mins)	0	2.76
Upper limit of agreement sedentary time (mins)	0	12.11
Lower limit of agreement sedentary time (mins)	0	6.59
Pearson's correlation sedentary time	1	0.97
Mean difference upright time (mins)	-0.02	0.04
Upper limit of agreement upright time (mins)	0.13	0.21
Lower limit of agreement upright time (mins)	-0.17	-0.13
Pearson's correlation upright time	1	0.94
Mean difference transfers	-0.05	-0.21
Upper limit of agreement transfers	0.39	1.65
Lower limit of agreement transfers	-0.49	-2.07
Pearson's correlation transfers	0.93	0.98
% agreement		95
% sensitivity for sedentary time		98
% sensitivity for upright time		66
% sensitivity for transfers		65
% predictive value for sedentary time		109
% predictive value for upright time		77
% predictive value for transfers		110

Table 4: Magnitude and percentage agreement, sensitivity and predictive value for the hip-ActiGraph during fixed and free living conditions

	Fixed activity	Free living
Mean difference sedentary time (mins)	-0.13	0.46
Upper limit of agreement sedentary time (mins)	1.17	3.7
Lower limit of agreement sedentary time (mins)	-1.43	-2.78
Pearson's correlation sedentary time	0.73	0.99
Mean difference low time (mins)	-0.20	-0.46
Upper limit of agreement low time (mins)	0.8	2.85
Lower limit of agreement low time (mins)	-1.2	-3.77
Pearson's correlation low time	0.92	0.91
% agreement		96
% sensitivity for sedentary time		96
% sensitivity for low time		80
% predictive value for sedentary time		97
% predictive value for low time		71

Table 5: Daily physical activity and sedentary time recorded by activity diaries compared to accelerometer

	Sedentary time in hours	Low PA time in hours	Light PA time in mins	Moderate PA time in mins
Mean difference	-0.53	0.44	1.01	-0.13
Upper limit of agreement	3.53	3.4	10.4	0.92
Lower limit of agreement	-4.59	2.47	-8.35	-1.18
Pearson's correlation	0.41	0.71	0.67	0

Appendix B: Search strategy for systematic review

Ovid Medline:

1. Nursing home/
2. nursing home*.tw.
3. Long-Term Care/
4. ((geriatric or elderly or convalescent or retir* or life care or continuing care) adj5 (facility or facilities or institution* or home* or residence* or centre* or center*)).tw.
5. ((long-term care or longterm care) adj2 (facilit* or institution* or setting* or resident* or provision)).tw.
6. (long-stay adj2 (facilit* or institution* or resident*)).tw.
7. (Institutionali* or institutional care or nursing facilit* or LTCF or care home* or rest home* or formal care or dementia care unit*).tw.
8. residential facilities/
9. ((skilled or intermediate) adj2 (nursing facility or nursing facilities)).tw.
10. intermediate care facilities/
11. skilled nursing facilities/
12. Institutionalization/
13. Assisted Living Facilities/
14. assisted living.tw.
15. ((extended care adj2 facility) or facilities).tw.
16. sheltered care.tw.
17. (healthcare adj2 (facility or facilities)).tw.
18. or/1-17 [care home terms]
19. exp aged/
20. Geriatrics/
21. Geriatric Nursing/
22. health services for the aged/
23. exp Medicare/
24. Geriatric Assessment/
25. (geriatr* or elder* or gerontolo* or seniors or senior citizen* or pensioner* or later life).tw.
26. (older adj (person or people or adult* or patient* or inpatient* or resident* or men or women)).tw.
27. (ageing or aging or "65+" or "70+" or "75+" or "80+" or "very old" or "oldest old").tw.

28. (over adj2 ("65" or "66" or "67" or "68" or "69" or "70" or "71" or "72" or "73" or "74" or "75" or "76" or "77" or "78" or "79" or "80" or "81" or "82" or "83" or "84" or "85" or "86" or "87" or "88" or "89" or "90" or "91" or "92" or "93" or "94" or "95" or "96" or "97" or "98" or "99" or "100") adj years).tw.
29. (("65" or "66" or "67" or "68" or "69" or "70" or "71" or "72" or "73" or "74" or "75" or "76" or "77" or "78" or "79" or "80" or "81" or "82" or "83" or "84" or "85" or "86" or "87" or "88" or "89" or "90" or "91" or "92" or "93" or "94" or "95" or "96" or "97" or "98" or "99" or "100") adj "years or over").tw.
30. (("65" or "66" or "67" or "68" or "69" or "70" or "71" or "72" or "73" or "74" or "75" or "76" or "77" or "78" or "79" or "80" or "81" or "82" or "83" or "84" or "85" or "86" or "87" or "88" or "89" or "90" or "91" or "92" or "93" or "94" or "95" or "96" or "97" or "98" or "99" or "100") adj "years and over").tw.
31. or/19-30 [old people]
32. 18 and 31 [care home and old people]
33. Homes for the Aged/
34. (aged adj5 (care or nursing or healthcare or residential) adj5 (facility or facilites or setting* or provision* or institution*)).tw.
35. or/33-34 [old age care homes]
36. 32 or 35 [all old people care home terms]
37. Exercise/
38. Motor Activity/
39. Physical Fitness/
40. Locomotion/
41. Energy Metabolism/
42. (physical activit* or exercise* or ambulatory activit* or physical exertion* or energy expenditure or movement).tw.
43. Sedentary Lifestyle/
44. sedentariness.tw.
45. ((sedentary or sitting or seated) adj5 (behavio* or lifestyle or life-style)).tw.
46. ((sitting or sit or seated or stationary or standing) adj3 (task* or time or bout*)).tw.
47. ((light or low) adj physical activ*).tw.
48. physical* inactiv*.tw.
49. low energy expenditure.tw.
50. passive standing.tw.
51. activ* count*.tw.

Appendix C: Ethical approval letter (Study 1, Chapter 6)

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
101 Clarendon Road
Leeds LS2 9LJ Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Biological Sciences Faculty Research Ethics Committee
University of Leeds

Jennifer Airlie
Centre for Sport and Exercise Science, School of Biomedical Science
Faculty of Biological Sciences
University of Leeds
Leeds LS2 9JT

29th January 2014

Dear Jennifer

Title of study: **Validation of the ActiGraph physical activity monitor worn on the wrist in community dwelling older adults.**
Ethics reference: **BIOSCI 13-022**

I am pleased to inform you that the above research application has been reviewed by the Faculty of Biological Sciences Research Ethics Committee and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	*Version*	*Date*
Health Status Questionnaire.doc	1	17/01/14
BIOSCI 13-022_Summary Response to ethics.doc	1	17/01/14
W VAL_PIS_OAs_V1.1.docx	1	17/01/14
Ethical Review Form_amended version.docx	1	17/01/14
W VAL_PIS_YA_V1.1.docx	1	17/01/14

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Karen Clinton

Administrative Support Officer, Research & Innovation Service

On behalf of Karen Birch, Chair, BIOSCI Faculty Research Ethics Committee

CC: Student's supervisor

Appendix D: Ethical approval letter (REACH, WS 2)

Health Research Authority

NRES Committee Yorkshire & The Humber - Bradford
Yorkshire & Humber REC Office
Millside
Mill Pond Lane
Meanwood
Leeds
LS6 4RA

Telephone: 0113 3050128

20 February 2013

Professor Anne Forster
Academic Unit of Elderly Care and Rehabilition,
Bradford Institute for Health Research,
Temple Bank House,
Bradford Royal Infirmary,
Duckworth Lane
BD9 6RJ

Dear Professor Forster

Study title:	**Exploration of routine physical activity in care homes and evaluation of assessment tools.**
REC reference:	**12/YH/0564**
IRAS project ID:	**107873**

Thank you for your letter of 27 December 2012, responding to the Committee's request for further information on the above research and submitting revised documentation. Further to your response an expert opinion was obtained which confirmed that the study meets the requirements of the MCA.

The further information was considered by a sub-committee of the REC at a meeting held on 19^{th} February. A list of the sub-committee members is attached.

We plan to publish your research summary wording for the above study on the NRES website, together with your contact details, unless you expressly withhold permission to do so. Publication will be no earlier than three months from the date of this favourable opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to withhold permission to publish, please contact the Co-ordinator Mrs Rachel Bell, nrescommittee.yorkandhumber-bradford@nhs.net.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Mental Capacity Act 2005

I confirm that the committee has approved this research project for the purposes of the Mental Capacity Act 2005. The committee is satisfied that the requirements of section 31 of the Act will be met in relation to research carried out as part of this project on, or in relation to, a person who lacks capacity to consent to taking part in the project.

Ethical review of research sites

NHS sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Non-NHS sites

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.</u>

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

1. The Committee seek confirmation that a consultee will be sought if a participant loses capacity.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

You should notify the REC in writing once all conditions have been met (except for site approvals from host organisations) and provide copies of any revised documentation with updated version numbers. The REC will acknowledge receipt and provide a final list of the approved documentation for the study, which can be made available to host organisations to facilitate their permission for the study. Failure to provide the final

versions to the REC may cause delay in obtaining permissions.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	*Version*	*Date*
Advertisement	1.0	31 December 2012
Covering Letter		01 January 2013
Interview Schedules/Topic Guides	1.0	31 December 2012
Investigator CV		02 January 2013
Other: Summary CV for student - Jennifer Airlie		02 January 2013
Other: Activity monitor instructions		31 December 2012
Other: information sheet for personal consultee interviews & consultee declaration form	1.0	31 December 2012
Other: interview sheet for personal consultee - activity monitors	1.0	31 December 2011
Other: Activity monitor log	1.0	31 December 2012
Other: proposed sites	1.0	31 December 2012
Participant Consent Form: consent form for care home manager	1.0	31 December 2012
Participant Consent Form: consent form for care home staff - interviews	1.0	31 December 2012
Participant Consent Form: consent form for residents interviews	1.0	31 December 2012
Participant Consent Form: consent form for residents individual observations	1.0	31 December 2012
Participant Consent Form: consent form for residents activity monitors	1.0	31 December 2012
Participant Consent Form: consent form for residents wireless	1.0	31 December 2012
Participant Consent Form: consent form for friends, relatives interviews	1.0	31 December 2012
Participant Consent Form: Individual observations	2.0	31 January 2013
Participant Information Sheet: information leaflet for relatives and friends - interviews	1.0	31 December 2012
Participant Information Sheet: information leaflet for residents - individual observations	1.0	31 December 2012
Participant Information Sheet: information leaflet for residents - interviews	1.0	31 December 2012
Participant Information Sheet: information leaflet for residents - activity monitors	1.0	31 December 2012
Participant Information Sheet: information leaflet for residents - wireless	1.0	31 December 2012
Participant Information Sheet: information sheet - care home staff - interviews	1.0	31 December 2012
Participant Information Sheet: information sheet - care home manager	1.0	31 December 2012
Participant Information Sheet: Individual observations	2.0	31 January 2013
Protocol	1.0	24 December 2012
REC application	1	02 January 2013

Referees or other scientific critique report		31 March 2011
Response to Request for Further Information		27 December 2012

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document *"After ethical review – guidance for researchers"* gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

Feedback

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

Further information is available at National Research Ethics Service website > After Review

12/YH/0564	**Please quote this number on all correspondence**

We are pleased to welcome researchers and R & D staff at our NRES committee members' training days – see details at http://www.hra.nhs.uk/hra-training/

With the Committee's best wishes for the success of this project.

Yours sincerely

RBell

Pp Dr Ian Woollands
Chair

Email:nrescommittee.yorkandhumber-bradford@nhs.net

Enclosures: *List of names and professions of members who were present at the meeting and those who submitted written comments*

"After ethical review – guidance for researchers"

Copy to: *Jane Dennison, Bradford Teaching Hospitals NHS Foundation Trust*

Appendix E: Ethical approval letter (REACH, WS 4)

Health Research Authority

NRES Committee East of England - Essex
The Old Chapel
Royal Standard Place
Nottingham
NG1 6FS

Telephone: 0115 8839695

03 November 2014

Professor Anne Forster
Professor of Stroke Rehabilitation
University of Leeds
Academic Unit of Elderly Care and Rehabilition, Bradford Institute for Health Research,
Temple Bank House, Bradford Royal Infirmary, Duckworth Lane
Bradford
BD9 6RJ

Dear Professor Forster

Study title:	**Evaluation of outcome assessment tools in care homes in the context of a service improvement initiative to reduce sedentary behaviour and improve physical activity**
REC reference:	**14/EE/1169**
IRAS project ID:	**161715**

Thank you for your letter of , responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to make a request to postpone publication, please contact the REC Manager, Helen Wakefield, at nrescommittee.eastofengland-essex@nhs.net.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Mental Capacity Act 2005

I confirm that the committee has approved this research project for the purposes of the Mental

Capacity Act 2005. The committee is satisfied that the requirements of section 31 of the Act will be met in relation to research carried out as part of this project on, or in relation to, a person who lacks capacity to consent to taking part in the project.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database within 6 weeks of recruitment of the first participant (for medical device studies, within the timeline determined by the current registration and publication trees).

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non clinical trials this is not currently mandatory.

If a sponsor wishes to contest the need for registration they should contact Catherine Blewett (catherineblewett@nhs.net), the HRA does not, however, expect exceptions to be made. Guidance on where to register is provided within IRAS.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Ethical review of research sites

NHS sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	*Version*	*Date*
Copies of advertisement materials for research participants	v1.0	15 September 2014
Covering letter on headed paper		
Instructions for use of medical device [Activity Monitor Care (Wrist)]	2.0	30 September 2014
Instructions for use of medical device [Activity Monitor Care (Waist)]	2.0	30 September 2014
Letter from funder [NIHR Programme Grants for Applied Research]		25 September 2012
Letters of invitation to participant [Letter to relatives re assent]	v1.0	15 September 2014
Letters of invitation to participant [Reply slip for relatives re assent]	v1.0	15 September 2014
Letters of invitation to participant [Follow up letter to relatives re assent]	v1.0	15 September 2014
Other [Activity Monitor Log]	2.0	31 October 2014
Other [NIHR Programme Grants Assessment Template]		31 March 2011
Participant consent form [Consent Form for Residents - Action Groups]	2.0	31 October 2014
Participant consent form [Consent Form for Staff - Action Groups]	2.0	31 October 2014
Participant consent form [Consent Form for Individual Observations - Visiting Relatives]	2.0	31 October 2014
Participant consent form [Consent Form for Relatives - Action Groups]	2.0	31 October 2014
Participant consent form [Consent Form for Individual Observations - Staff]	2.0	31 October 2014
Participant consent form [Consent Form for Care Home Managers]	2.0	31 October 2014
Participant consent form [Consent Form for Residents - Individual Observations]	2.0	31 October 2014
Participant consent form [Consent Form for Residents - Wireless]	2.0	31 October 2014
Participant consent form [Consent Form for Residents - Activity Monitors]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Staff Action Groups]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Individual Observations - Visiting Relative]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Residents - Wireless]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Care Home Managers]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Residents - Individual Observations]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Residents - Activity Monitors + Qs]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Residents - Action Groups]	2.0	31 October 2014

Participant information sheet (PIS) [Information Sheet for Consultees]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Relatives Action Groups]	2.0	31 October 2014
Participant information sheet (PIS) [Information Sheet for Individual observations - Staff]	2.0	31 October 2014
REC Application Form [REC_Form_16092014]		16 September 2014
Referee's report or other scientific critique report [Rp-PG-1210-12017]		
Research protocol or project proposal	2.0	31 October 2014
Summary CV for Chief Investigator (CI)		22 July 2014
Summary CV for student [Jennifer Airlie CV]		21 May 2013
Validated questionnaire [Six Item Cognitive Impairment Test (6CIT)]		
Validated questionnaire [Physical Activity in Care Homes Questionnaires]		
Validated questionnaire [Benjamin Rose Nurse Assistant Job Satisfaction Scale]		
Validated questionnaire [Elderly Mobility Scale (EMS)]		
Validated questionnaire [ICECAP-O About Your Quality of Life Questionnaire]		
Validated questionnaire [Barthel ADL Index]		
Validated questionnaire [Geriatric Depression Scale (GDS)]		
Validated questionnaire [Ageing Well Profile]		
Validated questionnaire [DEMQOL - Carer (version 4)]		
Validated questionnaire [The World Health Organisation Quality of Life (WHOQOL) - BREF]		
Validated questionnaire [CASP-19 Questionnaire]		
Validated questionnaire [EQ-5D-Y Health Questionnaire]		
Validated questionnaire [DEMQOL (version 4)]		
Validated questionnaire [The Residential Environment Impact Survey (REIS)]		

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document *"After ethical review – guidance for researchers"* gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol

- Progress and safety reports
- Notifying the end of the study

The HRA website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website:
http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/

HRA Training

We are pleased to welcome researchers and R&D staff at our training days – see details at
http://www.hra.nhs.uk/hra-training/

14/EE/1169	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project.

Yours sincerely

pp

Dr Alan Lamont
Chair

Email:nrescommittee.eastofengland-essex@nhs.net

Enclosures: "After ethical review – guidance for researchers"

Copy to: *Ms Jane Dennison, Bradford Teaching Hospitals NHS Foundation Trust*

Appendix F: Ethical approval letter (REACH cRCT)

NHS
Health Research Authority
NRES Committee East of England - Norfolk
The Old Chapel
Royal Standard Place
Nottingham
NG1 6FS

Telephone: 0115 883 9525

27 March 2015

Professor Anne Forster
Bradford Institute for Health Research
Temple Bank House
Bradford
BD9 6RJ

Dear Professor Forster

Study title:	**REACH: Research Exploring physical Activity in Care Homes**
REC reference:	**15/EE/0125**
IRAS project ID:	**172884**

Thank you for your letter of 25 March 2015, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Lead Reviewer.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this favourable opinion letter. The expectation is that this information will be published for all studies that receive an ethical opinion but should you wish to provide a substitute contact point, wish to make a request to defer, or require further information, please contact the REC Manager, Tracy Leavesley, NRESCommittee.EastofEngland-Norfolk@nhs.net. Under very limited circumstances (e.g. for student research which has received an unfavourable opinion), it may be possible to grant an exemption to the publication of the study.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Mental Capacity Act 2005

I confirm that the committee has approved this research project for the purposes of the Mental Capacity Act 2005. The committee is satisfied that the requirements of section 31 of the Act will be met in relation to research carried out as part of this project on, or in relation to, a person who lacks capacity to consent to taking part in the project.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database. This should be before the first participant is recruited but no later than 6 weeks after recruitment of the first participant.

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g. when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non-clinical trials this is not currently mandatory.

If a sponsor wishes to request a deferral for study registration within the required timeframe, they should contact hra.studyregistration@nhs.net. The expectation is that all clinical trials will be registered, however, in exceptional circumstances non registration may be permissible with prior agreement from NRES. Guidance on where to register is provided on the HRA website.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Ethical review of research sites

NHS sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Non-NHS sites

The Committee has not yet completed any site-specific assessment (SSA) for the non-NHS research site(s) taking part in this study. The favourable opinion does not therefore apply to any non-NHS site at present. We will write to you again as soon as an SSA application(s) has been reviewed. In the meantime no study procedures should be initiated at non-NHS sites.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	*Version*	*Date*
Covering letter on headed paper [REACH REC Cover Letter]	v1.0	03 March 2015
Covering letter on headed paper [REACH REC Response Letter]		25 March 2015
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [UoL - Evidence of Insurance]		
Instructions for use of medical device [REACH Activity Monitor Instructions for Residents]	v1.0	02 March 2015
IRAS Checklist XML [Checklist_27032015]		27 March 2015
Letters of invitation to participant [REACH Letter to relative/friend re assent]	v1.0	02 March 2015
Letters of invitation to participant [REACH Follow-up Letter to relative/friend re assent]	v1.0	02 March 2015
Non-validated questionnaire [Health Economic Resource Use Questionnaire]		
Participant consent form [REACH Resident Consent Form]	v1.0	02 March 2015
Participant consent form [REACH Personal Consultee Declaration Form]	v1.0	02 March 2015
Participant consent form [REACH Nominated Consultee Declaration Form]	v1.0	02 March 2015
Participant consent form [REACH Resident Consent Form - Qualitative Interviews]	v1.0	02 March 2015
Participant consent form [REACH Staff Consent Form - Qualitative Interviews]	v1.0	02 March 2015
Participant information sheet (PIS) [REACH Personal Consultee Information Sheet]	v1.0	02 March 2015
Participant information sheet (PIS) [REACH Nominated Consultee Information Sheet]	v1.0	02 March 2015
Participant information sheet (PIS) [REACH Information Sheet - Qualitative Interviews - Residents]	v1.0	02 March 2015
Participant information sheet (PIS) [REACH Information Sheet - Qualitative Interviews - Staff]	v1.0	02 March 2015
Participant information sheet (PIS) [REACH Study Poster]	v1.0	02 March 2015
Participant information sheet (PIS) [REACH Resident Information Sheet]	v2.0	25 March 2015
Participant information sheet (PIS) [REACH Care Home Information Sheet]	v2.0	25 March 2015
Participant information sheet (PIS) [REACH Staff Information Sheet]	v2.0	25 March 2015
REC Application Form [REC_Form_27032015]		27 March 2015
Research protocol or project proposal [REACH Study Protocol]	v1.0	02 March 2015

Summary CV for Chief Investigator (CI) [Anne Forster (CI) CV]		
Summary CV for student [Jennifer Airlie (PhD Student) CV]		
Summary, synopsis or diagram (flowchart) of protocol in non technical language [REACH Trial Summary]	v1.0	02 March 2015
Validated questionnaire [Physical Activity and Mobility in Residential Care Scale (PAM-RC)]		
Validated questionnaire [Barthel Index]		
Validated questionnaire [Elderly Mobility Scale]		
Validated questionnaire [Functional Ambulation Classification]		
Validated questionnaire [Six Item Cognitive Impairment Test]		
Validated questionnaire [Geriatric Depression Scale]		
Validated questionnaire [EQ-5D-5L]		
Validated questionnaire [EQ-5D-5L Proxy]		
Validated questionnaire [ICECAP-O]		
Validated questionnaire [ICECAP-O Proxy]		
Validated questionnaire [DEMQOL]		
Validated questionnaire [DEMQOL Proxy]		
Validated questionnaire [WHOQOL-BREF]		
Validated questionnaire [CASP-19]		
Validated questionnaire [Ageing Well Profile]		
Validated questionnaire [Benjamin Rose Nurse Assistant Job Satisfaction Scale]		

Statement of compliance

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After ethical review

Reporting requirements

The attached document *"After ethical review – guidance for researchers"* gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

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User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website:
http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/

HRA Training

We are pleased to welcome researchers and R&D staff at our training days – see details at http://www.hra.nhs.uk/hra-training/

15/EE/0125	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project.

Yours sincerely

Dr Michael Sheldon
Chair

Email:NRESCommittee.EastofEngland-Norfolk@nhs.net

Enclosures: "After ethical review – guidance for researchers"

Copy to: *Jane Dennison, Bradford Teaching Hospitals Foundation NHS Trust*

Appendix G: Barthel Index (BI)

REACH
RESEARCH IN ENHANCING PHYSICAL ACTIVITY IN CARE HOMES

BRADFORD INSTITUTE FOR HEALTH RESEARCH | MAKING RESEARCH REAL

Barthel ADL Index

One questionnaire to be completed per resident

ID No:

DATE (Day/Month/Year):

Activity	Activity Scoring System	Score
Bowels	0 = incontinent (or needs to be given enemas) 1 = occasional accident (once/week) 2 = continent	
Bladder	0 = incontinent (or needs to be given enemas) 1 = occasional accident (max once per 24 hours) 2 = continent (for over 7 days)	
Grooming	0 = needs help with personal care 1= independent face/hair/ teeth/ shaving (implements provided)	
Toilet Use	0 = dependent 1 = needs some help, but can do something alone 2 = independent (on and off, dressing, wiping)	
Feeding	0 = unable 1 = needs help cutting, spreading butter etc. 2 = independent (food provided in reach)	
Transfers (Bed to chair and back)	0 = unable – no sitting balance 1 = major help (one or two people, physical), can sit 2 = minor help (verbal or physical) 3 = independent	
Mobility (on level surfaces)	0 = immobile 1 = wheelchair independent, including corners etc. 2 = walks with help of one person (verbal or physical) 3 = independent (but may use any aid, e.g. stick)	
Dressing	0 = dependent 1 = needs help but can do about half unaided 2 = independent (including buttons, zips, laces etc)	
Stairs	0 = unable 1 = needs help (verbal, physical, carrying aid) 2 = independent up and down	
Bathing	0 = dependent 1 = independent (or in shower)	
Total Score:		/ 20

The BARTHEL ADL Index – Guidelines

General:

• The index should be used as a record of what a resident does, NOT as a record of what a resident could do.

• The main aim is to establish degree of independence from any help, physical or verbal, however minor and for whatever reason.

• The need for supervision renders the resident NOT independent.

• A resident's performance should be established using the best available evidence. Asking the resident, friends/relatives and nurses will be the usual source, but direct observation and common sense are also important. However, direct testing is not needed.

• Usually the performance over the preceding 24–48 hours is important, but occasionally longer periods will be relevant.

• Unconscious residents should score '0' throughout, even if not yet incontinent.

• Middle categories imply that patient supplies over 50% of the effort.

• Use of aids to be independent is allowed.

Bowels (preceding week):

• If needs enema from nurse, then 'incontinent'.

• Occasional = once a week.

Bladder (preceding week):

• Occasional = less than once a day

• A catheterised resident who can completely manage the catheter alone is registered as 'continent'.

Grooming (preceding 24–48 hours):

• Refers to personal hygiene: doing teeth, fitting false teeth, doing hair, shaving, washing face.

Implements can be provided by helper.

Toilet use:

• Should be able to reach toilet/commode, undress sufficiently, clean self, dress and leave.

• With help = can wipe self, and do some other of above.

Feeding:

• Able to eat any normal food (not only soft food). Food cooked and served by others. But not cut up.

• Help = food cut up, patient feeds self.

Transfer:

• From bed to chair and back.

Appendix H: Functional ambulation category (FAC)

Category	Definition
0 Nonfunctional ambulation	Patient cannot ambulate, ambulates in parallel bars only, or requires supervision or physical assistance from more than one person to ambulate safely outside of parallel bars.
1 Ambulator - dependent for physical assistance – Level II	Patient requires manual contacts of no more than one person during ambulation on level surfaces to prevent falling. Manual contacts are continuous and necessary to support body weight as well as maintain balance and / or assist coordination
2 Ambulatory-dependent for physical assistance – Level I	Patient requires manual contact of no more than one person during ambulation on level surfaces to prevent falling. Manual contact consists of continuous or intermittent light touch to assist balance or coordination
3 Ambulator - dependent for supervision	Patient can physically ambulate on level surfaces without manual contact of another person but for safety requires standby guarding of no more than one person because of poor judgement, questionable cardiac status, or the need for verbal cuing to complete the task.
4 Ambulator - independent level surfaces only	Patient can ambulate independently on level surfaces but requires supervision or physical assistance to negotiate any of the following: stairs, inclines or non-level surfaces.
5 Ambulator - independent	Patient can ambulate independently on non-level and level surfaces, stairs and inclines

Appendix I: Observational tool

Activity	Example
Active social interaction	Talking / conversation with staff / friends / family / other residents
Passive social interaction	Listening / watching staff / friends / family / other resident
Eating / drinking	Tea / coffee, biscuits, mealtimes
Sedentary recreational activity	Reading, watching TV, listening to music – no movement
Low intensity recreational activity	Craft, card game, board game
Light intensity recreational activity	Throwing / catching game, moving to music i.e. clapping hands
Moderate intensity recreational activity	Dancing, performing exercises
Walking (no. steps taken)	Walking with or without aid
Passive transference (wheelchair use)	
Receiving care	
Sit –stand transfer	
Stand-sit transfer	
Standing still	
Socially / recreational inactive	Apparently no engagement in any activity
Sleeping / dozing	
Unavailable for observation	No longer in communal area (toileting etc.)
Other	

Date: Start time: Care home: Participant initials: Monitor ID: Page: 1/12

Active social interaction																
Passive social interaction																
Eating / drinking																
Sedentary rec activity																
Low intensity rec activity																
Light intensity rec activity																
Moderate intensity rec activity																
Walking (no steps taken)																
Passive transference (wheelchair use)																
Receiving care																
Sit - stand transfer																
Stand - sit transfer																
Standing																
Socially / rec inactive																
Sleeping / dozing																
Unavailable for obs																
Other																

Appendix J: Activity log (WS 2)

BRADFORD INSTITUTE FOR HEALTH RESEARCH
MAKING RESEARCH REAL

A large-print version of this sheet is available on request

ACTIVITY LOG

Participant ID ________

Please remember to wear your activity monitor every day. Leave it somewhere you are likely to see it first thing in the morning.

Please note that once your activity monitor begins recording it will NOT flash

Please remember that your activity monitor does not like to get wet so please remove it if this might happen

Please complete the table below each day.

	Time put on	Time taken off	Reason for taking off	Time the activity monitor was off (minutes)
Example	7.30	10.00	Bathing	45 minutes
	10.45	21.00	Bed time	10 hours
Day 1				
Day 2				

Day 3				
Day 4				
Day 5				
Day 6				
Day 7				
Day 8				
Day 9				
Day 10				

If you have any queries please contact:

Jennifer Airlie

Research Assistant

Telephone: 01274 38 3912 / Email: Jennifer.Airlie@bthft.nhs.uk

Appendix K: Activity log (WS 4)

BRADFORD INSTITUTE FOR HEALTH RESEARCH
| MAKING RESEARCH REAL

ACTIVITY LOG

Participant ID ________

Please remember to wear your activity monitor every day. Leave it somewhere you are likely to see it first thing in the morning.

A large-print version of this sheet is available on request

Please note that once your activity monitor begins recording it will NOT flash

Please remember that your activity monitor does not like to get wet so please remove it if this might happen.

Please complete the table below each day.

	Time put on	Time taken off	Reason for taking off
Example	7.30	10.00	Bathing
	10.45	21.00	Bed time
Day 1			
Day 2			

Day 3			
Day 4			
Day 5			
Day 6			
Day 7			
Day 8			
Day 9			
Day 10			

If you have any queries please contact:

Jennifer Airlie, Research Assistant

Telephone: 01274 38 3912

Email: Jennifer.Airlie@bthft.nhs.uk

Activity Monitor

Appendix L: Activity log (REACH cRCT)

REACH
RESEARCH IN ENHANCING PHYSICAL ACTIVITY IN CARE HOMES

FORM 29

Page 1 of 2

Activity Monitor Log

Resident Initials		Resident Date of Birth	Day Month Year	Resident ID	Care Home No / Trial No
Care Home Name					

To be completed on a daily basis to document resident accelerometer wear. Please record the time the accelerometer is put on/removed each day – this is likely to be more than once.

Accelerometer ID

Time point ☐ Baseline ☐ 3 months ☐ 6 months ☐ 9 months

Did the resident wear the accelerometer during the data collection period? ☐ Yes ☐ No

If no, why not?

If yes, please complete the table below:

	Was the activity monitor worn? If not, why?	Time put on (24 hr clock)	Time taken off (24 hr clock)	Reason for taking off	Completed by: Staff	Researcher	Resident	Comments (I.e. any problems with wear)
Example	☑ Yes ☐ No	7.30	10.00	Bathing	☐	☑	☐	
		10.45	21.00	Bed time	☐	☐	☑	
Day 1 Date of day 1 (Day Month Year)	☐ Yes ☐ No				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 2 Date of day 2 (Day Month Year)	☐ Yes ☐ No				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 3 Date of day 3 (Day Month Year)	☐ Yes ☐ No				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	

Form continues on next page ►►

For office use only	Computerised: Date / Initials	Verified/Checked: Date / Initials

Version 3.0 31/03/2016

REACH
RESEARCH IN ENHANCING PHYSICAL ACTIVITY IN CARE HOMES

FORM 29
Page 2 of 2

Activity Monitor Log

Resident Initials		Resident Date of Birth	Day Month Year	Resident ID	Care Home No	Trial No
Time point	☐ Baseline	☐ 3 months	☐ 6 months	☐ 9 months		

	Was the activity monitor worn? If not, why?	Time put on (24 hr clock)	Time taken off (24 hr clock)	Reason for taking off	Completed by Staff	Researcher	Resident	Comments (I.e. any problems with wear)
Day 4 Date of day 4 Day Month Year	☐ Yes → ☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 5 Date of day 5 Day Month Year	☐ Yes → ☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 6 Date of day 6 Day Month Year	☐ Yes → ☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 7 Date of day 7 Day Month Year	☐ Yes → ☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	

Date accelerometer collected from Care Home — Day Month Year

Time collected — Hours : Minutes

Last Page ■

For office use only	Computerised *Date* *Initials*	Verified/Checked *Date* *Initials*

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Appendix M: Accelerometer tracking from

Accelerometer Tracking Form

Care Home ID:

REACH
RESEARCH IN ENHANCING
PHYSICAL ACTIVITY IN CARE HOMES

Resident	Floor/ Room	Trial ID	Monitor #	Time monitor on / off						
				Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Example: Mary Smith	Poppy	901	1	On:						
				Off:						
				On:						
				Off:						
				On:						
				Off:						
				On:						
				Off:						
				On:						
				Off:						

Appendix N: Activity log poster (A3 size) (REACH cRCT)

REACH
RESEARCH IN ENHANCING PHYSICAL ACTIVITY IN CARE HOMES

Resident initials		Care Home Name	
Resident Date of Birth	Day / Month / Year	Accelerometer ID	
Resident ID	Care Home No / Trial No	Time point	☐ Baseline ☐ 3 months ☐ 6 months ☐ 9 months

...is taking part in the REACH project

Please help them to wear their activity monitor and complete the log below for them every day.

Did the resident wear the activity monitor during the data collection period? ☐ Yes ☐ No → Why not?

	Was the activity monitor worn? If not, why?	Time put on (24 hr clock)	Time taken off (24 hr clock)	Reason for taking off	Completed by: Staff	Researcher	Resident	Comments (I.e. any problems with wear)
Example row	☑ Yes →	7.30	10.00	Bathing	☐	☑	☐	
	☐ No	10.45	21.00	Bed time	☐	☐	☑	
Day 1	☐ Yes →				☐	☐	☐	
Date of day 1 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 2	☐ Yes →				☐	☐	☐	
Date of day 2 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 3	☐ Yes →				☐	☐	☐	
Date of day 3 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 4	☐ Yes →				☐	☐	☐	
Date of day 3 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 5	☐ Yes →				☐	☐	☐	
Date of day 3 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 6	☐ Yes →				☐	☐	☐	
Date of day 3 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	
Day 7	☐ Yes →				☐	☐	☐	
Date of day 3 (Day / Month / Year)	☐ No ↓				☐	☐	☐	
					☐	☐	☐	
					☐	☐	☐	

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Appendix O: Summary of the data collected at each time-point

Assessment	Method of Completion	Time-point			
		Screening/ Baseline	3 Months	6 Months	9 Months
Care home eligibility	Researcher assessment	X			
Resident screening (demographics)	Researcher assessment	X			
Physical Activity and Mobility in Residential Care Scale (PAM-RC) and Barthel Index	Researcher interview / Self-completion (S)	X	X	X	X
Resident consent (including consultee)	Self-completion (R) (witnessed)	X			
Resident eligibility	Researcher assessment	X			
Care Home demographics	Researcher Interview (S)	X	X	X	X
Staff Profile	Researcher Interview (S)	X	X	X	X
Home level mortality rates, hospital admissions, HCP contacts, and adverse events	Researcher Interview (S)	X	X	X	X
Staff details questionnaire (including the Person-centred Care Assessment Tool (P-CAT))	Self-Completed (S)	X	X	X	X
Functional Ambulation Classification (FAC), and the Elderly Mobility Scale (EMS)	Researcher interview / Self-completion (S)	X	X	X	X

Level of cognitive impairment (6-CIT)	Researcher interview (R)	X	X	X	X
Mood (Geriatric Depression Scale (GDS))	Researcher interview (R)	X	X	X	X
Perceived health (EQ-5D-5L)	Researcher interview / Proxy completion (R / SP)	X	X	X	X
Quality of life (DEMQOL)	Researcher interview / Proxy completion (R / SP)	X	X	X	X
Accelerometer measurements	Researcher Assessment	X	X	X	X
Health Economics Questionnaire	Researcher Interview (S) / Review of Care notes	X	X	X	X
Service Usage	Routine Data sources	Collected throughout			
Hospital admissions / Safety reporting	Researcher Assessment / Routine Data sources	Collected throughout			
Usual care review	Researcher Assessment (Observations)	X	X	X	X
Intervention delivery and adherence	Researcher Assessment	X	X	X	X

Appendix P: Overview of the outcome measures trialled in the REACH cRCT

Outcome measure	Method of completion
Physical function: Grip strength	Researcher Assessment
Physical function: Elderly Mobility Scale (EMS)	Researcher interview/Self-completion (S)
Barthel Index (BI)	Researcher interview/Self-completion (S)
Physical activity and mobility: Physical Activity and Mobility in Residential Care Scale (PAM-RC)	Researcher interview/Self-completion (S)
Functional Ambulation Classification (FAC)	Researcher interview/Self-completion (S)
Perceived health: EQ5D	Researcher interview/Proxy completion (R/SP)
Wellbeing: ICEpop CAPability measure for Older people (ICECAP-O)	Researcher interview (R)
Quality of life: WHOQOL-BREF.	Researcher interview (R)
Quality of life: CASP-19	Researcher interview (R)
Quality of life: Ageing Well Profile	Researcher interview (R)
Quality of life: DEMQOL	Researcher interview/ Proxy completion (R/SP)
Mood: Geriatric Depression Scale (GDS)	Researcher interview (R)
Physical activity: Accelerometer measurements	Researcher Assessment
Level of cognitive impairment: Six Item Cognitive Impairment Test (6-CIT)	Researcher interview (R)

Appendix Q: Methodological framework for establishing feasibility, validity and reliability (Kelly et al., 2016)

Stage	Process
Proof of concept – feasibility	1. Field testing and pilot testing of measure in controlled and free-living settings
Content and Face validity	2. Examination of relevant literature 3. Consultation with relevant experts 4. Theoretical examination of measure and domain/dimension 5. Examination of proposed data processing and decision algorithms including sensitivity analysis
Convergent validity	6. Assessment of the agreement between your measure and an existing (non-criterion) measure
Criterion validity	7. Assessment of the agreement between your measure and a criterion measure
Internal validity	8. Examination of bias such as reactivity and missing data
External validity	9. Examination of sample bias (age, sex, ethnic origin, socio-economic status)
Inter-rater reliability	10. Assessment of stability of tests administered by different researchers
Inter-instrument reliability	11. Assessment of stability of tests administered using multiple versions of the same instrument
Test-retest reliability	12. Assessment of stability of consecutive tests
Behavioural reliability	13. Assessment of stability accounting for behavioural changes
Context validity	14. Based on all assessments, will measure give useful information in the proposed context?
Purpose validity	15. Based on all assessments and considering study design, are the validity and reliability results suitable for the proposed use and likely to allow the research question to be answered?