National dietary surveys in the WHO European Region: a review of provision, results and challenges

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Chapter 3

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Chapter 7

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Chapter 8

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Chapter 9

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Abstract

Background

The World Health Organisation (WHO) encourages countries to conduct national dietary surveys to inform preventative policies targeting malnutrition and noncommunicable diseases. This research reviews the provision of national dietary surveys across the 53 countries of the WHO European Region and uses intake data from these surveys to assess selected topics that are of concern to WHO.

Methods

National dietary surveys were gathered, survey characteristics were collated and survey-reported energy and selected nutrient intakes were examined in relation to recommended intakes for adults and children. Raw datasets were gathered from 12 countries and age-standardised weighted mean nutrient intakes presented by individual education level and Gross Domestic Product (GDP). Socio-economic and food consumption characteristics of high trans fatty acid (TFA) consumers were compared in the Dutch and UK surveys. The impact of body mass index (BMI) on consumed portion size was investigated in the French and UK surveys. Means and nutritional content of commercial UK serving-sizes were compared to consumed portion sizes in the UK survey in popular energy-dense foods.

Results

Less than two thirds of WHO European Member States conducted national dietary surveys; the main survey gaps lie in Central & Eastern European countries, where nutrition policies may lack an evidence base. Nutritional issues appeared widespread, particularly in females and Central & Eastern Europe, but differences in age group, methodology, under-reporting and nutrient composition databases hinder inter-country comparisons. Lower income countries and lower education groups had poorer diet, particularly for micronutrients. Higher

educational status appeared to have a mitigating effect on poorer diet in lower income countries. Although voluntary national reduction programmes may successfully reduce average TFA intakes, as shown in the Dutch and UK national dietary surveys, inequalities in TFA consumption may be hidden. Limited evidence of associations between portion size and BMI was found. UK consumed portion sizes were greater than on-pack serving sizes, suggesting that portion size guidance may need updating.

Conclusion

This project produced the first review of national dietary survey provision across the lifecourse, within the whole WHO European region, with reference to disadvantaged groups, obesity and nutrients of concern. All European countries should be encouraged to conduct harmonised national dietary surveys, which could facilitate effective, coordinated policy development to deliver dietary improvement across Europe.

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List of Abbreviations

BMI	Body Mass Index
BMR	Basal Metabolic Rate
CAPI	Computer assisted personal interview
CEEC	Central & Eastern European countries
CHD	Coronary heart disease
CVD	Cardiovascular disease
DH	Department of Health
DHA	Docosahexaenoic acid
DLW	Doubly labelled water
DNFCS	Dutch National Food Consumption Survey
EAR	Estimated average requirement
EC	European Commission
EFCOSUM	European Food Consumption Survey Method
EFCOVAL	European Food Consumption Validation
EFSA	European Food Safety Authority
EPA	Eicosapentaenoic acid
EPIC	European Prospective Investigation into Cancer and Nutrition
ESP	European Standard Population
EU	European Union
FAO	Food & Agricultural Organisation
FBDG	Food based dietary guidelines
FFQ	Food frequency questionnaire
FPQ	Food propensity questionnaire
FPS	Food portion size
GDP	Gross Domestic Product
INCA	Individuelle Nationale des Consommations Alimentaires
iTFA	Industrial trans fatty acids
LMIC	Low and middle income countries

MUFA	Monounsaturated fatty acids
NCD	Noncommunicable diseases
NDNS (RP)	National Diet and Nutrition Survey (Rolling Programme)
NDS	National dietary survey
OWOB	Overweight and/or obese
PAL	Physical Activity Level
PHO	Partially hydrogenated oils
PHRD	Public Health Responsibility Deal
PUFA	Polyunsaturated fatty acids
RACC	Reference amount customarily consumed
RNI	Recommended nutrient intake
SD	Standard deviation
SEG	Socioeconomic group
SME	Small and medium enterprise
SPADE	Statistical Program to Assess Dietary Exposure
TFA	Trans fatty acid
UK	United Kingdom
WHO	World Health Organisation

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Chapter 1 Introduction and thesis aims and objectives

1.1 Introduction

This chapter describes the context that informs the research questions and details the aims and specific objectives that direct the work involved in answering those questions.

1.1.1 NCDs in the WHO European Region

Noncommunicable diseases (NCDs) represent a pressing global health burden; it is expected that by 2020 almost 75% of all deaths worldwide and 60% of all disability-adjusted life years will be attributed to chronic diseases. This is particularly the case in Europe; of all the WHO regions, Europe is the most severely affected by NCDs (1).

Poor diet is a major behavioural risk factor for NCDs (2), which are the largest cause of disability and death across the European region. Here, the four most common NCDs account for 77% of disease and almost 86% premature mortality (1). NCDs and related conditions, including overweight and obesity, have significant and growing economic and social costs (1), which traditional clinical approaches are increasingly unable to address (3). Diet improvement across Europe is therefore needed to reduce the health, social and economic burden of NCDs. Indeed, reducing unhealthy diets is one of the major NCD risk factors addressed by the WHO 'Best Buys' to reduce and prevent NCDs (4). These 'Best Buys' comprise a set of interventions that are considered the most cost-effective and feasible in NCD-prevention, and include trans fatty acid (TFA) elimination as an 'effective' and portion size reduction as a 'recommended' intervention:

- Eliminate industrial trans-fats through the development of legislation to ban their use in the food chain.
- Replace trans-fats and saturated fats with unsaturated fats through reformulation, labelling, fiscal policies or agricultural policies.

- Limiting portion and package size to reduce energy intake and the risk of overweight/obesity.

Regular monitoring is identified as essential to their successful implementation (4).

Overweight and obesity is linked to more deaths globally than underweight; it is associated with NCDs like cardiovascular disease (CVD), diabetes and some cancers (5). Globally, obesity has nearly tripled since 1975, and in 2016 39% adults were overweight and 13% were obese (5). Evidence links childhood overweight and obesity to chronic disease (6, 7) and to an increased likelihood of these conditions in adulthood (8, 9). According to WHO (1) ‘energy dense, micronutrient poor foods’ high in energy, saturated fats, trans fats, sugar and salt should therefore be limited for a healthy diet throughout the lifecourse.

It is accepted that obesity is one of the biggest health problems facing the European population; in 46 countries (87%) of the WHO European Region >50% adults are overweight or obese. Obesity accounts for 2-8% of WHO European health costs (10) and is estimated to cause 320,000 deaths annually in Western Europe. In addition, obesity in Central & Eastern European countries has more than tripled since 1980 (1).

1.1.2 NCDs and the food environment

At a European Union (EU) level, the EU Action Plan on Childhood Obesity 2014-2020 aims to stem the rise in overweight and obesity in children and young people by 2020 by promoting healthier environments, making healthier choices easier and through monitoring and evaluation (11). Prior to this, the European Platform for Action on Diet, Physical Activity and Health was launched in 2005 and the Strategy on Nutrition, Overweight and Obesity-related Health Issues in 2007. The 2017 Maltese Council Conclusions called upon member states to collaborate in their intersectoral, whole society, national initiatives to enable environments that foster healthy diets (12). However, this does not represent the whole of the WHO European Region, focusing disproportionately on Western European countries.

Vallgarda et al. (13) examined how responsibility was assigned in obesity-reduction policies from the UK Department of Health (DH), EU and WHO Europe. They found that policies across all three bodies identified energy imbalance as the cause of obesity, but differed in their view as to who was responsible. WHO highlight changing environments and lifestyle factors as responsible for the obesity epidemic, and view blaming the individual as ‘unacceptable’. However, WHO assign ‘forward’ responsibility for reducing obesity to multiple actors, including individuals, without elaborating on the proportion of responsibility held by each actor (13). The DH and EU concur that industry action should be voluntary, and that individuals should be ‘empowered’ to make healthier choices, whereas WHO call for mandatory measures and focus on structural factors. All three entities put greater emphasis on external influences when discussing obesity in socio-economically disadvantaged groups, as these groups are considered less able to make informed choices (13).

WHO identify ‘limiting portion and package size to reduce energy intake and the risk of overweight/obesity’ as a ‘recommended intervention’ in reducing NCDs (4). This supports their view that environmental factors are key in the creation of a healthy food setting and that individuals do not hold responsibility for obesity and its related problems, as the consumption of smaller portions is highly influenced by those available in commercial products developed by the food industry (14).

WHO also highlight TFAs as a nutrient of concern relevant to the creation of a healthy food environment. The 2003 WHO/FAO technical report series 916 stipulated that TFA intake should be <1% energy intake (%E) due to the links with all-cause mortality and chronic diseases, most notably coronary heart disease (CHD) (15, 16). Elevated TFA intake is estimated to cause over 500,000 deaths globally each year, and for every 2% total energy gained from TFAs there is a corresponding 23% increase in CHD incidence (17). TFAs could also increase the risk of Alzheimer’s, diabetes and certain cancers (18). The mechanism behind this is the raising of LDL and decrease of HDL cholesterol levels; replacement of TFAs with unsaturated fats is thus desirable to reduce the risk of CHD (19).

The WHO European Food and Nutrition Action Plan calls for a ‘virtual elimination’ of TFAs, which has been described as one of the simplest public health measures to improve diet and reduce NCD risk. A ‘core indicator’ of the WHO framework for monitoring NCDs to 2025 is the adoption of national policies to replace TFAs with PUFAs (20). Elimination of industrial TFAs from the food supply is also a priority target in the WHO draft 13th General Programme of Work 2019-2023. The WHO REPLACE document (19) provides a ‘roadmap’ for countries to quickly and sustainably reduce TFAs. A core recommendation within this is the setting of legislative limits, which WHO regard as one of the simplest, most cost-effective, universal public health interventions for reducing CVD risk and improving diet quality (21).

1.1.3 NCDs and socioeconomic status

NCDs, including overweight and obesity, have progressed from being a problem mainly affecting developed nations to becoming increasingly prevalent in low and middle income countries (LMICs) where it was not previously a social issue (22). The proportion of economically disadvantaged groups in Central & Eastern Europe is higher than in Western and Northern Europe (23), meaning these countries face significant and growing health problems.

WHO (1) state that lower socio-economic groups are disproportionately affected by obesity, CVD and certain cancers, and that socioeconomic status is a major indicator of diet quality (23, 24). In their review, Darmon & Drewnowski (24) found that although a causal relationship could not be established, cross-sectional evidence showed that higher quality diets were consumed by more affluent, educated individuals, whereas lower quality diets were consumed by lower socioeconomic groups.

The UK Low Income Diet and Nutrition Survey found unequal consumption of TFAs by socio-economic status (25) – something that has also been observed in other European regions (26). Pearson-Stuttard et al. (27) suggest that reducing TFA intake could substantially reduce health inequalities in CHD mortality; they estimated that a 1% reduction in TFA of daily energy intake would result in five times fewer deaths and six times more life years in the most deprived quintile than the most affluent. Social pressure and other factors have resulted in significant national reductions in TFA intake from 2005-2013 in many, particularly Western, European populations. However, the same trend has not necessarily been observed in the more economically disadvantaged Central & Eastern European countries (26, 28, 29).

Key WHO policies and reports addressing socioeconomic inequalities include the *"WHO Global Strategy on Diet, Physical Activity and Health"*, which was adopted by the World Health Assembly in 2004 and describes actions required from all stakeholders at an international level to support healthy diets in populations. Since then, the 2011 Political Declaration of the High Level Meeting of the United Nations General Assembly on the Prevention and Control of Noncommunicable Diseases has reinforced the importance of policies promoting healthier diets via the "Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020". This plan is part of nine global NCD targets to be achieved by 2025, including curbing the rise in global obesity to match 2010 rates. WHO take a lifecourse approach and the 2016 Commission on Ending Childhood Obesity outlines six recommendations to highlight the obesogenic environment and key life stages where obesity can be addressed (5).

WHO assert that individual responsibility for reducing overweight and obesity within the obesogenic environment can only be achieved with the appropriate societal structures in place that facilitate better dietary choices. Governments should implement evidence-based policies to make healthier choices affordable and accessible to all social groups. Examples include restrictions on the marketing of processed food and beverages high in fat, sugar and salt, which currently exist in certain WHO European Member States, including Denmark, France, Norway, Slovenia, Spain, Sweden and the UK (30). In addition, the food industry also has a responsibility to enable healthier choices within a healthier food environment (5). This includes such measures as reducing portion sizes and promoting healthier snack foods, as snacking is increasingly prevalent, particularly in lower income and education groups (31).

It is clear that the current food environment across Europe requires monitoring and investigation in order to identify areas for improvement in which policy can be developed to tackle pressing concerns surrounding malnutrition related to NCDs. This is particularly relevant in disadvantaged groups, who are disproportionately affected by such issues.

1.2 Thesis aims and objectives

1.2.1 Thesis aims

Summary

This project uses national dietary surveys to address topics of concern within the European office of the World Health Organisation, whose remit covers 53 countries. The three main research areas are determined by WHO priority areas, and connected to the core national dietary survey element. These areas comprise an updated and extended review of national dietary surveys, alongside an examination of portion sizes and investigation of TFA intakes within the European region.

This project aims to highlight where national dietary survey, and consequently information provision, is lacking, thereby demonstrating where efforts should be focused to fill knowledge gaps. It will assess nutrient intakes in adults and children against WHO Recommended Nutrient Intakes (RNIs) to investigate potential inequalities and the most pressing areas of need. National dietary surveys will be used to investigate potential socioeconomic inequalities across Europe and whether vulnerable groups are potentially more susceptible to nutrition-related problems, both on a broader diet quality level and focusing on TFAs as a specific nutrient of concern. National dietary surveys will then be used to determine consumed portion sizes in commonly consumed energy-dense snack foods in two case study countries, with a view to addressing potential associations with body mass index (BMI) and consequently obesity. Consumed portion sizes will be compared to UK on-pack serving sizes to determine any disparities and explore whether policy should be developed to amend on-pack serving-sizes of certain food types in an attempt to limit excess energy intake and consequently obesity.

Taken together, this will be the first review of national dietary survey provision within the whole WHO European Region, across the lifecourse, and with reference to disadvantaged groups, obesity and nutrients of concern.

National Dietary Surveys

The WHO European Food and Nutrition Action Plan 2015-2020 aims to improve diet and nutrition in the European population and reduce diet-related NCDs, obesity and malnutrition (1). In addition to NCDs caused by overnutrition, on which public health policies typically focus, this also includes micronutrient deficiency, which remains prevalent throughout Europe (32). National dietary survey methodologies are developed primarily to assess the nutritional status of populations (33) and are therefore a suitable means of investigating nutrition-related problems across the WHO European region. Information from dietary surveys can be used as a means for governments and health bodies to monitor and reduce the diet-related risk of NCDs and related conditions, thereby contributing to the goals set out in the WHO action plan. To enable this it is first necessary to establish the current dietary situation across the 53 WHO Europe countries.

This research aims to:

- Conduct an updated national dietary survey review to determine which countries in the WHO Europe remit do and do not conduct national dietary surveys, and assess survey characteristics. This will help form a current picture of national dietary survey provision across Europe and enable insights into the scope for a common approach.
- Report nutrients by age and sex in both adults and children and compare these to WHO RNIs to highlight vulnerable groups at higher risk of nutrition-related ill health.
- Use raw national dietary survey data to examine intakes of selected key nutrients and assess whether socioeconomic inequalities exist on both an individual and national level.

Trans Fatty Acids

TFAs are a nutrient of concern found in processed foods in current European diets. According to WHO (1) 'energy dense, micronutrient poor foods' high in energy, saturated fats, *trans* fats, sugar and salt should be limited for a healthy diet, and monitoring and surveillance is a key priority in the process towards eliminating industrial TFAs. Ascertaining population consumption levels and assessing policies to limit consumption is therefore an important means of diet improvement.

This research aims to:

- Use national dietary surveys to determine TFA consumption levels across Europe, and assess the relative effectiveness of national TFA reduction strategies as a means of improving diets.
- Determine the characteristics of high compared to lower TFA consumers in the UK and a comparative European population (the Netherlands) and assess whether similarities in Dutch and UK consumers exist, with particular reference to socially disadvantaged groups and consumption of food groups.
- From the above aims, help advance understanding of the merits and limitations of voluntary TFA reduction as a national reduction strategy, in the context of minimising health inequalities.

Portion Sizes

Evidence indicates a link between food portion size and obesity (6, 34, 35); assuming portion size influences energy intake (6), availability of appropriate portion size is therefore key to a healthy food and drink environment. In addition to this 'portion size effect', which occurs in both adults and children (36), evidence suggests that portion sizes have increased in some energy-dense foods in the 20 years since UK government-based portion size guidelines (37) were released (38, 39, 40). There is little corresponding literature on changing European portion sizes over the same period, though the rise in French overweight and obesity levels over the past decade (41), suggests that increased portion size is a possibility.

This research aims to:

- Use national dietary surveys to identify commonly consumed energy, fat and sugar dense foods in the UK and a comparative European population (France), and to calculate the consumed portion size of these foods.
- Test for association between portion size and BMI in French and UK adults, which will enable insights into common areas of concern and how best to target dietary improvement measures.
- Compare the survey-derived consumed portion sizes with purchased on-pack serving sizes in the UK.
- Explore patterns to determine whether UK consumers of the energy dense foods identified from the national dietary surveys have consumed portion sizes above the serving sizes recommended on pack. This could have implications for whether on-pack serving sizes of certain food types should be amended, potentially influencing excess energy intake and consequently obesity.

1.2.2 Chapter objectives

***Chapter 2: Literature review*.**

- To briefly review the background to national dietary surveys.
- To briefly review measurement issues in national dietary surveys.
- To briefly review relevant aspects of food and nutrient intake, overweight and obesity and NCDs in the context of national dietary surveys.

***Chapter 3: National nutrition surveys in Europe: A review on the current status in the 53 countries of the WHO Europe region*.**

- To identify which of the 53 countries in the WHO Europe region have conducted nationally representative dietary surveys of whole diets at an individual level and those that have not.
- To identify key characteristics, centred on timeframe, sampling and dietary methodology, of known surveys undertaken since 1990 for adults and children. This will lay the foundations in establishing a clear picture of the current situation.

Chapter 4: Adult nutrient intakes from current national dietary surveys of European populations.

- To examine adult macro and selected micronutrient intakes in countries across WHO Europe via the latest national dietary surveys for which nutrient intake data is available.
- To compare these intakes to WHO RNIs to identify where in Europe there is a need to improve diets and whether inequalities exist.

***Chapter 5: Child and adolescent nutrient intakes from current national dietary surveys of European populations*.**

- To examine macro and selected micronutrient intakes in children and adolescents in countries across WHO Europe via the latest national dietary surveys for which nutrient intake data is available.
- To compare these intakes to age-appropriate RNIs to identify where in Europe there is a need to improve diets.

Chapter 6: Variation and socioeconomic disparities in nutrient intake data in national dietary surveys within the World Health Organisation European Region.

- To harmonise and present raw data for selected nutrient intakes from several European national dietary surveys.
- To explore geographical variations in key nutrient intakes, standardised to the European Standard Population (ESP).
- To investigate potential socioeconomic inequalities on an individual level via education and a country level using Gross Domestic Product (GDP).

Chapter 7: An exploration of socio-economic and food characteristics of high trans fatty acid consumers in the Dutch and UK national surveys after voluntary product reformulation.

- To analyse the Dutch and UK national dietary surveys to determine the characteristics of high compared to lower TFA consumers.
- To determine whether similarities between Dutch and UK consumers exist, with particular reference to socially disadvantaged groups and consumption of food groups.

Chapter 8: Portion size of energy-dense foods among French and UK adults by BMI status.

- To identify commonly consumed energy, fat and sugar dense snack food types in French and UK adults using their respective national dietary surveys, and determine their consumed portion size.
- To examine how portion size might vary with BMI, and explore how portion size may be affected by under-reporting.
- To report the two countries' consumed portion size and consider associations between consumption frequency and BMI.

Chapter 9: Comparison of consumed portion sizes and on-pack serving sizes of UK energy dense foods.

- To report the average manufacturer-set on-pack serving-size of frequently consumed energy, fat and sugar dense snack food types in the UK and then compare with consumed portion size derived from the UK National Diet & Nutrition Survey (NDNS).
- To explore patterns and similarities to determine whether consumers of such foods have consumed portion sizes above the serving-size recommended on pack.

Figure 1 gives a visual representation of the thesis structure and how each chapter contributes to the overall project.

Figure 2 gives an overview of the methods used for each published chapter (Chapters 3-9) – each chapter explains and discusses the methods used in detail.

Figure 1: Thesis framework

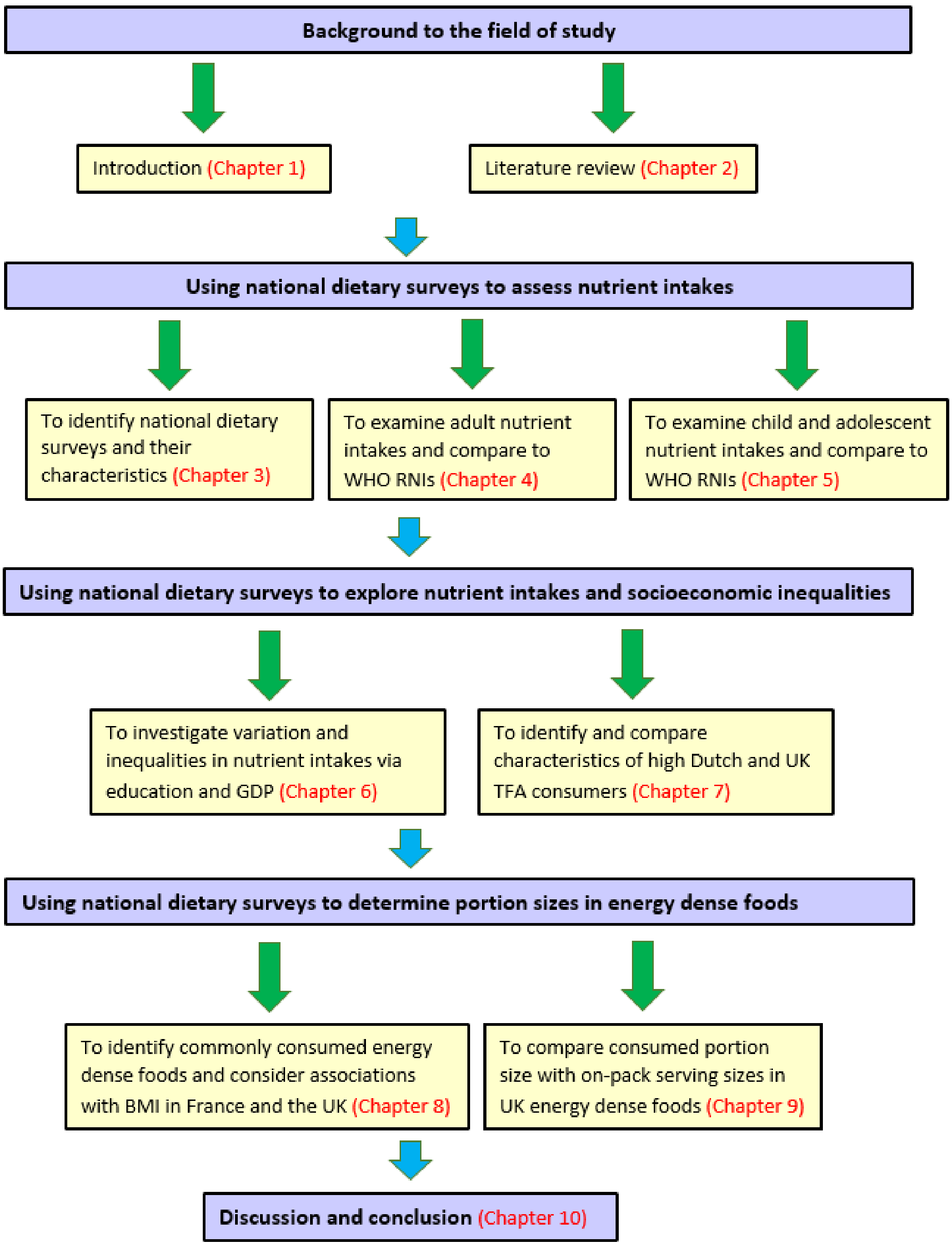
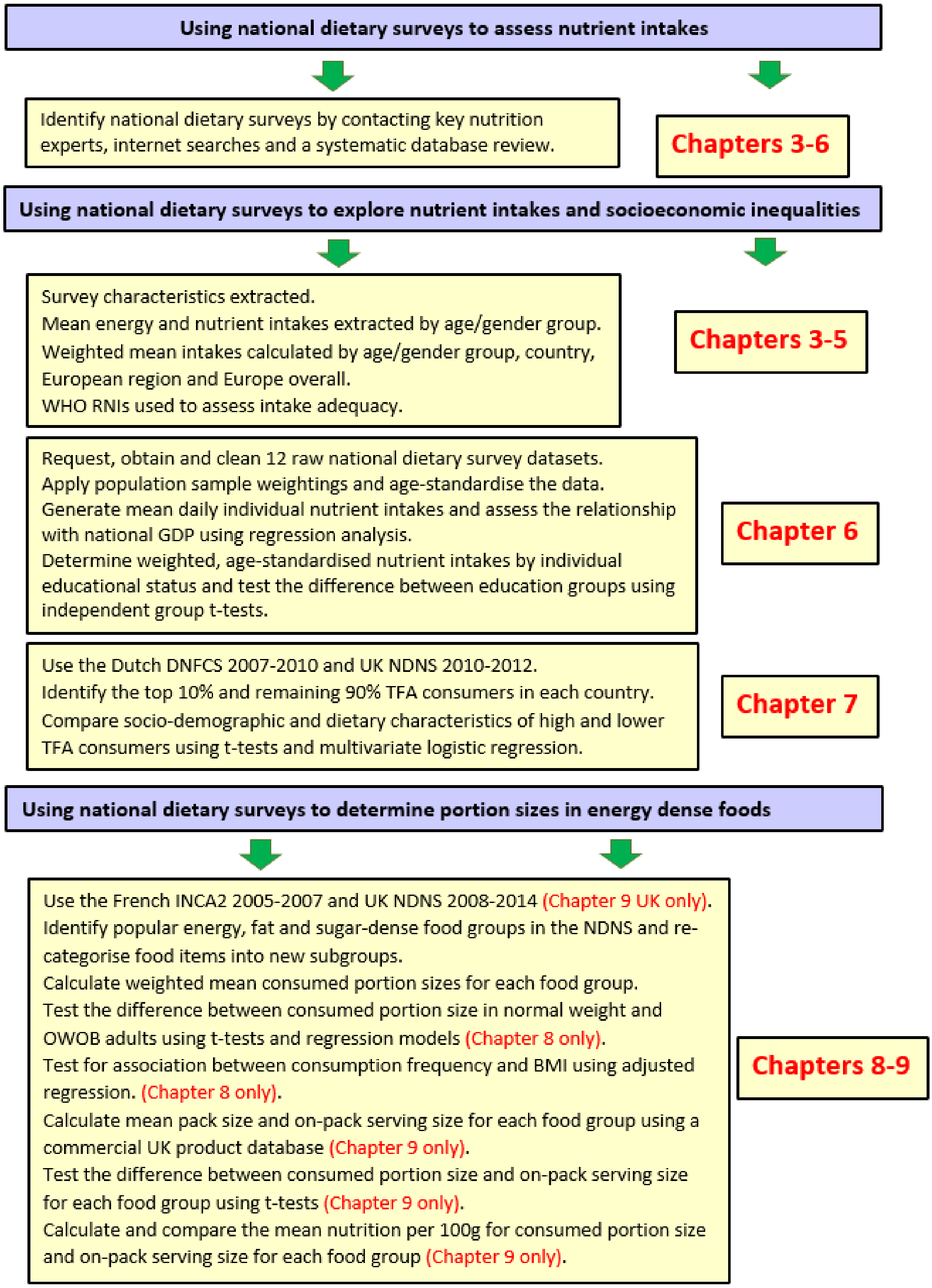


Figure 2: Methods framework



1.2.3 Innovation

This research builds on previous reviews and will enhance understanding in novel ways. It will explore the merits and limitations of using information gained from national dietary surveys to inform policy development to address NCDs like obesity, through portion size reduction, and CVD via TFA reduction.

Box 1: Assessing European diets – where are we now?

Context:

- NCDs are a major global health burden, particularly in Europe. Poor diet is a key behavioural risk factor for NCDs and related conditions, including obesity and CHD.
- In the majority (46 of 53) WHO European Member States over 50% of the population is overweight or obese.
- WHO encourage Member States to 'strengthen and expand nationally representative diet and nutrition surveys' (1).

What we already know:

- National dietary surveys are an essential tool for monitoring trends, identifying areas of concern and inequality, and evaluating policy impact.
- TFAs, particularly industrial TFAs, are linked to all-cause mortality and CHD (15).
- Although the majority of European populations have intakes below the WHO <1%E recommended limit, some population subgroups may have higher intakes (42).
- The 'portion size effect' demonstrates a positive link between portion size and food intake (43).
- In the UK commercially available serving sizes have increased in the last 25 years (44).
- Portion size guidance in the UK is outdated (38).

What this research adds:

- It provides a complete picture of national dietary survey provision across WHO Europe and is more comprehensive than previous, often Western-European focused reviews (32, 45, 46), that do not include surveys conducted after 2010.
- All surveys included are nationally representative, whereas previous reviews have included regional surveys, where some conclusions may not be generalizable to the national population.
- This work includes both adults and children, representing a more lifecourse oriented approach than previous studies, which often focus on a single life stage.
- It combines an assessment of national dietary survey characteristics and nutrient intakes, providing a range of macro and micronutrient intake levels across Europe, with insight into potential deficiencies across different populations and subgroups.
- Socioeconomic factors are considered and explored on both a broad and nutrient-specific level, enabling inferences into vulnerable groups and differential likelihood of nutrition-related health problems.
- This work will add to the body of literature on portion sizes in Europe, which is limited, particularly in low and middle-income countries (6), as the literature currently focuses primarily on America.

This chapter has explored the context informing the research questions and sets out the aims and objectives that will enable the answering of those questions.

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Chapter 2 Literature Review

This chapter explores in greater depth the context in which the research questions lie, and discusses the body of literature currently informing the various workstreams relevant to those questions.

2.1 Background on national dietary surveys

2.1.1 The importance of national dietary surveys in measuring diet in Europe

Historically, the recognition of nutrition as an essential socio-political consideration was contributed to by an understanding that soldiers fighting the Boer War were malnourished and that good nutrition was lacking in the working classes (1). Diet has since been identified as one of the most important modifiable factors affecting public health (2). Assessing the nutritional status of a population therefore has a key role in public health improvement.

National dietary surveys are a crucial part of the monitoring and surveillance required to ensure European populations have dietary patterns and nutrient intakes conducive to health. National dietary surveys assess food and nutrient intakes of whole diets at an individual level in a sample that is representative of the national population. However, until recently, dietary intakes were measured on a national scale by household level United Nations Food & Agricultural Organisation (FAO) food balance sheets (3). These are useful as they include most countries globally, use comparable methods and have open access data (3), but are calculated at household rather than individual level, do not account for household food wastage, home production or food eaten outside the home and do not allow sex and age comparisons (4). In contrast to the under-reporting associated with 24hr recall and food diary assessment methods, food balance sheets overestimate total energy intakes by up to 54% (3).

Knowledge and extension of individual-level national dietary survey provision is therefore important. Since the 1980s individual-level dietary assessment research has focused on the identification of food and its constituents relevant to the prevention and reduction of NCDs (2). However, as individual-level dietary assessment provides information on the distribution of food consumption in specific population subgroups, it has also arisen as a preferred means of assessing dietary exposure for risk assessment (5, 6). To gain an understanding of exposure risk, information on the frequency, conditions and duration of intakes is required for relevant foods containing potentially toxic substances (6). It is possible that national dietary surveys based on food safety have different and incompatible methodologies than those surveys evaluating the nutritional status of populations.

Although EFSA's primary motivation is exposure assessment and toxicology, EFSA regulation No.178/2002 recognised the lack of coordinated data on a European level and specified the coordinated collection of food consumption data as a major long-term objective (5).

The continued importance of national dietary surveys is demonstrated by previous and ongoing attempts to harmonise national food consumption data collection to better facilitate comparisons of intake levels, on a global as well as a European level. In their summary of the 2017 Global Burden of Disease study using Global Dietary Database data, Afshin et al. (7) recognise that dietary data has mixed sources and is not available for all countries, increasing statistical uncertainty. In addition, individual dietary intakes are often not standardised or comparable between countries, time periods or population subgroups.

The EFSA-led EU Menu initiative is a pan-European food-consumption survey designed to harmonise food consumption data in the EU by 2020 (8). This includes the 'Pilot study for the assessment of nutrient intake and food consumption among kids in Europe' (PANCAKE), the 'Pilot study in the view of a Pan-European dietary survey—adolescents, adults and elderly' (PILOT-PANEU) feasibility protocols to define and test computer-assisted data collection methods, and the 'Food Consumption Data Collection Methodology for the EU Menu

Survey' (EMP-PANEU) to marry the EPIC-Soft and FoodEx2 food classification systems (8).

EFSA recommends national dietary surveys use a 24hr recall for adults and dietary record for children over two non-consecutive days, with a supplementary food propensity questionnaire to be used as a covariate to model the estimation of usual intake of less frequently consumed foods (5, 8). The population should be sampled in two 'phases' – toddlers and children; and adolescents, adults and the elderly – with a sample size of at least 1000 in each phase (5). This is based on the selected summary statistic (mean), the level of precision required (5%) and the variability of dietary consumption in a population (taken from the preceding European Food Consumption Survey Method (EFCOSUM) project (9). EFSA also accounted for the accuracy of estimates of extreme consumption levels in determining a recommended sample size, as this is pertinent to risk assessment. Under-reporters should be identified, but not excluded (8). Interviewers should also be trained and sufficient time allocated to survey planning to 'reflect commonalities in Europe and underscore country-specific particularities in a harmonised way' (10). If these guidelines were adopted across Europe, data could be harmonised and pooled meta-analyses carried out, enabling valid comparisons of nutrient intakes across WHO European Member States. Currently this is not possible due to the high heterogeneity between surveys.

However, to produce quality, reliable data that can be used to monitor nutrition trends, national dietary surveys must be conducted regularly, and therefore must be sustainable. Tuffrey (11) concluded that sustainability depended heavily on cost, but also on capacity development, institutional base location, demand for the information and participation. Although 24hr recalls may be less costly than other dietary assessment methods (5), the scale of conducting national dietary surveys can have a heavy time and financial burden. In addition, there is a lack of reliable biomarkers, which means 24hr recall and food diaries remain the realistic 'gold standard' for use in national dietary surveys.

Biomarkers are objective and have greater accuracy than many dietary assessment methods, as they are not subject to many of the sources of bias that affect self-reported dietary assessment. However, collection of samples is costly and burdensome, particularly if more than a single 24hr collection is desired to improve estimates of usual intake. Barriers to conducting extensive biomarker studies include the invasiveness of sample collection, sample processing and storage and the resources needed for analysis (2). Biomarkers are typically used in national dietary surveys to validate dietary assessment methods, measuring the difference between true and reported intakes. These include doubly labelled water to measure energy intake – as used to measure under-reporting – and 24hr urine collections to measure intakes of protein, sodium and potassium (12).

A limitation of using self-reported 24hr recall and food diary methods to measure diet is that they are subject to recall and social desirability bias, highlighting the need for new technologies in dietary assessment to be more widely used (13). Web-based dietary assessments with self-administered record or recall methodologies can reduce data entry expense and allow data collection for large numbers on multiple days over different time periods (13). These technologies could therefore potentially reduce heterogeneity between surveys (14), measurement error, researcher burden (13) and encourage countries that historically lack national dietary surveys, particularly in Central & Eastern Europe, to undertake them. For example, myfood24 is a validated online 24-hr dietary assessment tool that can be used for either of the EFSA-approved (4) 24hr recall or dietary record methods (13) and is currently available with UK, German and Danish European food tables, as well as others internationally and across the lifecourse. This would increase the amount of dietary and nutrient intake data available in the WHO European region, directly contributing to the WHO objective of strengthening and expanding nationally representative diet and nutrition surveys (15).

The current lack of national dietary surveys in many WHO European Member States, and the inconsistency in those that do conduct national dietary surveys results in a lack of compatible information, which is needed to identify where policy focus should be. Comparable, robust data is needed to identify the population groups most in need of targeted dietary improvement measures, both on a national and European level. Without clear, consistent and widespread provision of national dietary surveys, at-risk groups cannot be identified nor health inequalities assessed and prevented. In addition, intakes of nutrients of concern cannot be determined; for example, TFAs, although a WHO nutrient of concern, were one of the least reported nutrients in national dietary surveys across Europe, as shown in Chapter 7 (16). TFA content has decreased significantly in Western Europe, but the same trend has not necessarily been seen in Central & Eastern Europe (17). This demonstrates that patterns in one European region cannot be extrapolated to another, and gaps in national dietary survey provision in certain regions mean intake levels cannot accurately be determined.

In another example, lack of consistent and universal national dietary survey implementation also limits the ability to accurately determine consumed portion sizes and monitor these over time. Consequently, the most pressing contributors to excess energy intake and nutrients of concern or requirement cannot be identified, limiting the ability to formulate effective obesity policy and change the current obesogenic environment.

2.1.2 Previous reviews of national dietary surveys

There have been previous reviews of national dietary surveys – Micha et. al (18) conducted a global review of dietary fats and oils using country-specific nutrition surveys from 1990-2010. However, it does not explore the differences in dietary surveys. The earlier EFCOSUM review (9) advocated a comparable measurement of food consumption across Europe, but is now outdated. Novakovic et al. (19) looked at selected micronutrient intakes in Central & Eastern Europe compared to other European countries and found that Central & Eastern countries lacked comparable studies on micronutrient intakes across all ages, particularly in children. However, only a small range of micronutrients were studied, limiting the wider impact and usefulness of any conclusions in terms of whole diets. Mensink et al. (20) assessed a range of micronutrient intakes in eight European countries and found that vitamin D intakes were of universal concern, but that mineral deficiencies depended on nutrient, sex and age group. The authors also used raw survey data to create their own standardised age groups, but the majority of countries were Western European, preventing regional comparisons. Similarly, although Roman-Vinas et al. (21) aimed to study intakes from all European regions, the final 12 countries they reported on did not include any from Central & Eastern Europe, because survey data from these countries did not meet the inclusion and/or quality criteria.

Merten et al. (22) reviewed the methodological characteristics of national dietary surveys in EU countries and noted that the surveys contributed nutrient intake data to the EFSA Comprehensive European Food Consumption Database. However, the review only included surveys employing certain dietary assessment methods, used regional surveys of children and was limited to EU member states, so only discussed 22 surveys from 20 countries, rather than all 53 countries of the WHO European region. Yet this is a valuable review that discusses methodological heterogeneity between surveys, including dietary assessment method, data collection period, sample frame and response rate, sample size and stratification, seasonality, exclusion criteria, portion size estimation, dietary software and nutrient composition database, under-reporters and uncertainty analysis. These comprise more characteristics than this research will cover in detail, but Merten et al. (22) include fewer surveys than this research (see chapter 3), all prior to 2010 and do not discuss nutrient intakes (16). The Global Dietary Database houses information on food and nutrient consumption levels in countries globally (3) and aims to provide current, reliable food and nutrient consumption estimates, particularly in poor and vulnerable populations. However, the Global Dietary Database currently includes regional surveys, does not cover children or go beyond 2010, and includes limited food categories and nutrients. More recently, the Global Nutrient Database provides information on 156 nutrients across 195 countries globally up to 2013 (23). However, nutrient intakes were generated from consumption data from the Global Burden of Disease study, which also includes regional surveys and focuses on adults aged 25y and older (24). There remains a need for an updated review of nationally representative dietary surveys across WHO Europe, with a comprehensive set of nutrient intake data for use in devising evidence-based policies for dietary improvement in different population groups.

2.2 Measurement issues in national dietary surveys

2.2.1 Differences between national dietary surveys

There is a clear need for a complete, updated review of national dietary surveys across the lifecourse that encompasses the entire WHO European Region – this work fills that gap. A key reason this research gap exists is the lack of compatibility between national dietary surveys, which makes inter-country comparisons difficult and has discouraged work examining nationally representative surveys across the WHO European Region. The main barriers to data harmonisation include differences in dietary methodologies, age groupings and food classifications (20). However, there are numerous ways in which surveys differ; consequently, previous reviews of national dietary surveys have focused on different aspects and have different strengths and limitations, as previously discussed. For example, Micha et al. (18) do not examine whole diets or differences between surveys; Novakovic et al. (19) and Mensink et al. (20) focus on micronutrients only; Merten et al. (22) limit their review to Western Europe, and all include some regional surveys in addition to nationally representative dietary surveys. Consequently, there is no overarching review, or series of comparable reviews, that illustrate a comprehensive, nationally representative picture of diet survey provision or nutrient intakes across Europe.

2.2.2 Policy uses of national dietary surveys

National dietary surveys are an important cornerstone in providing information to policymakers to help direct resources into areas where policy to reduce the risk of diet-related diseases is most needed. For example, as shown in chapter 4, Hungary has the highest salt consumption in the WHO European region, and two thirds of the population are obese (25, 26). To help alleviate this situation and limit the rise of NCD prevalence, the Hungarian 2011 public health tax introduced a levy on ‘unhealthy’ products in selected food categories that exceeded a set threshold. Following its implementation approximately 40% of affected products were reformulated or replaced, consumer shopping behaviour changes were made and nutrition literacy improved, in addition to raising revenue for public health spending (26). Other countries, including Estonia, France, Latvia, Lithuania Ireland, Portugal and the UK, have introduced specific policies to limit free sugar intakes (27-30). These are designed as NCD and obesity-reduction measures and several use intake data from national dietary surveys to justify policy implementation.

Using national dietary surveys to determine consumed portion sizes in different populations and subgroups could form a key part of the anti-obesity policymaking process, particularly the formation of food-based dietary guidelines (FBDG). To create FBDG, food sources contributing highly to population intakes of relevant nutrients must be identified; appropriate intakes must also be determined and compared to actual intakes to assess the level of action required (31). If a key food is consumed by a large proportion of the population, then either increasing or decreasing population intake of that food and therefore the target nutrient it provides, can be achieved by altering either the recommended portion size or the frequency of consumption.

Using national dietary surveys to update portion size guidance as part of an NCD and obesity-reduction policy framework could be applied on a European level, extending benefits from those countries with national dietary surveys to those without. Gibney et al. (32) investigated the potential for developing portion sizes for nutritional labelling using two European dietary surveys – the Irish National Adult Nutrition Survey and the EU Food4Me study. Despite survey differences, which reflect those present in national dietary surveys across the WHO European region, the portion sizes analysed had high agreement (32). This suggests that despite their differences, the use of European national dietary surveys to develop a standardised European approach to portion size setting is a viable policy approach. This is supported by Kirwan et al. (33), who found that frequency of consumption, rather than portion size, accounted for differences in European intakes, thereby suggesting that standardisation of serving sizes is a possibility. However, defining food categories across a standardised European portion size system could be difficult, reiterating the need to encourage all countries to conduct and harmonise national dietary surveys.

On a micronutrient level, policies to address certain population deficiencies may have initially been prompted by population intake data. For example, based on dietary survey information, Mensink et al. (20) found that vitamin D intakes were of concern across all ages in certain Western European countries, whilst various mineral intakes were lacking depending on sex and age group. Novakovic et al. (19) identified low iodine, calcium, folate and vitamin D intakes in Central & Eastern European children and Roman Vinas et al. (21) found higher levels of inadequate vitamin D, folic acid, calcium, selenium and iodine intakes in adults in selected countries across Europe. Such findings could be used to inform fortification policies or government advice on supplementation to prevent population-wide deficiencies. In the UK, the Scientific Advisory Committee on Nutrition recommends folic acid fortification based on national dietary survey and other results (34).

Intake data from national dietary surveys can also be used as a monitoring tool to assess the success of existing health-related policies. For example, WHO call for a ‘virtual elimination’ of TFAs, as elevated intakes are estimated to cause more than 500,000 deaths globally each year (15). Replacement of TFAs with unsaturated fats would also reduce the risk of CHD, which has prompted industry product reformulation and policy formation in many Member States to achieve this (35). Such policies include legislated bans (Denmark, Switzerland, Austria, Hungary, Iceland, Norway and Latvia), mandatory labelling (Slovenia, Kazakhstan) and voluntary reduction and awareness campaigns (Netherlands, Slovenia, UK) (17). TFA reduction methods appear to have had some success, as chapters 4 and 5 demonstrate that the vast majority of countries measuring TFA intakes report levels below the WHO RNI in all age groups (25, 36). Indeed, in 2004 Denmark became the first country globally to introduce a legislative ban (max 2g/100g fat) on TFAs in imported and domestic foods, which all but eradicated TFAs from the food supply. This policy led to a reduction in deaths from CVD by 14.2 deaths per 100,000 per year in the three years after the policy was implemented (37). Additionally, Austria introduced a ban in 2009, no TFAs were present in the food products analysed in 2011 or 2013 (38).

WHO state that a ‘suite’ of policy options built around a legislative ban is the most effective TFA-reduction strategy (35). This is supported by Hyseni et al. (39), whose systematic review into interventions to reduce population TFA intake found that multicomponent interventions incorporating legislation were the most effective measures. The evidence suggests that reduction policies are achievable and likely to have a positive impact on public health, regardless of the specific strategy employed, and that TFAs have thus far primarily been replaced with non-PHO unsaturated fats (40).

However, current national dietary survey data on TFA intakes across certain areas of Europe is limited, particularly Central & Eastern countries. For this reason, legislative measures would be even more effective in Central & Eastern European countries, where TFA consumption and CVD rates are higher (37). In addition, intakes could be higher for certain population subgroups such as ethnic minorities, lower income groups and younger adults/students, putting them at greater risk of associated NCDs (38, 41). Stender et al. (42) conducted a market basket investigation of TFA levels in baked goods in various retailers across 20 European countries and concluded that TFAs were present in popular foods across Europe and that these population subgroups were at risk of high TFA exposure. This illustrates the importance of being able to compare national dietary survey parameters across WHO European Member States in order to identify, determine the extent of, and address such inequalities.

2.2.3 Nutrient composition databases

A further measurement issue that affects all nutrient intakes, but is particularly evident when investigating TFAs, is that of the nutrient composition databases used to generate intakes from food consumed. Of those member states that do measure TFAs, intakes are based on the TFA levels ascribed to foods in national nutrient composition databases, which may be outdated, or incomplete. TFA levels may have changed to varying degrees in different Member States following TFA-reduction strategies and not all nutrient composition database values will have captured these changes, particularly in processed food categories where most changes have occurred. Some countries do not routinely analyse for TFAs, or only include certain isomers. Others, such as Sweden, have stopped reporting TFA intakes because intakes have dropped below 1%E and are therefore no longer a public health concern (43).

This lack of alignment between food composition databases extends to other nutrients, such as folate or fibre, which can be calculated differently from country to country. Similarly, some countries' databases account for retention factors and fortification, whereas others do not, preventing data harmonisation and potentially misrepresenting intakes (20). Diverse fortification policies could cause intake variation, as with vitamin D in Northern European countries, which is lower in Denmark than other Nordic nations (44). However, Flynn et al. (45) claim individual use of supplements, rather than state-driven fortification, accounts for the largest differences between countries in micronutrient intakes reported in national dietary surveys. As most national dietary surveys report nutrient intakes from food without supplements, the effect of fortification or supplement-use on intakes could be reduced.

Yet even assuming food composition databases are up to date and accurate, values are based on a composite sample of a limited selection of foods. This may not include foods typically eaten by certain population subgroups; intake in these groups may therefore be higher than the population average reported in national diet surveys, hiding potential health inequalities.

There have been numerous attempts to create a common European food composition database. EuroFir was established in 2009 to develop, publish and use coordinated food composition information, drawing together the best available food information in a single online platform (46). However, it does not cover the whole WHO European Region as it is limited to 26 countries, not all of which are European, and each country still offers a country-specific database, which precludes harmonisation. The EFSA Comprehensive European Food Consumption Database (47) was built from national dietary survey information on food consumption and provides detailed information on European food consumption. However, it only covers seven EU countries, none of which are Central & Eastern European, so like EuroFir, does not represent the entire WHO European Region. EFSA also advises against inter-country comparisons because methodological differences exist, both in the surveys the information is based on and the level of food description and classification detail for different countries (48).

These measurement issues and the differences in national dietary survey provision and characteristics impact on this work and the scope for future research. Conclusions and inferences made from the nutrient intakes extracted from national dietary survey summary reports are subject to the bias and variation derived from different dietary assessment methodologies, sampling methods, age groups, nutrient composition databases and more. The lack of national dietary survey data in some, particularly Central & Eastern European countries, means the methodology used to identify commonly consumed energy-dense foods may not be applicable in some Member States, reducing its use as a tool to gather and compare data across Europe. This further highlights the need for comparable, up-to-date national dietary survey data across Europe, to ensure that nutrition policies are based on accurate and robust evidence.

2.3 Food and nutrient intake; overweight and obesity; and NCDs

This project will use national dietary surveys to address potential links between aspects of diet and obesity and related NCDs, which are dominant health issues in Europe. To create a fuller picture of diet in Europe this will be done from a broader perspective, by investigating portion sizes of food consumed, and by taking a more targeted approach exploring specific nutrient intakes. A range of macro and micronutrient intakes will be determined, providing a wider view of European intakes, and an investigation of TFA intakes will provide the targeted perspective focusing on a specific nutrient of concern. As already discussed, previous reviews cover fewer nutrients; the Global Dietary Database has a limited nutrient profile based primarily on fatty acids and focuses on adults only (3, 49-51) and the Global Nutrient Database is based on consumption data focused on adults and includes regional surveys (24). Both Mensink et al. (20) and Roman Vinas et al. (21) examined micronutrients only, although the former included children in addition to adults.

2.3.1 Portion sizes

The accuracy of food and nutrient intake measurements in national dietary surveys is limited by portion size estimates, which could lead to incorrect associations between diet and NCDs (52). Much of the literature on portion size focuses on America, where larger portion sizes increasingly available in the food environment are linked to rising adult obesity levels via increased energy intakes (53, 54). Similar studies on European adults are less extensive – much of the literature is devoted to changes in food portion sizes over time in the UK (55-57) and in Ireland (58).

Experimental literature suggests that consumption increases when individuals are exposed to larger portions (59-61). However, this association was not necessarily linear – Zlatevska et al. (62) found that overall energy intake increased by 35% when the offered serving size was doubled, and was not uniform across all population groups. Steenhuis et al. (63) discuss the mechanisms behind this, although there is limited research into portion size interventions and measures of portion control; it is unclear as to what type of interventions work best, for whom and in what context. Positive associations between BMI and portion size have been found in children; Albar et al. (64) found that BMI increased in UK adolescents with every extra 10g of biscuits and cakes consumed. Lioret et al. (65) found similar positive associations in croissants and sweetened pastries in French children.

Others focus on the policy implications of portion size changes, and the potential links between portion size and overweight and obesity, particularly in adults (66, 67). As the experimental literature consensus links elevated portion size and increased consumption, Marteau et al. (67) infer that reducing portion size could reduce energy intake and therefore help tackle obesity, yet claim current policy does not adequately reflect this. They found that removing large portions from the food environment could reduce energy intake by 12-16% in UK adults and recommend reducing default portion sizes and making larger portions less readily available.

Packaging and product format affects portion size estimation accuracy (52), but few studies consider consumed portion sizes in the context of manufacturer-set on-pack serving sizes. Hieke et al. (59) explore the effect of pack size on portion size estimates in six European countries and identify a ‘pack size effect’, where larger packs result in larger portion size estimates. This differed across country and other characteristics, including gender, age and whether or not individuals found on-pack information relevant. Effect sizes were small, but over time this could result in significant increases in energy intakes; therefore smaller pack sizes could help reduce consumption and obesity, though further research is needed. The authors focused on energy-dense food groups, but did not select these in a systematic manner, for example based on consumption frequency and energy, fat and sugar density, as in this research. Bucher et al. (68) conducted a systematic review on the association between on-pack serving size and consumed portion size, but found only five studies, which had different outcomes. They concluded that the effect of serving size labelling on consumed portion size remains unclear, demonstrating a clear need for more research in this area.

However, Herman et al. (69) challenge the view that the body of evidence indicates that larger portion sizes are a primary factor in the obesity epidemic, stating that much of the evidence for larger portion sizes increasing energy intake is only tested in one day. The authors accept that portion sizes have increased in line with obesity, but claim that there is little quality evidence to show that it has led to increased weight gain, citing frequency of consumption as an equally contributory factor. However, Kelly et al. (70) investigated whether different portion sizes of pre-packed foods influenced food consumption and energy intake in normal and overweight adults over four days. They found that food consumption and energy intake was significantly higher in the larger portion condition, with little evidence of compensation over the four-day study period. Duffey & Popkin (71) looked at the effect of energy density, portion size and eating occasion on energy intake and found that increased frequency of consumption contributed more to increased energy intake than did portion size and energy density. However, this was based on a single 24hr recall, warranting the same criticism employed by Herman et al. Therefore uncertainty remains as to the relative impact of portion size and frequency of consumption on energy intake and consequently weight gain.

Others are similarly divided over the relative impact of portion size and consumption frequency on energy intake. Kirwan et al. (33) examined 156 food items across seven European countries and found that frequency of consumption varied across countries, but there was no difference in individual country mean portion size and the average portion size across all countries in 84%

comparisons. This suggests that dietary patterns vary across countries, but adds weight to the notion expressed by Gibney et. al. (32) that there is less variation in portion size, supporting the use of European national dietary surveys to develop a standardised approach to portion size setting in Europe. Hartmann et al. (72) found no association between snacking frequency and BMI in Swiss adults, whilst both O'Connor et al. (73) and Murakami & Livingstone (74) concluded that consumption frequency was associated with measures of adiposity in some cases. The former found positive associations between snacking frequency and obesity measures in overweight, but not normal, individuals, whilst the latter found that associations varied depending on sex, adjustment model and under-reporting.

Due to the lack of consensus, this research will examine associations between consumption frequency and BMI in addition to portion size to gain a fuller picture and better inform policy development. It will focus on energy-dense foods, but split wider food groups into product-based subgroups, as previous studies tend to use broader food groups, where the diversity of foods in each group is higher and therefore comparability is lower (33, 57, 58). Other studies compare incompatible food groups from multiple survey iterations, where the foods within these groups do not correspond across surveys (75). Under-reporting will also be accounted for, either by exclusion (Chapter 9) or adjustment (Chapter 8), as the impact of under-reporting is acknowledged across the literature.

The literature on consumed portion size and health is limited in scope in terms of generalising to whole dietary intakes across national populations, as it typically focuses on selected food groups, as in this research, or specific population groups. In addition, evidence on national populations or subgroups is typically cross-sectional, so cannot determine causality. This could explain the lack of a causal link between portion size and obesity and related health conditions – much of the evidence base is either small-scale experimental or cross-sectional. This limitation is also present in studies of portion size in children and adolescents (64, 65, 76, 77), whilst studies examining trends over time are based on a series of national cross-sectional surveys (33, 58, 71, 78).

Steenhuis et al. (63) highlight that relatively few interventions have been conducted and those that have often have small samples, are conducted on relatively young, healthy populations and are not evaluated. To address this, more interventions and studies in real-life settings are needed. Marteau et al. (67) identify the limitation that much of the evidence on the effects of portion size reduction is based on very large portions, making it uncertain as to whether the same effect would be seen in smaller, but still large, portions. In addition, not all studies account for under-reporting, despite the fact that cross-sectional studies are limited by errors in portion size estimates (52), so resulting inferences may be less accurate. This is supported by Murakami & Livingstone (74), who use cross-sectional data and acknowledge that under-reporting may be a key factor in the lack of association between dietary intake and adiposity.

Doubly labelled water (DLW) studies are considered the gold standard in measuring energy expenditure and therefore misreporting of energy intake (79). However, such studies are too costly and burdensome to run on entire national dietary survey samples, so are conducted on survey subsamples to accurately measure under-reporting and project estimated levels across the whole survey sample (80). As a result, the most common method of measuring under-reporting in large studies is the Goldberg cut-off method, which calculates confidence intervals (cut-offs) that determine whether or not reported energy intake is a plausibly valid measure of food intake (81).

Under-reporting can affect associations between portion size or consumption frequency and BMI (82), and in their study Murakami & Livingstone (74) found that adjusting for under-reporting had a greater impact on diet quality and adiposity outcomes than the definition of meal/snack frequency employed. Devlin et al. (83) also identified energy misreporting as a crucial area for further investigation in their review of the use of cluster analysis to derive dietary patterns.

2.3.2 Trans fatty acids and socioeconomic status

As a known contributor to CHD and estimated cause of over 500,000 deaths globally each year (35), TFAs will be investigated in-depth as a specific nutrient of concern. In addition to identifying the sources of and health risks linked to TFAs (84-87), the literature largely examines TFA levels either following or preceding the implementation of TFA-reduction strategies (37, 88-90). In the TRANSFAIR study, Huhlsof et al. (91) investigated TFA intakes in 14 Western European countries, but much of the data behind these intakes derive from nutrient composition databases compiled before widespread reformulation to reduce TFA levels in food. In addition, the study does not look at population characteristics or disadvantaged groups.

Although national dietary surveys may present population mean TFA intakes that are compliant with the WHO RNI, as shown in Chapters 4 and 5 (25, 36), these averages could still overshadow inequalities within certain groups, like those on low incomes. This can be seen historically – the 2007 UK Low Income Diet and Nutrition Survey showed unequal TFA consumption, with the most deprived groups having higher intakes of processed foods and takeaways, which are a known source of TFAs (92). Although TFA intakes have reduced, inequalities do not seem to have improved; in their modelling study, Pearson-Stuttard et al. (93) estimated that a 1% reduction in TFA of daily energy intake would result in five times fewer deaths and six times more life years in the most deprived quintile than the most affluent. Reducing industrial TFA intake could therefore substantially reduce health inequalities in CHD mortality.

TFA content has decreased substantially in Western Europe, but the same trend has not necessarily been seen in Central & Eastern Europe. Zupanic et al. (17) assessed the presence of pre-packed products with TFA-containing PHOs in Slovenia and found that voluntary reformulation and public education on the risks related to TFA consumption impacted upon, but did not eradicate, PHO levels in the food supply. The authors found that levels in the highest PHO-containing products in 2015 had decreased in 2017 by 4% in vegetable cream substitutes, 5% in soups and 8% in biscuits. However, TFA levels in cakes, muffins and pastries increased in 2017. This corresponds with research showing that TFA removal in bakery goods across Europe has been slower than other food categories (42). Zupanic et al. (17) call for legislative measures to reduce TFA levels across all categories, as they claim mandatory labelling and voluntary reduction has had limited success.

In research set in a real-world situation, Stender et al. (42) conducted market basket investigations of TFA levels in biscuits, cakes and wafers in supermarkets and ethnic shops across 20 European countries to assess the effectiveness of voluntary TFA reduction strategies. Nine, mainly Central & Eastern countries, had products with high TFA levels and in the ethnic shop sample 60% products had >20% fat as TFAs. TFA levels in some products imported to Malmo in Sweden were also similar to those of Central & Eastern European countries with high TFA products, showing that trade where borders are fluid can undermine voluntary national reduction strategies. The authors concluded that TFAs were present in popular foods across Europe and that certain population subgroups like ethnic minorities and those on lower incomes were at greater risk of high TFA exposure and therefore had elevated NCD risk. This is substantiated in part by evidence that Swedish immigrants have a greater mortality rate than the rest of the population (94). Similarly, in Portugal, Casal et al. (95) found that imported biscuits and pastry products available in budget outlets had higher TFA levels than the majority of products overall, which met WHO guidelines.

The case of TFAs illustrates how nutritional inadequacies in disadvantaged, particularly lower income groups, can be obscured by population-level mean intakes from national dietary surveys. It is crucial that these groups be considered when devising preventative policies. WHO (15) highlight an association between obesity and being in a lower socioeconomic group and state that the greatest policy impact would be achieved in children of less educated parents and deprived groups. Darmon & Drewnowski (96) reviewed diet quality and socioeconomic status and found that higher values of the Healthy Eating Index, Diet Quality Index, dietary variety and diversity scores, and other diet quality measures have all been associated with higher socioeconomic status. In their overview of definitions and methods used in portion size research, Almiron-Roig et al. (52) also state that portion size estimates are affected by socioeconomic status.

2.3.3 Next steps

It is clear that socioeconomic status affects multiple aspects of diet. Consequently, this work will explore nutrient intakes across socioeconomic groups, using education as a proxy for socioeconomic status as this was the only compatible variable across the 12 datasets gathered. This will aid the identification of vulnerable groups and nutrients of concern and help target policy efforts effectively.

This chapter has discussed the body of literature currently informing the various workstreams relevant to the research questions. It has highlighted knowledge gaps and measurement issues, which will be further addressed in the following chapters.

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Chapter 3 National nutrition surveys in Europe: A review on the current status in the 53 countries of the WHO Europe region

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3.1 Abstract

Objective: 1) To determine the coverage of national nutrition surveys in the 53 countries monitored by the WHO Regional Office for Europe and identify gaps in provision. 2) i, To describe relevant survey attributes and ii, whether energy and nutrients are reported with a view to providing information for evidence-based nutrition policy planning.

Design: Dietary survey information was gathered using three methods: i) direct email to survey authors and other relevant contacts; ii) systematic review of literature databases and iii) general web-based searches. Survey characteristics relating to timeframe, sampling and dietary methodology and nutrients reported were tabled from all relevant surveys found since 1990.

Setting: 53 countries of the WHO Regional Office for Europe, which has need for an overview of dietary surveys across the lifecourse.

Subjects: European individuals (adults and children) in national diet surveys.

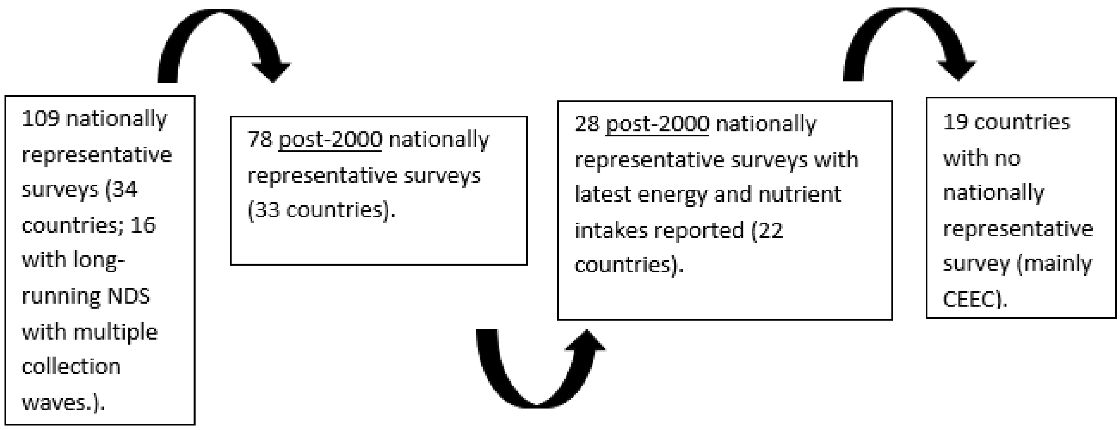
Results: 109 nationally representative dietary surveys undertaken post-1990 were found across 34 countries. Of these, 78 surveys from 33 countries were found post-2000 and of these, 48 surveys from 27 countries included children and 60 surveys from 30 countries included adults. No nationally representative surveys were found for 19 of 53 countries, mainly from Central & Eastern Europe. Multiple 24hr recall and food diaries were the most common dietary assessment methods. Only 22 countries reported energy and nutrient intakes from post-2000 surveys; macronutrients were more widely reported than micronutrients.

Conclusions: Less than two thirds of WHO Europe countries have nationally representative diet surveys, mainly collected post-2000. The main availability gaps lie in Central & Eastern European countries, where nutrition policies may therefore lack an appropriate evidence base. Dietary methodological differences may limit the scope for inter-country comparisons.

Keywords:

- National diet surveys.
- WHO European region.
- Dietary assessment methodologies.
- Scoping review – gaps.
- Multi-criteria analysis.
- Nutritional epidemiology.

3.1.1 Graphical Abstract: National diet surveys identified.



3.2 Introduction

The World Health Organisation (WHO) European Food and Nutrition Action Plan aims to 'significantly reduce the burden of preventable diet-related noncommunicable diseases, obesity and all other forms of malnutrition still prevalent in the WHO European Region' and improve diet and nutrition in the European population (1). An unhealthy diet is one of the four major behavioural risk factors for noncommunicable diseases (NCDs) in all WHO regions (2), with the European region proportionately suffering the greatest NCD burden. Other risk factors include alcohol, tobacco misuse and physical inactivity (2). In Europe, the four most common NCDs account for 77% of disease and almost 86% premature mortality (1).

NCDs and related conditions, including overweight and obesity, have significant and growing economic and social costs (1), which traditional clinical approaches are increasingly unable to address (3). Mozaffarian et al. (3) call for a shift in emphasis from such pharmacological treatments to primary prevention through addressing lifestyle risk factors like dietary patterns in order to reduce cardiovascular risk and NCD-associated problems.

Dietary surveys thus have an important role in assessing dietary patterns in the whole population. Nutrition and health surveys formed the main source of information for dietary risk factors and physical inactivity in a systematic analysis of disease risk in 21 regions worldwide across two decades (4). Such surveys can provide a means of monitoring trends, identifying areas of concern and inequality and evaluating policy impact, thereby ultimately contributing to the promotion of best practice across the region (1). The WHO European Food & Nutrition Action Plan (1) explicitly encourages member states to 'strengthen and expand nationally representative diet and nutrition surveys.'.

Many western European countries currently have established dietary surveys that assess food and nutrient intake. A global review of country-specific surveys from 1990-2010 only reported dietary fat and oil intake (5). A comprehensive, updated review of total nutrient and food intakes across different populations and subgroups in Europe is needed, the results of which could identify where in Europe there is a need to improve diets and whether inequalities exist. This paper makes the first step in this; establishing which countries have nationally representative dietary surveys and highlighting gaps in nutrition survey provision across Europe.

This review aims to identify which of the 53 countries in the WHO Europe region have conducted nationally representative dietary surveys of whole diets at an individual level and those that have not. It identifies key characteristics, centred on timeframe, sampling and dietary methodology, of known surveys undertaken since 1990 for adults and children and aims to lay the foundations in establishing a clear picture of the current situation. Following this, future papers will examine energy and nutrient intakes in different population groups across Europe to better assess where both gaps in knowledge and dietary inadequacies lie. Information from dietary surveys can be used as a means for governments and health bodies to monitor and reduce the diet-related risk of NCDs and related conditions across Europe, thereby contributing to the goals set out in the WHO action plan.

3.3 Methods

We used three key approaches to identifying national diet surveys; 1) contacting authors of surveys; 2) systematic literature review; and iii) general web-based searches.

3.3.1 Identifying authors of national diet surveys

We identified authors of national surveys within the WHO Europe remit using listed contact names and other information from two main reports of national dietary surveys (5, 6). If no response was obtained from those authors, internet searches of nutrition organisations by country and the survey titles listed in the review of 1990-2010 surveys (5) and the European Food Consumption Survey (6), were carried out to find other potentially useful contact details. For countries where this approach did not yield usable contact details, internet searches using various search terms were performed on organisations specialising in nutrition, including known government and public health agencies. WHO also provided contact details for some those countries for which they had relevant associates. Contacts identified were asked to complete a questionnaire (appendix 1) to provide information on nationally representative dietary surveys conducted at an individual level since 1990, including links or references to relevant reports.

3.3.2 Systematic Database Search

For countries where no contact could be identified, systematic searches were undertaken across Web of Science, Medline and Scopus for nationally representative dietary surveys that collected data at an individual level from 1990 to June 2016. The following query terms were run without language restrictions: (survey* OR research* [TS]) AND (nutrition* OR diet* OR food* [TS]) AND (list of countries).

The title of each paper generated by the database searches was screened for relevance according to the criteria in Table 1; those not relevant were excluded. The remaining papers were screened by title and abstract, and full article where available, and their appropriateness for inclusion checked by a second reviewer. Further surveys, related papers and nutrition expert contact names were gathered by general internet searching to capture any recently released information, targeting known government and public health agencies using various search term combinations in order to maximise returns. Although there were no language restrictions in the initial search, the WHO Regional Office for Europe, Division of Noncommunicable Diseases and Promoting Health through the Life-Course conducted an additional database search of papers in the Russian language as an extra check to maximise returns in the 12 Central & Eastern European countries where Russian is an official or widely spoken language (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan). However, no papers or reports that met the inclusion / exclusion criteria were found. The databases searched were PubMed, Web of Science and Google Scholar, using the search terms mentioned above, translated into Russian. Further searches with these terms were undertaken in three specific Russian-language databases: Kazakh Academy of Nutrition; 1st Moscow Medical Academy named after Sechenov and Electronic scientific library in Russian.

3.3.3 Database Extraction

Where long-running surveys had multiple collection waves e.g. the French INCA 1 and INCA 2 or UK NDNS 2000-1 and NDNS 2008-12, each collection wave was counted as a separate survey (see table 2). Survey characteristics were extracted and tabled from the relevant publications, which were accessed in various forms, including summary reports, academic articles and completed questionnaires (see table 2). These characteristics were: country name, survey name, year of survey (data collection), information source, sample size and age range, dietary methodology, nutrient composition database and reference. The availability of energy and selected nutrients from the latest surveys collected after 2000 are listed in appendices 1 and 2.

3.4 Results

3.4.1 Data Extracted

109 nationally representative surveys that obtained data on whole diets (rather than focusing only on certain foods) at an individual level since 1990 were found for 34 out of the 53 countries in the WHO office region. Table 2 shows the characteristics of these surveys and that the majority of countries with NDS had conducted multiple surveys. Of the 34 countries with NDS, almost half (n=16) had long-running surveys with waves conducted over various years; 10 of these also had standalone surveys (table 2). Countries for which relevant survey characteristics were gathered were: Andorra, Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Former Yugoslav Republic of Macedonia, Turkey and the UK.

Of the 109 nationally representative surveys found, 78 were conducted since 2000, covering 33 countries – those listed previously, excluding Slovakia. Reports of energy and nutrient intakes were not found for each of these surveys. Only 28 surveys from 22 countries were found with post-2000 survey reports of energy and nutrient intakes.

The majority of the surveys were found via internet searches or emailing contacts gathered by the methods discussed. Current contact details were found for the following 30 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Malta, the Netherlands, Poland, Portugal, Romania, Russian Federation, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom (UK). WHO provided details for Andorra, Kazakhstan and The Former Yugoslav Republic of Macedonia. Contact details were not available for the following 20 countries: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kyrgyzstan, Luxembourg, Monaco, Montenegro, Republic of Moldova, San Marino, Serbia, Slovakia, Slovenia, Tajikistan, Turkey, Turkmenistan, Ukraine, and Uzbekistan. For countries where no contact could be identified, the original systematic literature search returned 6654 papers across the three databases, but only eight of these met the inclusion criteria. Of the 78 surveys undertaken since 2000, 30 papers or reports relating to them were acquired through email contacts, four from information extracted by WHO from the WHO Global Nutrition Policy Review 2017, 35 via internet searching, two via the systematic literature search, 18 via the Micha review (5) and one from the EFCOSUM survey (6); 11 reports had multiple sources. See figure 2 for the full dietary survey screening and table 2 for the characteristics of all dietary surveys conducted since 1990.

No nationally representative surveys were found by any method that collected dietary intake of whole diets at individual level for 19 European countries (see table 3 and figure 1). Although one survey of children was found for Croatia, it was not nationally representative (7). In addition, no nationally representative surveys have been found for Slovakia that have been conducted since 2000, and none for Bulgaria and Czech Republic since 2005. In Western Europe, no surveys have been found for Italy or Israel conducted since 2006, or for Andorra since 2005.

Of the 109 nationally representative surveys, 45 obtained dietary information on both adults and children, a further 41 surveys collected dietary information on adults aged 18+ only, and 23 on children aged <18 only. For the 86 surveys that included adults, 60 across 30 countries were conducted since 2000. Of the 68 surveys that included children, 48 were conducted since 2000 and spanned 27 countries. Nationally representative surveys for children were missing in 9 countries: Croatia, Finland, Hungary, Israel, Lithuania, Luxembourg, Romania, Slovakia, and Switzerland. Further gaps were found for Andorran children aged <12 years, Bulgarian children aged above 5 years, Icelandic, Kazakh and Slovenian children aged <15 years, Macedonian children aged <16 years, Polish children post-2000 and Spanish micronutrient intake in children of all ages.

Non-nationally representative dietary surveys were found for eight countries (Croatia; Czech Republic; Germany; Greece; Iceland; Luxembourg; Russia;

Switzerland), but because of our exclusion criteria they were not included in the list of nationally representative surveys in table 2. Additionally, 16 studies conducted in Central and Eastern European countries were returned from the systematic literature search in English and 49 from the WHO Russian-language database search and were not included in any tables; common reasons for rejection were no or partial dietary intake collected, data not collected at individual level, duplicate, sample size too small (<200). Eight countries completed the WHO STEPwise approach to noncommunicable disease risk factor surveillance (STEPS) adult survey (8-15). However, although these were nationally representative population-based surveys with large sample sizes, they were not included in this review because they only covered specific food groups, not whole diets, and as such did not meet our inclusion criteria.

3.4.2 Dietary Methodologies

The most common dietary assessment methodologies used across the 109 nationally representative surveys were the 24hr recall and food diary. Of these surveys, 45 used 24hr recall, 35 of which were surveys conducted since 2000 (table 2). Of the 45 surveys using 24hr recall the range of daily recalls was 1-4; 29 surveys used *multiple* 24hr recalls, 26 of which were conducted post-2000. Table 2 illustrates that where countries used both 24hr recall and food diaries, this was a combination of methodological changes in waves of long-running surveys, different surveys using different methodologies, or both methods being employed within the same survey for different population groups e.g. adults and children. A 2x24hr recall is the method recommended by the European Food Safety Authority (EFSA) for adults NDS (16). Countries with surveys conducted post-2000 using multiple 24hr recall were: Austria, Belgium, Bulgaria, Czech Republic, Estonia, Finland, France, Greece, Iceland, Kazakhstan, Latvia, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, The Former Yugoslav Republic of Macedonia and the UK. Spain calculated usual nutrient intake from 24hr recall and a 3-day dietary diary.

Food diaries were used as a primary method by 47 surveys, 33 of which were conducted post-2000. The range of diary days per survey was 1-7. 38 surveys used *multiple* day diaries as the primary method, and 26 of these were conducted post-2000 from the following countries: Austria, Cyprus, Denmark, France, Greece, Hungary, Ireland, Italy, the Netherlands, Norway, Sweden and the UK. The majority of these were performed over consecutive days. Weighed diaries were used as the sole method by some surveys in France, Ireland, Italy and the UK, but also as a primary method by one survey in Germany.

Food frequency questionnaires (FFQs) were used by 12 surveys, five of which were conducted post-2000 (Estonia, Ireland, Norway, Romania and Slovenia). FFQs were used by Ireland, Norway and Slovenia in pre-2000 surveys and as a supplementary, rather than primary, dietary assessment tool by other countries (Andorra, Belgium, Greece, Hungary, Iceland, Latvia, Lithuania, the Netherlands, Poland, Slovakia, Spain and Turkey).

Of the 28 surveys that reported energy and nutrient intakes (see table 2 for older NDS approaches where available), 10 used interviews – these were primarily (n=8) face-to-face rather than telephone-based, and three of these were electronic, for example, computer or tablet-based. Respondents self-completed in 11 surveys, which were all food-diaries. Electronic resources were utilised in five surveys, just two of which were web-based. Five surveys used multiple approaches – these were mainly a combination of face and telephone interviews with the exception of Spain, which used both interview forms, plus a tablet and camera-photos.

3.4.3 Energy and Nutrient Coverage

Of the 22 countries that had post-2000 nationally representative survey reports of energy and nutrient intakes; 20 countries reported data for adults and 16 for children. This was provided by 28 of the latest post-2000 surveys that reported energy and nutrient data for these countries; 13 surveys included both adults and children, eight surveyed adults only and seven sampled children only (3 being separate surveys of children in Ireland). Table 2 identifies these 28 surveys and illustrates their differing methodological approaches.

All 28 surveys included energy and also carbohydrate, fibre, fat and protein intakes. Most surveys (n=25) included intake data on saturated fat (Germany and the Irish child and teen surveys did not); MUFAs (n=25) (Germany, Irish child and teen surveys did not) and PUFAs (n=24) (Germany, Irish child and teen surveys, and the Dutch DNFCS young children did not). See appendix 2 and figure 3.1 for tabular and graphical summaries of the macronutrients included by each survey. The majority of surveys (n=21) included intake levels of sugars in some form, either as total sugars or as added sugars/sucrose. However, Cyprus, Germany, the Irish child and teen surveys, Latvia, the Spanish ENIDE survey and Turkey included neither. Given current concerns about sugar consumption, this is an important gap. Few surveys (n=6) included data on starch intakes and less than half (n=9) included trans fatty acid (TFA) intakes (see appendix 2).

All surveys with the exception of the Spanish ANIBES study included some micronutrients of interest (see appendix 3 and figure 3.2). However, none of the micronutrients investigated was reported by every survey. Vitamin A, riboflavin, thiamine, vitamin B6, vitamin B12, vitamin C, vitamin D, calcium, magnesium and iron were reported by 26 or more surveys. Copper (13), iodine (13), selenium (11) and fluoride (1 – not tabled) were reported by fewer than half the surveys.

3.5 Discussion

3.5.1 Data collection

This report details the initial findings of a review into dietary surveys across the 53 countries within the WHO Europe remit (17). Nationally representative surveys which collected data on whole diets at individual level since 1990 were found for only 64% of countries, the main gaps clearly lying in 17 countries in the Central & Eastern European region of the WHO Europe remit. Although eight countries without NDS had recently completed a comprehensive WHO STEPS survey, including questions on fruit and vegetable intake, salt consumption and use of fats and oils in cooking and eating, the survey does not address whole diets and only included adults; therefore this represents a knowledge gap. However, non-nationally representative surveys were found in two countries that had no other NDS, which demonstrates that although some countries have no nationally representative surveys, other initiatives are in place and the expertise and fieldwork experience needed to conduct NDS may be present. All Western European countries had published survey information after 2000. Of countries with NDS, 16 conducted long-running surveys with multiple collection waves, which could generate important information for trends analysis. Fewer surveys were available that measured diet in children than adults; again gaps were primarily in Central & Eastern European countries. This implies that nutrition policies in this region are based on limited data, which is of concern, as overweight and obesity have tripled in some of these countries since 1980 and NCD prevalence rates are reaching those of Western Europe (1).

Emailing nutrition experts and general internet searches were the most successful data gathering methods. A major source for contacts and survey information was a global survey review from 1990-2010 (5). Few academic papers met the pre-set inclusion criteria in the systematic database search performed for countries – particularly Central & Eastern countries – with no surveys or contacts mentioned in previous reviews, which also minimises the risk of bias. A possible explanation is that survey results and characteristics may be published as government or other official reports rather than academic papers. However, we also undertook wider web-based searches, targeting known government and public health agencies using various search terms to account for this. Another reason is that dietary assessment in large-scale studies like national diet surveys are costly, due to the labour intensive nature of study preparation and data collection, and therefore may not be undertaken by some countries (18). This could explain the disproportionate concentration of gaps in survey provision in Central & Eastern European countries, which tend to have lower national incomes (19). This highlights a need to clarify major barriers and work with countries to establish mechanisms to overcome these and subsequently to devise and implement NDS.

3.5.2 Dietary Methodologies of Post-2000 Surveys

The most common methods of collecting dietary intake used in the 78 post-2000 surveys were the 24 hour recall and food diary; the majority of which were collected over multiple days. Although 24hr recalls are known for under-reporting (20), their increased use could reflect their advantage in being less onerous for respondents and potentially providing more consistent results across all age and sex groups compared with other methods (21). Retrospective dietary recalls can provide detailed information on eating patterns and exert less influence on food choice than food diaries (22), thereby generating a more accurate and realistic report on population nutrient intake. However, such short-term dietary assessment methods are associated with within-person errors and wider variation of intakes within the population, particularly when only one or two days are collected, the latter as recommended by EFSA (16). Although FFQs provide long term assessment, they nevertheless can present inflated energy and nutrient intakes (21), which could explain why few post-2000 surveys used FFQs as the primary dietary assessment method.

Prospective weighed and non-weighed food diaries allow very detailed information to be gathered on multiple days (22) and are sometimes used to validate other methods using a small sub-sample, but have a high respondent burden and like the 24hr recall, are susceptible to under-reporting (23). Food dairies with weighed intake are particularly burdensome and prone to response bias and respondent fatigue (24) – most likely the reason why fewer studies used it as a primary assessment method and the UK moved from weighed intake to estimated.

Many studies used multiple tools to collected food intake. Of the 22 countries for which energy and nutrient intakes were reported, all surveys that collected dietary intake using more than one tool generated energy and nutrient intake data from a primary method and used the other method(s) as a means of validation and calibration. The exception was Spain, which was the only country that used a truly mixed methods approach. Food diaries and 24hr recalls do not provide insight into usual intakes, whereas FFQs are less accurate in estimating individuals' absolute intakes; combining methods could help rectify these shortcomings (24). Spain, Belgium and the Netherlands estimated ‘usual’ intakes using the Statistical Program to Assess Dietary Exposure (SPADE) (25), although the Dutch intakes presented by age group in this report reflect the average of actual intakes reported by individuals. Of the other countries employing FFQ as a supplementary method, Greece and Iceland also explicitly stated that this was used to estimate usual intake. This approach is designed to overcome within-person errors and wider intake variations when only 2 days of intake have been collected, although methodological limitations cannot be fully negated.

Of the 23 surveys that sampled children only, over half (n=15) used some form of food diary. This could be because children are expected to remember less retrospectively, so prospective methods of capturing intake, although subject to under-reporting and the limitations mentioned above, are deemed preferable and more accurate. This also fits with EFSA guidance on the collection of national food consumption data, which recommends countries “…use the dietary record method for infants and children and the 24-hour recall method for adults.” (16). EFSA further recommend data be collected on two non-consecutive days and that it be supplemented with a food propensity questionnaire (16). It remains to be seen whether more countries will move towards non-consecutive diaries in future surveys; at present, the majority of multiple food diaries are conducted on consecutive days. More detailed methodological recommendations for NDS of children are available via the Pilot study for the Assessment of Nutrient intake and food Consumption Among Kids in Europe (PANCAKE) project (26).

Of the 28 surveys that reported energy and nutrient intakes, Austria, Estonia, Iceland and Norway moved to 2x24hr recall in the latest NDS, perhaps to comply with the latest EFSA guidance (16). The UK switched from a 7-day weighed to a 4-day estimated food diary, which is more likely a move to reduce respondent burden. Although methodological changes make comparisons problematic across survey waves, the move towards a common approach will ease comparisons between countries in the long-term and should be actively encouraged in line with EFSA recommendations. Although, this could be logistically and financially challenging it would assist in making inter-country comparisons and identifying vulnerable groups, therefore enabling the effective targeting of policy resources.

3.5.2.1 Technology in National Dietary Surveys

Care is needed in any dietary assessment method to minimise measurement error. Many dietary assessment methods require highly skilled interviewers, which increases survey costs and presents a potential barrier to conducting NDS (24). Technology like computer-administered interviews and image-capture could help overcome this obstacle and also promote standardised practices. The EPIC-Soft software package developed by the European Prospective Investigation into Cancer and Nutrition (EPIC) Study provided uniform templates for various aspects of NDS including conducting 24hr recall, which has since been modified by the European Food Consumption Validation (EFCOVAL) Study and renamed 'Globodiet'. It aimed for Europe-wide use, but is limited by the need for professionals to be trained in its use (27).

At present, none of the surveys identified used mobile technologies to collect dietary information, though Belgian, German and Portuguese surveys employed electronic interviews, the Spanish ANIBES used tablets and the Norwegian Ungkost3 and Swedish Riksmaten used a web-based food diary (see table 2). This current lack of use may be due to lack of validation or differential usability across population groups. However, web-based dietary assessments with self-administered record or recall methodologies have the potential to reduce data entry expense and allow data collection for large numbers on multiple days over different time periods (28). They could therefore be more cost-effective and encourage countries for which cost has been a significant barrier to undertake surveys. For example, myfood24 is an online 24-hr dietary assessment tool that can be used for either of the EFSA-approved (16) 24hr recall or a food diary methods (28). It employs country-specific food databases and is currently in operation in Denmark, Germany and the UK. Technologies like this could reduce the onus on researchers by automatically coding food records (28). These benefits could encourage countries that historically lack national diet survey provision to undertake surveys and enable countries that already undertake surveys to implement these at more regular intervals. This would serve to increase the amount of dietary and nutrient intake data available in the WHO Europe remit, directly contributing to the WHO objective of strengthening and expanding nationally representative diet and nutrition surveys World Health Organisation (1).

3.5.3 Energy and nutrient intakes

Energy and nutrient intake provision was documented from the *latest* survey collected after 2000 for each country for which we could locate intake data. For some countries, more recent surveys had been conducted (see table 2), but intake data was not yet available in all cases. An additional limitation on data available was the range of nutrients each survey covered. Of the countries that specified nutrient intakes, Germany and Belgium were the most likely to have gaps in reported intakes of macro and micronutrients respectively, and the Spanish ANIBES survey (29-31) only reported macronutrient data (see appendix 3). This suggests that the reporting of nutrient intakes is inconsistent, making it harder to assess nutrient coverage and make inter-country comparisons.

Inconsistent age groupings across countries also make inter-country comparisons potentially problematic. In Andorra, the youngest age group spanned adults and children, meaning that although children were sampled, intake levels would not be valid in any comparisons. Future investigation could be undertaken using raw data and consistent age groups to obtain more reliable conclusions.

Differences in dietary methodologies may be a limiting factor when making inter-country comparisons. The relatively low levels seen in Turkish adult and child energy intakes compared to other countries could potentially be explained by methodological differences. The Turkish survey used a single 24hr recall, whereas the Belgian, Danish, German, Hungarian, Dutch, Norwegian and Spanish surveys, whilst using different methodologies (see table 2), all collected data on multiple days. Collection on a single day is more likely to result in error due to less control over day-to-day variation (32).

Lack of alignment and completeness of national food composition databases and classification systems represents a further limitation. For example, some food composition databases may not be updated to account for reformulated products, which could introduce differences and potential error in the energy and nutrient content of foods and therefore population intakes as reported in NDS. Common approaches to food composition databases are set out in more detail in the EFCOVAL study (33). Energy and nutrient intake values will be reported and discussed in more detail in future publications (34).

3.5.4 Strengths and Limitations

The strength of the current review is that it presents a unique, current overview of dietary survey characteristics in all WHO Europe countries since 1990. The existence of newer studies such as Bel-Serrat et al. (35) illustrates the fluidity of the situation and the need for updated, comprehensive reviews. This review includes surveys covering both adults and children, so provides a full picture of the current state of dietary survey provision across the lifecourse. It also discusses methodologies, enabling insights into common methods and paving the way for future exploration of best practice and policy recommendations.

However, the surveys employed different methodologies, both between surveys and within long-running surveys with multiple collection waves, potentially making the task of comparing countries problematic. Despite this, we feel that there is still a need to use the available information to make inter-country comparisons where possible. Another limitation of the review was that we were unable to establish contact with nutrition experts or government officials who may be working in nutrition in some of the 19 countries where no surveys were found, which were mainly Central & Eastern European countries. Therefore we cannot be certain that these countries do not have any relevant dietary surveys. We also cannot be certain that there are no other nationally representative surveys in countries where we did obtain survey information from contacts. However, it is likely that these contacts would be aware of other surveys in their countries; in the distributed questionnaire contacts were asked for details of all surveys in their country.

3.6 Conclusion

This review found that less than two thirds of the 53 countries in the WHO European region conducted national diet and nutrition surveys since 1990, with only 22 countries reporting nutrient intake data since 2000. The main survey gaps for both adults and children lie in the Central & Eastern European countries, where nutrition policies may therefore lack an appropriate evidence base. Differing dietary assessment methodologies may impact upon the ability to make inter-country comparisons; existing efforts to harmonise NDS across all ages, particularly guidelines set by EFSA (16), should continue to be encouraged, including beyond Western Europe. It would therefore be beneficial to target future efforts at standardising methodologies and filling knowledge gaps for the countries that have no surveys post-2000 in order to increase the information available for evidence-based policy planning. By establishing which countries have NDS, this review lays the foundations in paving the way for a future review and stratified analyses of actual nutrient intakes across population groups in Europe.

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Table 1: Survey inclusion and exclusion criteria

Included	Excluded
Surveys conducted at an individual level	Surveys collected at group i.e. household level
Nationally representative surveys	Non-nationally representative, regional only surveys
Results of surveys reported by published and unpublished reports, academic journals and websites	Surveys with data collected prior to 1990
Surveys that included individuals >2y	Surveys with samples exclusively <2y
Surveys based on whole diet rather than specific food groups	Surveys with incomplete food group coverage
	Surveys with small sample sizes (n<200)

Table 2: National diet surveys across the WHO Europe remit 1990-2016

Country *	Survey Name	Survey Year	Source **	Sample Size	Sample Age	Dietary Methodology	Nutrient Reference Database †	Energy Intake Graphed Y/N‡	Reference
Albania	None found								
Andorra	Evaluation of the Nutritional Status of the Andorran Population	2004-2005	6	900	12-75	24h recall (x2 for 35% sample), FFQ. Face-to-face and phone interview.	CESNID. *Tablas de composición de alimentos*. Barcelona: Edicions Universitat de Barcelona-Centre d'Ensenyament Superior de Nutrició i Dietètica, 2002	Y	(36)
Armenia	None found								
Austria*	Austrian nutrition report 2012 (OSES)	2010-2012	3	1002	7-14; 18-80	3-day diary (consecutive) (children); 2*24h recall (adults). Face-to-face and phone interview.	Analysis run with software “(nut.s) science” based on Bundeslebensmittelschlüssel 3.01 / Goldberg cut-offs for data cleaning.	Y	(37)
	Austrian Study on Nutritional Status 2007	2007	4	2472	7-100	Single dietary diary		N	(38)

	Austrian Study on Nutritional Status (ASNS)	1993-1997	5	2065	19-95	24h recall, diet history		N	(39)
	Austrian Study on Nutritional Status (ASNS)	1991-1994	5	2173	6-18	7-day diary		N	(40)
Azerbaijan	None found								
Belarus	None found								
Belgium*	Belgium National Food Consumption Survey (BNFCS) 2014	2014-2015	2/3	3146	3-64	2*24h recall. Face to face electronic interview.	The NIMS Belgian Table of Food Composition (Nubel); Dutch NEVO	Y	(41, 42)
	Belgium National food consumption survey (BNFCS)	2004	3/4	3245	15-100	2*24h recall. Face to face interview. FFQ.		N	(43)
Bosnia and Herzegovina	None found								
Bulgaria	National survey on nutrition of infants and children under 5 and family child rearing, 2007	2007	3	1723	0-5	2*24h recall via mother (non-consecutive). Face to face interview with the mother,	FCTBL_BG (Food Composition Tables – Bulgaria)	Y	(44-46)
	National Nutrition Survey	2004	4	853	20-100	Single dietary diary		N	

Croatia	None found								
Cyprus	A study of the dietary intake of Cypriot children and adolescents aged 6-18 years	2009-2010	3	1414	6-18	3-day food record (consecutive inc 1 weekend). Self-completed.	USDA Nutrient Database for Standard Reference and Research	Y	(47)
Czech Republic	Individual Food Consumption Study (SISP04)	2003-2004	2	2590	4-90	2*24h recall. Face to face interview,		N	(48, 49)
	Czech Post-MONICA study	1997-1998	4	2158	19-64	Single dietary diary		N	
Denmark*	Danish National Survey of Diet and Physical Activity (DANSDA) 2011-2013	2011-2013	3	3946	4-75	7-day diary (consecutive). Self-completed.	Danish Food Composition Databank	Y	(50)
	Danish National Survey of Diet and Physical Activity (DANSDA) 2003-2008	2003-2008	3	4431	4-75	7-day diary (consecutive). Self-completed.		N	(51)
	Dietary Habits of Denmark 2000-2002	2000-2002	4	4120	4-75	7-day diary		N	(52)
	National Dietary Survey	1995	5	3098	1-80	7-day diary		N	(53)

Estonia	National Dietary Survey	2014-15	2	4906	4m-74yrs	2*24h recall (age >10); 2*24h food diary (age <10); FFQ (age >2). Face to face electronic interview.		N	Not yet available.
	Nutrition and Lifestyle in the Baltic Republics	1997	1/4	2015	16-64	24h recall + questionnaire		N	(54, 55)
Finland*	The National FINDIET 2012 survey	2012	3	1708	25-74	48h recall. Face to face interview.	Fineli 7 Food Composition Database	Y	(56)
	FINDIET 2007	2007	2/3/4	2039	24-74	48h recall. Face to face interview.		N	(57, 58)
	FINDIET 2002	2002	3	13437	25-34, 35-44, 45-54, 55-64, 65-74	48h recall. Face to face interview.		N	(59)
	FINDIET 1997	1997	5	3152	25-74	24h recall		N	(60)
	FINDIET1992	1992	4/5	1861	25-64	3-day diary		N	(61)
France*	ESTEBAN	2015-16	2	3617	Children 6-17 1108; adults 18-74 2509.	3*24h recalls		N	Not yet available.

	Enquête Nutri-Bébé 2013	2013	3	1184	15d-35m	3-day weighed diary (non-consecutive). Face to face interview.		N	(62)
	Individual National Food Consumption Survey (INCA2)	2006-2007	3	4079	3-79	7-day diary (consecutive). Self-completed.	Food Composition Database of CIQUAL of Afssa.	Y	(63)
	Etude nationale nutrition sante (ENNS); National Nutrition and Health survey	2006-2007	2/4	4780	Children 3-17 1665; adults 18-74 3115.	3*24h recalls (non-consecutive)		N	(64)
	Enquête Nutri-Bébé 2005	2005	3	706	1-36m	3-day weighed diary (non-consecutive inc weekend). Face to face interview.		N	(65)
	Individual National Food Consumption Survey (INCA)	1998-1999	5	1018 1985	3-14 15+	7-day diary		N	(66)
	Enquête Nutri-Bébé 1997	1997	3	660	0-30m	3-day weighed diary. Face to face interview.		N	(67)
	National food consumption survey (ASPCC)	1993-1994	5	1500	2-85	7-day diary		N	(68)

Georgia	None found								
Germany	German National Nutrition Survey (Nationale Verzehrstudie) II (NVSII)	2005-2007	2/4	15371	14-80	DISHES diet history interview, 24h-recall, diet weighing diary (2*4 days). Face to face electronic interview.	Bundeslebensmittelschlüssel (BLS)	Y	(69, 70)
	Der Kinder- und Jugendgesundheitssurvey (KiGGS)	2003-2006	3	17641	0-17	Questionnaire.		N	(71)
	German Nutrition survey 1998	1997-1999	4/5	3861	20-79	FFQ		N	(72)
Greece	HYDRIA – Greek National Diet and Health Survey	2013-14	2	4011	18+	2*24h recalls; food propensity questionnaire. Face to face interview.		N	(73, 74)
	Nutrient Intakes of Toddlers and Pre-schoolers in Greece: The GENESIS Study	2003-2004	3	2374	1-5	3-day diary (includes nutrient data). Face to face interview.		N	(75)
Hungary*	Hungarian Diet & Nutritional Status Survey (OTÁP 2014)	2014	2	857	18-34, 35-64, 64+	3-day diary (non-consecutive). Self-completed.		N	Not yet available.

	Hungarian Diet & Nutritional Status Survey (OTÁP 2009)	2009	2	1165	18-34, 35-64, 64+	3-day diary (non-consecutive), Self- completed.	Nutricomp.	N	(76)
	Hungarian dietary survey 2009	2009	3	3077	19-30, 31-60, 60+	3-day diary (non-consecutive), FFQ, Self- completed.	Új tápanyagtáblázat.	Y	(77, 78)
	3rd National Hungarian Survey	2003	4	3633	18-100	Multiple dietary diary		N	(79)
	2nd National Hungarian Survey	1992-1994	4/5	2559	18-100	3*24h recall + FFQ		N	(80)
Iceland*	The Diet of Icelanders – a national dietary survey 2010-2011	2010-2011	2	1312	18-80	2*24h recall + FFQ. Telephone interview.	Icelandic Database of Food Ingredients (ÍSGEM); Public Health Institute for Raw Materials in the Icelandic Market.	Y	(81-83)
	The Diet of Icelanders, Dietary survey of the Icelandic nutrition council 2002	2002	4	1118	15-80	Single dietary diary		N	(84)
	Dietary survey of the Icelanders	1990	4/5	1240	15-80	Diet history		N	(85)

Ireland*	National Pre-school Nutrition Survey	2010-2011	2	500	1-4	4-day weighed food diary (consecutive). Self- completed (by carer).	McCance and Widdowson's The Composition of Foods 5&6 editions	Y	(86)
	National adult nutrition survey 2011 (NANS)	2008-2010	2	1500	18-90	4-day semi weighed food diary (consecutive). Self-completed.	McCance and Widdowson's The Composition of Foods 5&6 editions	Y	(87, 88)
	Survey of Lifestyle, Attitudes & Nutrition in Ireland (SLAN), 2007	2007	3/4	9223	18+	FFQ. Face to face.		N	(89, 90)
	National Teens' Food Survey	2005-2006	2	441	13-17	7-day semi-weighed food diary (consecutive). Self-completed.	McCance and Widdowson's The Composition of Foods 5&6 editions	Y	(91)
	National Children's Food Survey.	2003-2004	2	594	5-12	7-day weighed food diary (consecutive). Self-completed.	McCance and Widdowson's The Composition of Foods 5&6 editions	Y	(92)
	SLAN 2002	2002	3	5992	18+	Semi quantitative FFQ.		N	
	SLAN 1998	1998	3	6539	18+	Semi quantitative FFQ.		N	
	North-South Food Consumption Survey	1998	5	1379	18-64	7-day diary. Self-completed.		N	(93)

	Irish National Nutrition Survey	1990	5	1214	8-18+	Diet history		N	(94)
Israel*	Mabat national health and nutrition survey of the Elderly (Zahav)	2005-2006	4	1782	65-100	Single dietary diary		N	
	Mabat First Israeli national health and nutrition survey	1999-2001	4	3240	25-64	Single dietary diary		N	
Italy	The third Italian National food consumption survey INRAN-SCAI 2005-2006	2005-2006	3	3323	0.1-97.7	3-day diary (consecutive). Self- completed,	Banca Dati di Composizione degli Alimenti. INRAN-DIARIO 3.1	Y	(95)
	INN-CA 1994-1996	1994-1996	4/5	2734	0-94	7-day weighed diary. Self-completed,		N	(96)
Kazakhstan	Nutritional and health status survey of the population in Kazakhstan	2008	6	3526	15-59	2*24hr recall		N	
Kyrgyzstan	None found								
Latvia	National Diet Survey 2012-14	2012-2014	2	3418	0-74	2*24hr recall (non-consecutive), FFQ, dietary diary		N	Results not yet available

	Latvian National Food Consumption Survey 2007-2009	2008	2	1949	7-64	2*24hr recall (non-consecutive), FFQ. Face to face interview.	Latvian National Food Composition Data Base 2009	Y	(97)
	Nutrition and lifestyle in the Baltic Republics	1997	1/4	2299	19-64	24h recall + questionnaire		N	(54, 55)
Lithuania	Study of actual nutrition and nutrition habits of Lithuanian adult population	2013-2014	2	2513	19-75	24h recall + questionnaire. Face to face interview,	EuroFIR Food Classification	Y	(98)
	Food consumption survey in adult Lithuanian population	2007	1/2	1936	19-65	24h recall		N	(99, 100)
	Nutrition and Lifestyle in the Baltic Republics	1997	1/4/5	2094	20-65	24h recall + questionnaire		N	(54, 55)
Luxembourg	None found								
Malta	None found								
Monaco	None found								
Montenegro	None found								

Netherlands*	Dutch National food consumption survey 2012-2016 (DNFCS 2012-16)	2012-2016	2	4340	1-79	2*24hr recall & 1-day food diary (some age groups), FFQ.		N	Not yet available: (101)
	Dutch National Food Consumption Survey 2007-2010 (DNFCS 2007-10)	2007-2010	2/3	3819	7-69	2*24h recalls. Telephone (adults)/ face to face (children) interview, FFQ	Dutch Food Composition Database (NEVO)	Y	(102-104)
	Dutch National Food Consumption Survey – young children (DNFCS 2008)	2005-2006	2	1279	2-6	2-day diary (non-consecutive). Self- completed (by adult), FFQ	Dutch Food Composition Database (NEVO)	Y	(105)
	Dutch National food consumption survey (DNFCS 2003)	2003	2/4	750	19-30	2*24h recall (non-consecutive, telephone).		N	(106)
	Dutch National food consumption survey (DNFCS-3) 1997-1998	1997-1998	2/4/5	6250	1-97	2-day diary		N	(107)
	Dutch National food consumption survey (DNFCS-2) 1992	1992	2/4/5	6218	1-92	2-day diary		N	(107)

Norway*	UNGKOST 3	2015-2016	2	1721	4-13	4-day online diary plus FFQ (consecutive). Self- completed via web.	The Norwegian Food Composition Tables	Y	(108, 109)
	Norwegian national diet survey NORKOST3	2010-2011	3	1787	18-70	2*24h recall and FFQ. Telephone interview.	The Norwegian Food Composition Tables	Y	(110)
	Sub-sample of NOWAC (component of EPIC)	2002	1	2000 (female)	46-75	FFQ		N	(111)
	UNGKOST-2000	2000	3	394 815 1009	4, 9 & 13	4-day diary, self-completed.		N	(112)
	Norwegian national dietary survey (NORKOST 1997)	1997	4/5	2672	16-79	FFQ		N	(113)
	Norwegian national diet survey (NORKOST 1993-1994).	1993-1994	1/5	3144	16-79	FFQ		N	(114)
	UNGKOST-1993	1993	5	1705 1564	13 18	FFQ		N	(115)
	Pilot study	1992	1	1200	16-79	FFQ		N	(114)

Poland*	WOBASZ II study	2013-2014	3	6170	20+	24h recall and FFQ. Face to face interview.		N	(116)
	WOBASZ-National Multicentre Health Survey	2003-2005	4	6661	20-74	Single dietary diary		N	
	Sub-sample of the Household Food Consumption and Anthropometric Survey	2000	4/5	4200	1-100	24h recall, face to face.		N	(117)
	Dietary habits and nutritional status of selected populations	1991-1994	5	1126 2193 4945	11-14 18 20-65	24h recall		N	(118, 119)
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015-2016	6	4221	3m-84y	2*24h recall (non-consecutive) and FPQ (electronic interview) 2-day food diary for children <10y. Face to face electronic interview.	Portuguese Food Composition Table (INSA)	Y	(120, 121)
	Dietary calcium and body mass index in Portuguese children	2002-2003	3	4511	7-9	24h recall, face to face.		N	(122)

Republic of Moldova	None found								
Romania	National synthesis, 2006	2006	4	1036	19-100	FFQ			
Russian federation*	The Russia Longitudinal Monitoring Survey – Higher School of Economics (RLMS-HSE)	2011-2012	2/3	21686	0-102	24h recall		N	(123)
	The Russia Longitudinal Monitoring Survey – Higher School of Economics (RLMS-HSE)	1994, 1995, 1996, 1998, 2000, 2001, 2002, 2003, 2004, 2005	2	1994-11295, 1995-10632, 1996-10448, 1998-10663, 2000-10969, 2001-12100, 2002-12489, 2003-12634, 2004-12639, 2005-12228.	0-102	24h recall		N	(124)
San Marino	None found								
Serbia	None found								

Slovakia‡‡	Nutrient intake in the adult population of the Slovak Republic	1991-1994 & 1995-1999	1	4018	19-80	24h recall. Face to face interview,		N	(125, 126)
	Nutrient intake in children and adolescents in Slovakia	1991-1999	5	3337 4556	11-14 15-18	24h recall and FFQ		N	(126)
Slovenia	Dietary Intake of Macro- and Micronutrients in Slovenian Adolescents	2012	3	2224	15-16	FFQ, self-completed.		N	(127)
	Dietary Habits of the Adult Population Slovenia in Health Protection	2007-2008	2	1193	18-65	2*24hr recall (non-consecutive), FFQ. Face to face interview,		N	(128)
Spain*	ENALIA 2 study	2014-2015	3	933 plus 157 pregnant women.	18-74	2*24hr recall, FFQ. Face to face electronic interview,		N	(129) Nutrient intake data not yet available.
	ENALIA study	2012-2014	3	1780	6m-17	2*1-day diary (<11y); 2*24hr recall (11+); FFQ (all)		N	(130) Nutrient intake data

									not yet available.
	ANIBES study	2013	3	2285	9-75	3-day diary + 24h recall (consecutive). Face to face, telephone (interview), tablet and camera (self-report).	Tablas de Composición de Alimentos, 15ª ed	Y (children only)	(29-31)
	ENIDE study (Sobre datos de la Encuesta Nacionalde Ingesta Dietética)	2009-2010	3	3000	18-24; 25-44; 45-64	3-day diary + 24h recall (consecutive). Interview and self- completed.	Base de Datos Española de Composición de Alimentos – RedBEDCA	Y	(131-134)
	The Catalan Nutrition Survey (ENCAT 2002-2003)	2003	4	1923	10-100	2*24hr recall (non-consecutive), face to face, FFQ.		N	
	EnKid Study	1998-2000	3	3534	2-24	24hr recall (*2 in 25% sample), face to face. FFQ.		N	(135, 136)
Sweden*	Riksmaten adolescents	2016-2017	2	?	11-12; 14-15; 17-19	2*24h recall		N	Data collection not yet completed.

	Riksmaten 2010-2011 Swedish Adults Dietary Survey	2010-2011	3	1797	18-80	4-day food diary (consecutive). Self- completed via web.	NFA Food Composition Database	Y	(137)
	Riksmaten-barn 2003 Swedish children's Dietary survey	2003	3	590 ,889, 1016	4y, 8-9,11-12	4-day food diary (consecutive), self-completed >4y, by adult 4y.		N	(138)
	Riksmaten 1997-1998	1997-1998	4/5	1214	18-74	7-day diary		N	(139)
Switzerland	MenuCH	2014-15	2					N	
	National Nutrition Survey Switzerland (NANUSS). Pilot for MenuCH.	2008-2009	2					N	
Tajikistan	None found								
The former Yugoslav Republic of Macedonia	First Macedonian Food Consumption Survey	2015	6	504	16+	2*24hr recall. Interview.		N	Report not yet available.
Turkey	Turkey nutrition and health survey 2010 (TNHS)	2010	3	14248	0-100	24hr recall, FFQ. Face to face interview.	BEBS Nutritional Information System Software; Turkish Food Composition Database	Y	(140, 141)

Turkmenistan	None found								
UK*	National Diet and Nutrition Survey Rolling Programme Y5-6 (NDNS RP 2012-2014)	2012-2014	3	2546	1.5 -94	4-day diary (consecutive). Self- completed.		N	(142)
	National Diet and Nutrition Survey Rolling Programme (NDNS RP 2008-2012)	2008-2012	3	6,828	1.5 -94	4-day diary (consecutive). Self- completed.	McCance and Widdowson's The Composition of Foods integrated dataset	Y	(143)
	Low Income Diet and Health Survey (LIDNS)	2003-2005	4		2-100	4*24h recalls		N	(144)
	NDNS 2000-2001 Adults	2000-2001	4	1724	19-64	7-day weighed dietary diaries		N	(145)
	NDNS 1997 children	1997		1701	4-18	7-day weighed dietary diaries		N	(146)
	NDNS 1994-95 65years and over	1994-1995	4	1275	65-100	Single dietary diary		N	(147)
Ukraine	None found								
Uzbekistan	None found								

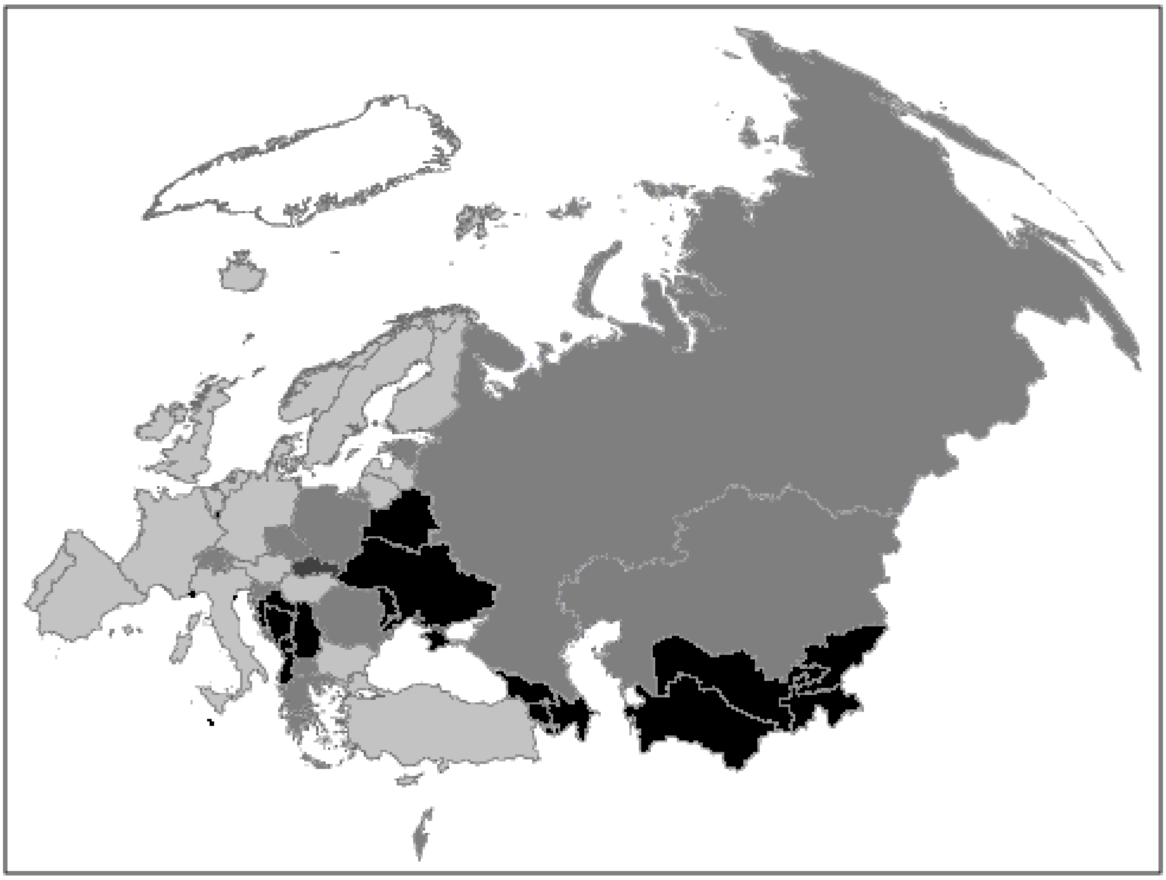
* Countries conducting long-running surveys comprising of multiple collection waves.
** 1 = database searches; 2 = email contacts; 3 = general internet searches; 4 = Micha et al. (5); 5 = European Food Consumption Survey 2001 (6); 6) WHO Global Nutrition Policy Review 2017 extracted information.

† Information regarding nutrient composition databases has been added for those surveys for which energy and nutrient intakes were reported and graphed.
‡ Y = energy intakes were taken from the latest survey for which they were reported; N = energy and nutrient intakes were either not reported or were not extracted because intakes for that country were available in a later survey.
‡‡ The Slovakian surveys were not truly nationally representative, but were country-wide and designed to 'recruit a diverse sample of subjects of different age categories and socio-economic background' (125).
NB – the EFSA guidance for the standardised collection of national food consumption data was released in 2009.

Table 3: Level of Nationally Representative Survey Provision by Country

Countries with No Surveys	Countries with Pre-2000 Surveys only	Countries with Post-2000 Surveys without reports of energy & nutrient intakes	Countries with Post-2000 Survey plus Energy & Nutrient Intakes
Albania	Slovakia	Czech Republic	Andorra
Armenia		Estonia	Austria
Azerbaijan		Greece	Belgium
Belarus		Israel	Bulgaria
Bosnia & Herzegovina		Kazakhstan	Cyprus
Croatia		Poland	Denmark
Georgia		Romania	Finland
Kyrgyzstan		Russian Federation	France
Luxembourg		Slovenia	Germany
Malta		Switzerland	Hungary
Monaco		The Former Yugoslav Republic of Macedonia	Iceland
Montenegro			Ireland
Republic of Moldova			Italy
San Marino			Latvia
Serbia			Lithuania
Tajikistan			The Netherlands
Turkmenistan			Norway
Ukraine			Portugal
Uzbekistan			Spain
			Sweden
			Turkey
			UK

Figure 1 – Map of National Dietary Survey Provision by Country



Light grey – Post-2000 Survey plus Nutrient Intakes (28 surveys in 22 countries)

Medium grey – Post-2000 Survey (78 surveys in 33 countries)

Medium-dark grey – Pre-2000 Survey (3 surveys in 1 country)

Dark grey – No Survey (19 countries)

White – countries not in the WHO Europe remit.

Figure 2 – Screening and selection of national dietary surveys:

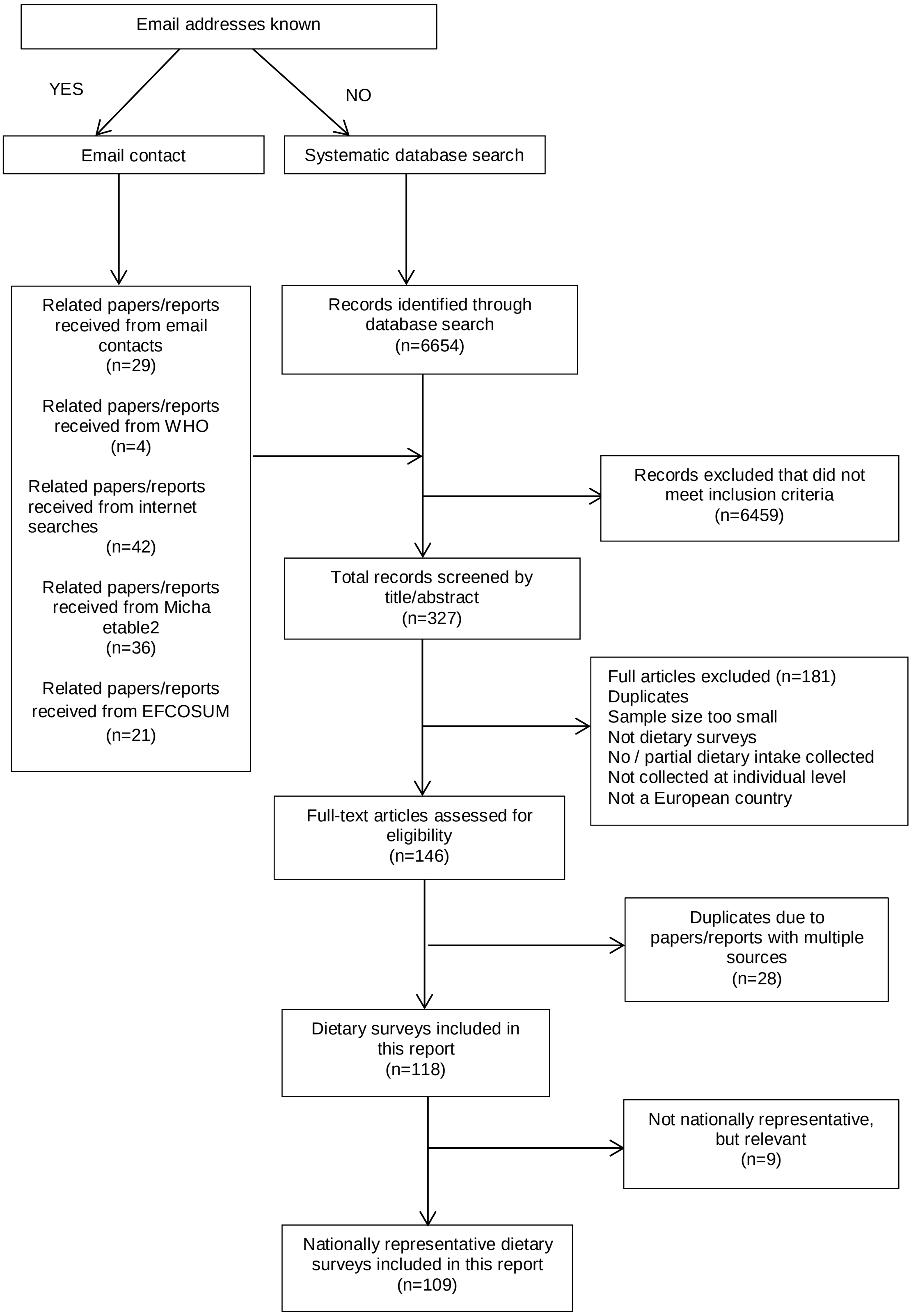
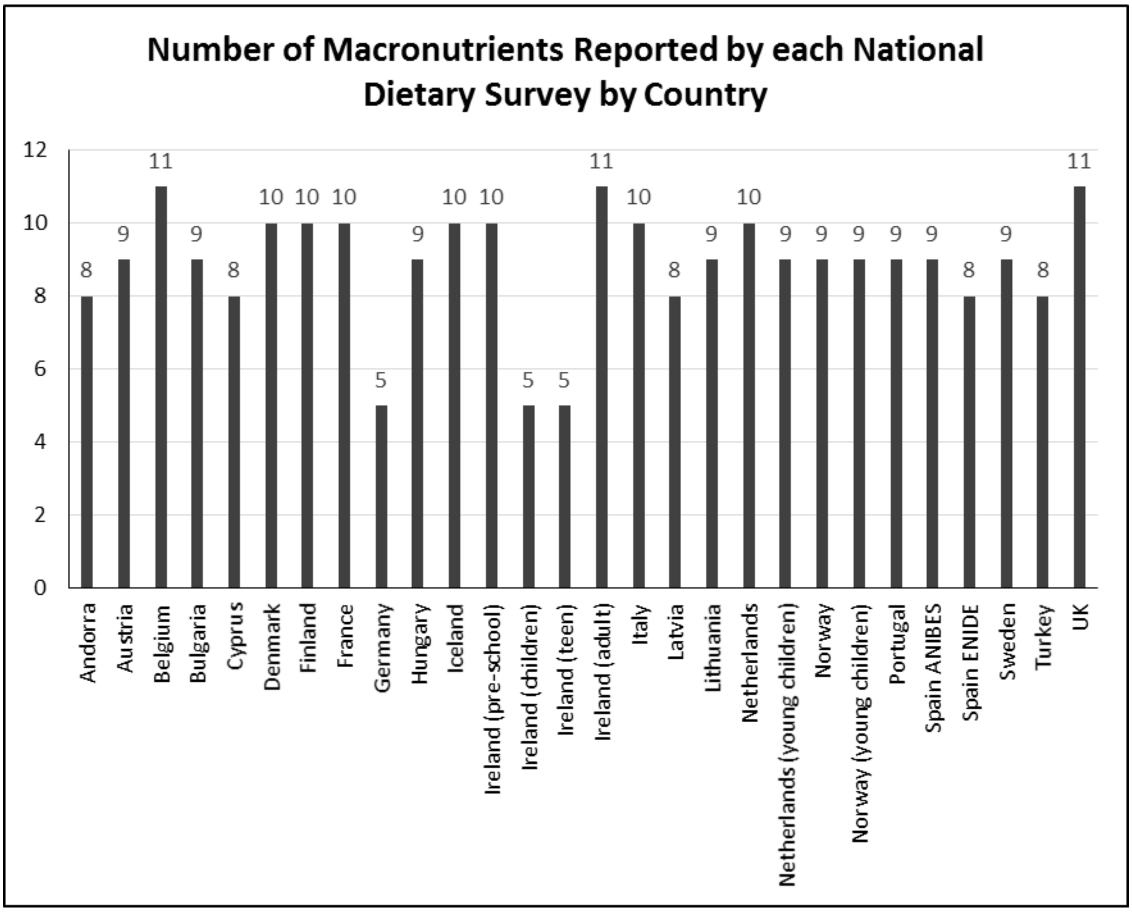
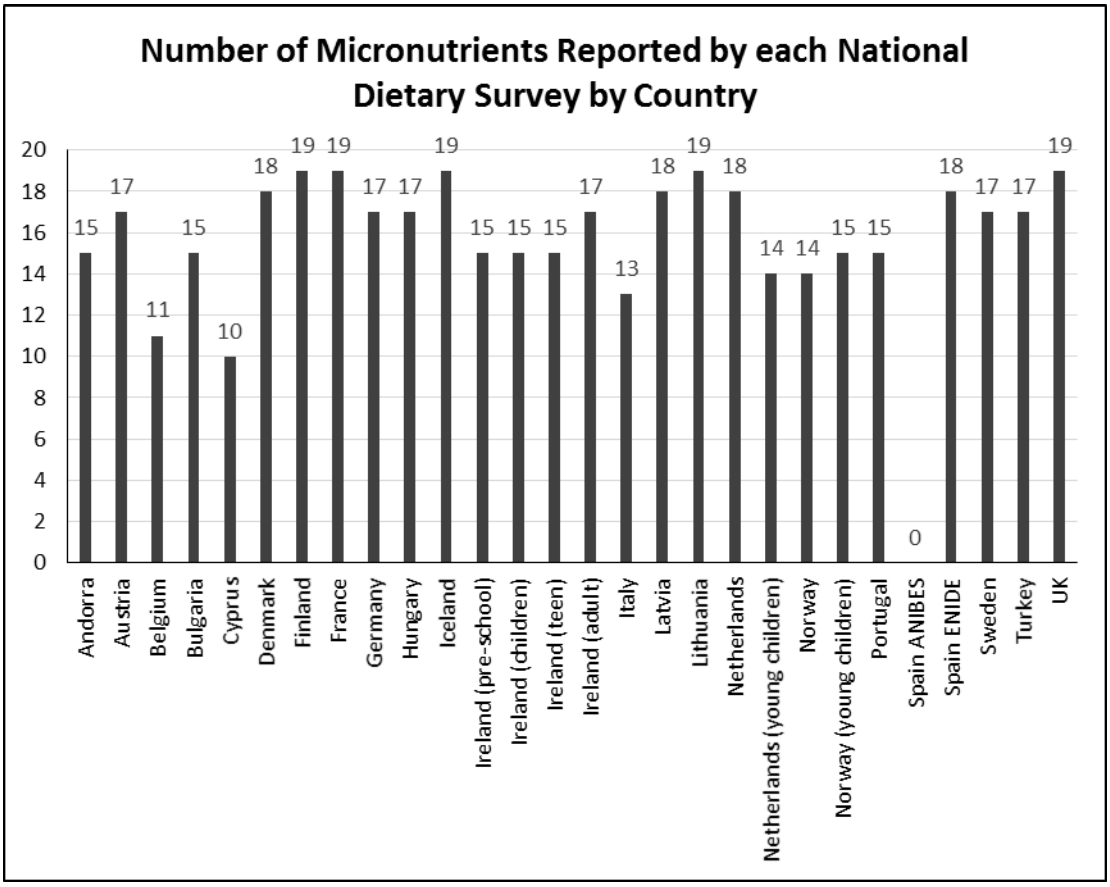


Figure 3.1 – Number of macronutrients reported by each national dietary survey by country*:



* Where 12 is the maximum potential number of selected macronutrients of interest being reported in NDS reports: energy, protein, carbohydrate, sugars, sucrose, starches, fibre, total fat, saturated fat, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), trans fatty acids (TFA).

Figure 3.2 – Number of micronutrients reported by each national dietary survey by country*:



* Where 19 is the maximum potential number of selected micronutrients of interest being reported in NDS reports: folate (B9), niacin (B3), vitamin A, riboflavin (B2), thiamine (B1), vitamin B12 (biotin), vitamin B6 (pyridoxine), vitamin C, vitamin D, vitamin E, calcium, magnesium, potassium, sodium, iron, copper, iodine, selenium, zinc.

Appendix 1 – Questionnaire concerning nationally representative diet and nutrition surveys and their methodologies

Please complete one questionnaire *per diet and nutrition survey (DNS)* for questions 1-3; if necessary make multiple copies. If there any questions in sections 1-3 that you cannot answer, please provide contact details of a person(s) who may be able to answer the outstanding questions.

Please email the completed questionnaire(s) to Holly Rippin fshr@leeds.ac.uk at the University of Leeds, who will be collating this information for the European Office of the World Health Organisation.

Country: xxx

Contact (please provide the correct contact person if this is incorrect): Prof/Dr. xxx

For each DNS carried out in your country since 1990 please fill in the below information:

Please note that any survey to be included should meet the following criteria:

The survey should collect dietary intakes across all food groups which are then converted into nutrient values.
The survey uses national population-based samples or representative regional samples.
The survey should not be restricted to a specific part of the population (e.g. children, occupational groups or patients).
Preferably there should be plans to repeat the survey later, unless it already has been repeated. You can also record standalone surveys.

Survey name
……………………………………………………………………………………….………

Year(s) when survey data collected………………………………………………………

Dietary assessment method/tool used………………………………………………….

Genders included in sample…………………………………………………………………

Age ranges included in sample……………………………………………………………..

Sample size (N)

National or regional ………………………………………………………………………….

Nationally representative (yes/no)…………………………………………….…………..

Institute responsible for the survey…………………………………………………..

Key contact for survey…………………………………………………………………………

Email for contact person listed above………………………………………………..

Please provide details of any relevant publications e.g. summary reports, user guides (please provide web links)

Macro and micro nutrients included in your DNS (please tick all that apply):

Energy
Total carbohydrates
Sugars
Sucrose
Starches
Fibre
Total fat
Saturates
MUFA
PUFA
Trans fatty acids
Protein
Vitamins:
Folic acid
Niacin
Retinol equivalents
Riboflavin
Thiamine
B12
B6
Minerals:
Calcium
Magnesium
Potassium
Sodium
Iron
Copper
Fluoride
Iodine
Selenium
Zinc

THANK YOU FOR TAKING THE TIME TO ANSWER THESE QUESTIONS.

Appendix 2 – Macronutrient provision across dietary surveys

COUNTRY	SURVEY	YEAR	Energy (MJ/kcal)	Protein (g)	CHO g/%E	Sugars (g)	Sucrose (g)	Starch (g)	Fibre (g)	Total fat (g)	Saturates (g)	MUFA (g)	PUFA (g)	TFA (g)
Andorra	Evaluation of the nutritional status of the Andorran population	2004-2005	Y	Y	Y	Y			Y	Y	Y	Y	Y	
Austria	Austrian nutrition report	2010-2012	Y	Y	Y		Y		Y	Y	Y	Y	Y	
Belgium	The Belgian food consumption survey 2014-15	2014-2015	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
Bulgaria	National survey on nutrition of infants and children under 5 and family child rearing, 2007	2007	Y	Y	Y	Y			Y	Y	Y	Y	Y	
Cyprus	A study of the dietary intake of Cypriot children and adolescents aged 6-18 years	2009-2010	Y	Y	Y				Y	Y	Y	Y	Y	
Denmark	Danish Dietary habits 2011-2013	2011-2013	Y	Y	Y		Y		Y	Y	Y	Y	Y	Y
Finland	The national FINDIET 2012 survey	2012	Y	Y	Y		Y		Y	Y	Y	Y	Y	Y
France	INCA2	2006-2007	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	

Germany	German National Nutrition Survey II	2005-2007	Y	Y	Y				Y	Y				
Hungary	Hungarian Dietary Survey 2009	2009	Y	Y	Y		Y		Y	Y	Y	Y	Y	
Iceland	The Diet of Icelanders – a national dietary survey 2010-2011	2010-2011	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
Ireland	National Pre-school Nutrition Survey	2010-2011	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	
Ireland	National children's Food Survey	2003-2004	Y	Y	Y				Y	Y				
Ireland	National Teens' Food Survey	2005-2006	Y	Y	Y				Y	Y				
Ireland	National adult nutrition survey	2008-2010	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
Italy	The third Italian National food consumption survey INRAN-SCAI	2005-2006	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	
Latvia	Latvian National Food Consumption Survey 2007-2009	2007-2009	Y	Y	Y				Y	Y	Y	Y	Y	

Lithuania	Study and evaluation of actual nutrition and nutrition habits of Lithuanian adult population	2013-2014	Y	Y	Y	Y			Y	Y	Y	Y	Y	
Netherlands	Dutch National Food Consumption Survey (DNFCS) 2007-2010	2007-2010	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
Netherlands	Dutch National Food Consumption Survey – young children (DNFCS 2008)	2005-2006	Y	Y	Y	Y			Y	Y	Y	Y		Y
Norway	Norkost3	2010-2011	Y	Y	Y		Y		Y	Y	Y	Y	Y	
Norway	Ungkost3	2015-2016	Y	Y	Y		Y		Y	Y	Y	Y	Y	
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015-2016	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
Spain	ANIBES	2013	Y	Y	Y	Y			Y	Y	Y	Y	Y	
Spain	ENIDE 2011	2009-2010	Y	Y	Y				Y	Y	Y	Y	Y	
Sweden	Riksmaten 2010-11 Swedish Adult Dietary Survey	2010-2011	Y	Y	Y		Y		Y	Y	Y	Y	Y	

Turkey	Turkey nutrition and health survey 2010 (TNHS)	2010	Y	Y	Y				Y	Y	Y	Y	Y	
UK	National Diet and Nutrition Survey (NDNS) Years 1-4	2008-2012	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
TOTAL	**28**		**28**	**28**	**28**	**14**	**7**	**6**	**28**	**28**	**25**	**25**	**24**	**9**

Appendix 3 – Micronutrient provision across dietary surveys

COUNTRY	SURVEY	YEAR	B9 (µg)	B3 (mg)	VA (µg)	B2 (mg)	B1 (mg)	B12 (µg)	B6 (mg)	VC (mg)	VD (µg)
Andorra	Evaluation of the nutritional status of the Andorran population	2004-2005	Y	Y	Y	Y	Y	Y	Y	Y	Y
Austria	Austrian nutrition report	2010-2012	Y	Y	Y	Y	Y	Y	Y	Y	Y
Belgium	The Belgian food consumption survey 2014-15	2014-2015	Y			Y	Y	Y	Y	Y	Y
Bulgaria	National survey on nutrition of infants and children under 5 and family child rearing, 2007	2007	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cyprus	A study of the dietary intake of Cypriot children and adolescents aged 6-18 years	2009-2010			Y	Y	Y		Y	Y	
Denmark	Danish Dietary habits 2011-2013	2011-2013	Y	Y	Y	Y	Y	Y	Y	Y	Y
Finland	The national FINDIET 2012 survey	2012	Y	Y	Y	Y	Y	Y	Y	Y	Y
France	INCA2	2006-2007	Y	Y	Y	Y	Y	Y	Y	Y	Y
Germany	German National Nutrition Survey II	2005-2007	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hungary	Hungarian Dietary Survey 2009	2009	Y	Y	Y	Y	Y	Y	Y	Y	Y

Iceland	The Diet of Icelanders – a national dietary survey 2010-2011	2010-2011	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ireland	National Pre-school Nutrition Survey	2010-2011	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ireland	National children's Food Survey	2003-2004	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ireland	National Teens' Food Survey	2005-2006	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ireland	National adult nutrition survey	2008-2010	Y	Y	Y	Y	Y	Y	Y	Y	Y
Italy	The third Italian National food consumption survey INRAN-SCAI	2005-2006			Y	Y	Y	Y	Y	Y	Y
Latvia	Latvian National Food Consumption Survey 2007-2009	2007-2009	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lithuania	Study and evaluation of actual nutrition and nutrition habits of Lithuanian adult population	2013-2014	Y	Y	Y	Y	Y	Y	Y	Y	Y
Netherlands	Dutch National Food Consumption Survey (DNFCS) 2007-2010	2007-2010	Y		Y	Y	Y	Y	Y	Y	Y

Netherlands	Dutch National Food Consumption Survey – young children (DNFCS 2008)	2005-2006	Y		Y	Y	Y	Y	Y	Y	Y
Norway	Norkost3	2010-2011	Y		Y	Y	Y	Y	Y	Y	Y
Norway	Ungkost3	2015-2016	Y		Y	Y	Y	Y	Y	Y	Y
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015-2016	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spain	ANIBES	2013									
Spain	ENIDE 2011	2009-2010	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sweden	Riksmaten 2010-11 Swedish Adult Dietary Survey	2010-2011	Y	Y	Y	Y	Y	Y	Y	Y	Y
Turkey	Turkey nutrition and health survey 2010 (TNHS)	2010	Y	Y	Y	Y	Y	Y	Y	Y	Y
UK	National Diet and Nutrition Survey (NDNS) Years 1-4	2008-2012	Y	Y	Y	Y	Y	Y	Y	Y	Y
TOTAL	**28**		**25**	**20**	**26**	**27**	**27**	**26**	**27**	**27**	**26**

COUNTRY	SURVEY	YEAR	VE (mg)	Ca (mg)	Mg (mg)	K (mg)	Na (mg)	Fe (mg)	Cu (mg)	I (µg)	Se (mg)	Zn (µg)
Andorra	Evaluation of the nutritional status of the Andorran population	2004-2005	Y	Y	Y	Y	Y	Y				Y
Austria	Austrian nutrition report	2010-2012	Y	Y	Y	Y	Y	Y		Y		Y
Belgium	The Belgian food consumption survey 2014-15	2014-2015		Y			Y	Y		Y		
Bulgaria	National survey on nutrition of infants and children under 5 and family child rearing, 2007	2007	Y	Y	Y		Y	Y				Y
Cyprus	A study of the dietary intake of Cypriot children and adolescents aged 6-18 years	2009-2010		Y	Y	Y	Y	Y				
Denmark	Danish Dietary habits 2011-2013	2011-2013	Y	Y	Y	Y	Y	Y		Y	Y	Y
Finland	The national FINDIET 2012 survey	2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
France	INCA2	2006-2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Germany	German National Nutrition Survey II	2005-2007	Y	Y	Y	Y	Y	Y		Y		Y
Hungary	Hungarian Dietary Survey 2009	2009	Y	Y	Y	Y	Y	Y	Y			Y

Iceland	The Diet of Icelanders – a national dietary survey 2010-2011	2010-2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ireland	National Pre-school Nutrition Survey	2010-2011	Y	Y	Y			Y	Y			Y
Ireland	National children's Food Survey	2003-2004	Y	Y	Y			Y	Y			Y
Ireland	National Teens’ Food Survey	2005-2006	Y	Y	Y			Y	Y			Y
Ireland	National adult nutrition survey	2008-2010	Y	Y	Y	Y	Y	Y	Y			Y
Italy	The third Italian National food consumption survey INRAN-SCAI	2005-2006	Y	Y	Y	Y		Y				Y
Latvia	Latvian National Food Consumption Survey 2007-2009	2007-2009	Y	Y	Y	Y	Y	Y	Y	Y		Y
Lithuania	Study and evaluation of actual nutrition and nutrition habits of Lithuanian adult population	2013-2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Netherlands	Dutch National Food Consumption Survey (DNFCS) 2007-2010	2007-2010	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Netherlands	Dutch National Food Consumption Survey – young children (DNFCS 2008)	2005-2006	Y	Y	Y			Y	Y		Y	
Norway	Norkost3	2010-2011	Y	Y	Y	Y	Y	Y				
Norway	Ungkost3	2015-2016	Y	Y	Y	Y	Y	Y			Y	
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015-2016	Y	Y	Y	Y	Y	Y				Y
Spain	ANIBES	2013										
Spain	ENIDE 2011	2009-2010	Y	Y	Y	Y	Y	Y		Y	Y	Y
Sweden	Riksmaten 2010-11 Swedish Adult Dietary Survey	2010-2011	Y	Y	Y	Y	Y	Y			Y	Y
Turkey	Turkey nutrition and health survey 2010 (TNHS)	2010	Y	Y	Y	Y	Y	Y		Y		Y
UK	National Diet and Nutrition Survey (NDNS) Years 1-4	2008-2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
TOTAL	**28**		**25**	**27**	**26**	**21**	**22**	**27**	**13**	**13**	**11**	**22**

Key

B9	Folic acid
B3	Niacin
VA	Vitamin A (retinol equivalent)
B2	Riboflavin
B1	Thiamine
B12	Vitamin B12
B6	Vitamin B6
VC	Vitamin C
VD	Vitamin D
VE	Vitamin E

Ca	Calcium
Mg	Magnesium
K	Potassium
Na	Sodium
Fe	Iron
Cu	Copper
I	Iodine
Se	Selenium
Zn	Zinc

Chapter 4 Adult Nutrient Intakes from Current National Dietary Surveys of European Populations

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Abstract: The World Health Organization (WHO) encourages countries to undertake national dietary survey (NDS) but implementation and reporting is inconsistent. This paper provides an up-to-date review of adult macro and micronutrient intakes in European populations as reported by NDS. It uses WHO Recommended Nutrient Intakes (RNIs) to assess intake adequacy and highlight areas of concern. NDS information was gathered primarily by internet searches and contacting survey authors and nutrition experts. Survey characteristics and adult intakes by gender/age group were extracted for selected nutrients and weighted means calculated by region. Of the 53 WHO Europe countries, over a third (*n* = 19), mainly Central & Eastern European countries (CEEC), had no identifiable NDS. Energy and nutrient intakes were extracted for 21 (40%) countries but differences in age group, methodology, under-reporting and nutrient composition databases hindered inter-country comparisons. No country met more than 39% WHO RNIs in all age/gender groups; macronutrient RNI achievement was poorer than micronutrient. Overall RNI attainment was slightly worse in CEEC and lower in women and female elderly. Only 40% countries provided adult energy and nutrient intakes. The main gaps lie in CEEC, where unknown nutrient deficiencies may occur. WHO RNI attainment was universally poor for macronutrients, especially for women, the female elderly and CEEC. All countries could be encouraged to report a uniform nutrient set and sub-analyses of nationally representative nutrient intakes.

Keywords: national diet surveys; WHO European region; macronutrient intakes; micronutrient intakes; Recommended Nutrient Intakes (RNIs); nutritional epidemiology

4.1 Introduction

The burden of malnutrition in the form of overweight and obesity, nutrient deficiency and preventable diet-related non-communicable diseases (NCDs) is significant and worsening (1). An unhealthy diet is one of the four major behavioral risk factors for NCDs in all WHO regions (2), with the European region proportionately suffering the greatest burden. Here, the four most common NCDs account for 77% of disease and almost 86% premature mortality (1). The World Health Organization (WHO) European Food and Nutrition Action Plan aims to 'significantly reduce' the human, economic and social costs of all forms of malnutrition in the WHO European region (1).

National diet surveys (NDS) have an important role to play in assessing dietary patterns and intakes in populations and informing policy decisions; the WHO European Food & Nutrition Action Plan (1) explicitly encourages member states to 'strengthen and expand nationally representative diet and nutrition surveys.' Nutrition and health surveys formed the main source of information for dietary risk factors and physical inactivity in a systematic analysis of disease risk in 21 regions worldwide between 1990–2010 (3). NDS can help monitor NCDs and malnutrition, identify specific areas of concern, highlight inequalities, guide interventions and evaluate policy impact, thereby ultimately contributing to the promotion of best practice across the region (1). Imamura et al. (4) evaluated change in global diet patterns over time through either greater consumption of healthy or lesser consumption of unhealthy items and assessed heterogeneity by age, gender, national income and dietary pattern. Higher national income was associated with better diet quality via greater consumption of healthier items but also with higher intake of unhealthy items, demonstrating that socio-economic inequalities persist.

NDS provision across Europe is inconsistent. A recent review found that less than two thirds of countries in WHO Europe have nationally representative NDS and that the majority of gaps lie in Central & Eastern European countries (CEEC) (5). This is concerning, as nutrition policies in these countries may therefore lack an appropriate evidence base. Novakovic et al. (6) examined selected micronutrient intakes in CEEC compared to other European countries and found that CEEC lacked intake data across all ages. Only 40% of countries in the WHO Europe remit reported adult energy and nutrient intakes from NDS conducted post-2000 and in these, macronutrients were more widely reported than micronutrients (5). The Global Dietary Database (GDD) houses information on food and nutrient intakes in countries across the world but only includes broad food categories with limited nutrient data and is limited by the inclusion of some regional rather than national data (7).

A comprehensive, updated review of total nutrient intakes across different European populations and subgroups is therefore needed, the results of which could identify where in Europe there is a need to improve diets and whether inequalities exist. This review aims to examine macro and selected micronutrient adult intakes in countries across WHO Europe via the latest NDS for which nutrient intake data is available.

4.2 Materials and Methods

4.2.1 Identifying National Diet Surveys (NDS)

The methods for identifying and accessing NDS have been reported (5). Briefly, authors of national surveys within WHO Europe were identified using listed contact names and other information from two main reports of NDS (8, 9). Where no response was obtained from authors, further general internet searches were performed on organizations specializing in nutrition to find other potentially useful contact details. Additionally, country responses to WHO questionnaires were mined to obtain relevant references to NDS. Contacts identified were asked to complete a questionnaire to provide information on nationally representative dietary surveys conducted at an individual level since 1990, including links or references to relevant reports. For countries without usable contact details, a systematic database search was performed across Web of Science, Medline and Scopus for nationally representative dietary surveys of adults and children that collected data at an individual level from 1990 to June 2016.

Papers returned were screened for relevance according to the criteria in Table 1. We found 109 nationally representative surveys that collected data on whole diets at an individual level since 1990 across 34 of the 53 countries in the WHO office region; 86 of these included adults. Of these, 78 were conducted since 2000, 60 of which included adults. Further details of all the surveys found are presented in Rippin et al. (5).

Table 1. Survey inclusion and exclusion criteria.

Included	Excluded
Surveys conducted at an individual level	Surveys collected at group i.e. household level
Nationally representative surveys	Non-nationally representative, regional only surveys
Results of surveys reported by published and unpublished reports, academic journals and websites	Surveys with data collected prior to 1990
Surveys that included individuals >2 y	Surveys with samples exclusively <2 y
Surveys based on whole diet rather than specific food groups	Surveys with incomplete food group coverage
	Surveys with small sample sizes (n < 200)

4.2.2 Data Extracted

Where available, estimated energy and nutrient intake (excluding supplements) by age group and gender was extracted and graphically presented from the latest NDS collected after 2000; for adults, this included surveys from 21 countries. These countries were grouped into regions—Western, Northern and Central & Eastern Europe. For some countries, more recent surveys have been conducted but intake data was not yet available. For example, the Spanish ANIBES survey (2013) did not include micronutrients, so the ENIDE (2011) survey was used instead. Mean intake values were reported by the majority of the 21 countries but where medians were the sole measure of central tendency, these were extracted and used instead. Where energy intakes were given in kcal, these were converted to MJ for consistency across studies.

All macronutrients reported by the 21 countries were included in the data extraction but micronutrients extracted (see Table 2) were limited to those explicitly mentioned in the WHO European Food and Nutrition Action Plan (1) as being currently important to population health in the region. Where possible, WHO nutrient-based guidelines—hereby referred to as Recommended Nutrient Intakes (RNIs)—were used to assess intake adequacy and to highlight areas of concern (10-14), although WHO RNIs for iron are given for different bioavailabilities, so UK Reference Nutrient Intakes (RNIs) were used instead (15). The RNI for monounsaturated fats (MUFAs) is calculated by the difference between total fat and the sum of saturates (SFA), polyunsaturated fats (PUFA) and trans fats (TFAs), so has not been included. The WHO RNI for free sugars (14) has been adopted as the RNI for added sugars, as no WHO RNI exists for added sugars, yet all surveys that reported sugar in this way used the added rather than free sugar definition. The definition for added sugars is similar but more restrictive to that of free sugars, meaning that free sugar intake would not be overestimated. Depending on the nutrient, the RNIs were variously maximum, minimum or target amounts.

Table 2. Nutrients of interest in dietary surveys.

Macronutrients	RNI	Micronutrients	RNI
Energy (MJ and kcal)	N/A	Folic acid (µg)	Minimum
Carbohydrates (g and %Energy (E))	Target	Vitamin B12 (µg)	Minimum
Sugars (g)	Maximum	Vitamin D (µg)	Target
Sucrose (g)	Maximum	Calcium (mg)	Minimum
Starches (g)	N/A	Potassium (mg)	Minimum
Fiber (g)	Target	Sodium (mg)	Maximum
Total fat (g)	Maximum	Iron (mg)	Minimum
Saturates (g)	Maximum	Iodine (µg)	Minimum
Monounsaturated fatty acids (MUFA) (g)	N/A	Zinc (mg)	Minimum
Polyunsaturated fatty acids (PUFA) (g)	Target		
Trans Fatty Acids (TFAs) (g)	Maximum		
Protein (g)	Target		
Omega fatty acids (g)	Target		

To harmonize data where possible, units of measurement were converted to a common standard unit. Energy intakes and selected nutrients by age group and gender as reported in these latest surveys collected after 2000 were graphed. Omega-3 and omega-6 fatty acids were reported in surveys in various ways, including omega-3, omega-6, linoleic acid and α-linolenic acid in g/day and percentage energy (%E) and eicosapentaenoic acid + docosahexaenoic acid (EPA + DHA) in mg/day. These were converted to grams and %E and grouped into omega-3 and omega-6 fatty acids for clarity. Additionally, mean intakes by age group and gender were weighted by number of individuals surveyed in each group to produce weighted means by country. Regional and overall European weighted means were calculated by multiplying the male/female mean for each country by the latest total national population numbers from 2016 (16), adding this figure for each country and dividing by the total sum of the national populations in each region.

Characteristics of the surveys from the 21 countries were also extracted and reported: these were country name, survey name, year of survey (data collection), dietary methodology, age range and sample size. The percentage WHO RNIs not met by all gender/age groups was recorded. Where reported, surveys presenting nutrient intakes by socio-economic group (SEG) based on social class, income (continuous or grouped) and education level were also noted.

4.3 Results

4.3.1 Data Extracted

Results of NDS coverage across Europe have previously been documented (5). Adult energy and nutrient intakes (excluding supplements) were extracted from 21 surveys across 21 countries from three regions: five (100%) of Northern European countries (Denmark, Finland, Iceland, Norway, Sweden); 11 (65%) of Western European countries (Andorra, Austria, Belgium, France, Germany, Ireland, Italy, The Netherlands, Portugal, Spain, UK) and five (16%) of CEEC (Estonia, Hungary, Latvia, Lithuania, Turkey). Table 3 shows the characteristics of these surveys. Adult energy and nutrient intakes could not be extracted for

60% (32) of European countries; 19 of these, mainly CEEC, had no identifiable nationally representative survey, making up over a third of WHO Europe countries.

All 21 surveys that reported nutrient information included energy and also carbohydrate, fiber, fat and protein intakes (see Table 4). Most surveys (*n* = 20) included intake data on saturates, MUFAs and PUFAs (Germany did not); however, less than half (*n* = 9) surveys included TFA intakes. The majority of surveys (*n* = 17) included intake levels of sugars, either as total sugars or as added sugars/sucrose; however, Germany, Latvia, Spain and Turkey included neither. Few surveys (*n* = 5) included starch intake data. Half the countries included either omega-3 (*n* = 10) or omega-6 (*n* = 9) fatty acid intakes in some form; eight surveys included both.

All surveys included some micronutrients of interest (see Table 5). Vitamin B12, vitamin D, calcium and iron intakes were reported by all surveys; potassium (not Belgium), folate and sodium (not Italy) were each reported by all but one survey and zinc by all but two (not Belgium and Norway). Iodine was the least reported micronutrient extracted (*n* = 14), though it was still reported by more than half the surveys. Considering all macro and micronutrients investigated, no country met more than 39% WHO RNIs in all age/gender groups.

Of the 21 countries for which nutrient intakes were extracted, seven reported intakes by SEG in addition to age and gender (Estonia, Finland, France, Ireland, The Netherlands, Norway, UK). Whilst this comprises a third of countries listed in Table 3, only 13% of the 53 countries in the WHO remit represented nutrient intakes by SEG.

Table 3. National diet surveys across countries in WHO Europe 1990–2016 with nutrient intakes reported.

Country	Survey Name	Survey Year	Source *	Sample Size	Sample Age	Dietary Methodology	Nutrient Reference Database	Nutrient Intakes by SEG Y/N **	WHO RNIs Not Met by All Age Groups (%) †	Reference
Andorra	Evaluation of the Nutritional Status of the Andorran Population	2004–2005	4	900	12–75	24 h recall (×2 for 35% sample), FFQ	CESNID. *Tablas de composición de alimentos*. Barcelona: Edicions Universitat de Barcelona-Centre d'Ensenyament Superior de Nutrició i Dietètica, 2002	N	83	(17)
Austria	Austrian nutrition report 2012 (OSES)	2010–2012	2	1002	7–14; 18–80	3-day diary (consecutive) (children); 2*24 h recall (adults).	Analysis run with software "(nut.s) science" based on Bundeslebensmittelschlüssel 3.01/Goldberg cut-offs for data cleaning	N	72	(18)
Belgium	Belgium National Food Consumption Survey (BNFCS) 2014	2014–2015	1/2	3146	3–64	2*24 h recall	The NIMS Belgian Table of Food Composition (Nubel); Dutch NEVO	N	78	(19, 20)
Denmark	Danish National Survey of Diet and Physical Activity (DANSDA) 2011–2013	2011–2013	2	3946	4–75	7-day diary (consecutive)	Danish Food Composition Databank	N	67	(21)
Estonia	National Dietary Survey	2014–2015	1	4906	4 m–74 y	2*24 h recall (age > 10); 2*24 h food diary (age < 10); FFQ (age > 2)		Y—income, poverty threshold, education	78	

Finland	The National FINDIET 2012 survey (FINRISK)	2012	2	1708	25–74	48 h recall	Fineli 7 Food Composition Database	Y—education	61	(22)
France	Individual National Food Consumption Survey (INCA2)	2006–2007	2	4079	3–79	7-day diary (consecutive)	Food Composition Database of CIQUAL of Afssa	Y—education	83	(23)
Germany	German National Nutrition Survey (Nationale Verzehrstudie) II (NVSII)	2005–2007	1/3	15,371	14–80	DISHES diet history interview, 24 h-recall, diet weighing diary (2*4 days)	Bundeslebensmittelschlüssel (BLS)	N	78	(24, 25)
Hungary	Hungarian dietary survey 2009	2009	2	3077	19–30, 31–60, 60+	3-day diary, FFQ,	Új tápanyagtáblázat	N	72	(26, 27)
Iceland	The Diet of Icelanders—a national dietary survey 2010–2011	2010–2011	1	1312	18–80	2*24 h recall + FFQ	Icelandic Database of Food Ingredients (ÍSGEM); Public Health Institute for Raw Materials in the Icelandic Market	N	72	(28, 29)
Ireland	National adult nutrition survey 2011 (NANS)	2008–2010	1	1500	18–90	4-day semi weighed food diary (consecutive)	McCance and Widdowson's The Composition of Foods 5&6 editions	Y—social class and education	72	(30, 31)
Italy	The third Italian National food consumption survey INRAN-SCAI 2005–2006	2005–2006	2	3323	0.1–97.7	3-day diary (consecutive)	Banca Dati di Composizione degli Alimenti	N	83	(32)
Latvia	Latvian National Food Consumption Survey 2007–2009	2008	1	1949	7–64	2*24 h recall, FFQ	Latvian National Food Composition Database 2009	N	78	(33)
Lithuania	Study of actual nutrition and nutrition habits of Lithuanian adult population	2013–2014	1	2513	19–75	24 h recall + questionnaire	EuroFIR Food Classification	N	83	(34)

The Netherlands	Dutch National Food Consumption Survey 2007–2010 (DNFCS 2007–2010)	2007–2010	1/2	3819	7–69	2*24 h recalls	Dutch Food Composition Database (NEVO)	Y—education	61	(35-37)
Norway	Norwegian national diet survey NORKOST3	2010–2011	2	1787	18–70	2*24 h recall and FFQ	The Norwegian Food Composition Tables	Y—education	83	(38)
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015–2016	4	4221	3 m–84 y	2*24 h recall (non-consecutive) and FPQ (electronic interview) 2-day food diary for children <10 y	Portuguese Food Composition Table (INSA)	N	78	(39, 40)
Spain	ENIDE study (Sobre datos de la Encuesta Nacionalde Ingesta Dietética)	2009–2010	2	3000	18–24; 25–44; 45–64	3-day diary + 24 h recall (consecutive)	Tablas de Composición de Alimentos, 15th ed	N	83	(41-44)
Sweden	Riksmaten 2010–2011 Swedish Adults Dietary Survey	2010–2011	2	1797	18–80	4-day food diary (consecutive)	NFA Food Composition Database	N	78	(45)
Turkey	Turkey nutrition and health survey 2010 (TNHS)	2010	2	14,248	0–100	24 h recall, FFQ	BEBS Nutritional Information System Software; Turkish Food Composition Database	N	78	(46, 47)
UK	National Diet and Nutrition Survey Rolling Programme (NDNS RP 2008–2012)	2008–2012	2	6828	1.5–94	4-day diary (consecutive)	McCance and Widdowson's The Composition of Foods integrated dataset	Y—income	72	(48)

* 1 = email contacts; 2 = general internet searches; 3 = Micha et al. [9]; 4 WHO Global Nutrition Policy Review 2017 extracted information. ** Countries that have reported nutrient intakes by socio-economic group (SEG) in addition to age and gender. † For those countries that do not report all nutrients, the RNIs for nutrients not reported are considered not met.

Table 4. Weighted means * by country for macronutrients in 21 national dietary surveys in the WHO Europe region.

COUNTRY	Energy (MJ)	Protein (g)	CHO (g)	Sugars (g)	Sucrose (g)	Starch (g)	Fibre (g)	Total Fat (g)	Saturates (g)	MUFA (g)	PUFA (g)	TFA (g)	n-3 (g)	n-6 (g)
Estonia	**National Dietary Survey 2014–2015**													
Female	6.7	64	194				17	65	26	24	11	0.5	1.8	8.2
Male	8.7	86	235				19	83	32	31	14	0.6	3.2	10.9
Hungary	**Hungarian Dietary Survey 2009**													
Female	8.9	79	253		44		21	87	26	27	22		0.9	21.6
Male	12.0	106	315		50		25	122	36	40	29		1.2	28.4
Latvia	**Latvian National Food Consumption Survey 2007–2009**													
Female	6.4	55	190				16	68	28	24	11			
Male	8.9	79	246				20	93	38	33	15			
Lithuania	**Study and evaluation of actual nutrition and nutrition habits of Lithuanian adult population 2013–2014**													
Female	6.5	56	178	56			15	71	22	27	16			
Male	9.2	75	224	55			17	108	34	41	24			
Turkey	**Turkey nutrition and health survey 2010 (TNHS)**													
Female	6.5	50	197				20	61	20	22	16		1.1	14.5
Male	8.6	67	260				23	78	26	28	19		1.4	17.4
CEEC TOTAL Female	6.7	53	202	56	44		20	64	21	23	16	0.5	1.1	15.2
CEEC TOTAL Male	9.0	72	264	55	50		23	84	28	30	20	0.6	1.4	18.5
Denmark	**Danish Dietary habits 2011–2013**													
Female	8.4	76	211		43		21	83	33	31	13	1.3		
Male	11.2	101	269		56		24	111	45	41	17	1.7		
Finland	**The national FINDIET 2012 survey**													
Female	7.0	70	181		42		21	67	26	24	12	0.8	2.8	8.7
Male	9.1	91	225		49		22	88	34	32	15	1.1	3.5	11.0
Iceland	**The Diet of Icelanders—a national dietary survey 2010–2011**													
Female	7.4	76	188	87			16	72	29	23	12	1.5	2.9	9.0
Male	10.0	106	240	104			18	99	40	32	16	2.2	3.8	11.9
Norway	**Norkost3 2010–2011**													
Female	8.0	81	205		36		22	75	29	25	14			
Male	10.9	112	278		48		27	102	39	34	19			
Sweden	**Riksmaten 2010–2011 Swedish Adult Dietary Survey**													
Female	7.4	72	193		37		19	70	27	26	12		2.5	8.6
Male	9.3	92	238		41		21	87	33	33	14		2.9	10.5
NORTH TOTAL Female	7.6	74	197	87	39		20	73	28	26	13	1.1	2.6	8.6
NORTH TOTAL Male	10.0	98	250	104	47		23	95	37	35	16	1.4	3.1	10.7
Andorra	**Evaluation of the nutritional status of the Andorran population 2004–2005**													
Female	6.8	81	164	77			17	75	22	32	10			
Male	8.4	95	197	86			17	84	28	41	13			
Austria	**Austrian nutrition report 2010–2012**													
Female	7.5	67	209		43		21	72	31	24	13		1.4	11.6
Male	8.9	79	235		48		21	86	37	28	14		1.5	12.3

Belgium	**The Belgian food consumption survey 2014–2015**													
Female	7.9	71	202	94			18	77	28	28	14	0.8		
Male	10.9	95	274	124			20	102	36	37	18	1.0		
France	**INCA2 2006–2007**													
Female	7.6	74	199	89			16	80	32	29	12			
Male	9.8	100	262	101			19	100	41	36	15			
Germany	**German National Nutrition Survey II 2005–2007**													
Female	7.9	67	227				25	74						
Male	10.5	89	279				27	100						
Ireland	**National adult nutrition survey 2008–2010**													
Female	7.1	70	198	81			18	66	29	27	14	1.0	1.6	
Male	9.8	98	260	100			21	90	38	35	16	1.6	1.9	
Italy	**The third Italian National food consumption survey INRAN-SCAI 2005–2006**													
Female	8.0	75	236	79			18	77	24	37	10			
Male	9.9	92	282	85			20	94	29	46	12			
The Netherlands	**Dutch National Food Consumption Survey (DNFCS) 2007–2010**													
Female	8.2	75	220	106			19	76	29	26	14	1.3	1.7	11.8
Male	11.1	98	291	128			23	103	38	36	20	1.6	2.2	17.0
Portugal	**National Food and Physical Activity Survey (IAN-AF) 2015–2016**													
Female	7.2	78	195	77			17	60	22	25	11	0.8		9.5
Male	9.8	106	246	85			20	77	27	32	13	1.0		12.3
Spain **	**ENIDE 2011**													
Female	9.2	88	199	72			19	93	26	39	13			
Male	9.8	109	242	76			21	115	33	48	15			
UK	**National Diet and Nutrition Survey (NDNS) Y1-4 2008–2012**													
Female	6.7	65	195	85			13	60	22	21	10	1.1	1.8	8.6
Male	8.7	83	247	105			15	77	28	28	13	1.5	2.2	11.0
WEST TOTAL Female	7.8	73	212	84	43		19	75	26	30	12	1.1	1.7	9.5
WEST TOTAL Male	9.8	94	264	96	48		21	96	33	38	14	1.4	2.1	12.2
EUROPE TOTAL Female	7.6	69	209	84	41		19	73	25	28	13	1.1	1.5	11.9
EUROPE TOTAL Male	9.7	90	264	96	48		21	94	32	36	16	1.4	1.9	14.9

* For each country weighted means were calculated for each nutrient by multiplying the male/female mean for each age group by the number of men/women in that age group, then dividing the total by the total number of men/women in the country in question. For each nutrient regional weighted means were calculated by multiplying the male/female mean for each country by the total national population (16), adding this figure for each country and dividing by the total sum of the national populations in that region. For each nutrient total European weighted means were calculated by multiplying the male/female mean for each age country by the total national population (16), adding this figure for each country and dividing by the total sum of the national populations in all three European regions. ** Figures for Spain are based on median rather than mean values.

Table 5. Weighted means* by country for micronutrients in 21 national dietary surveys in the WHO Europe region.

SURVEY	Folic Acid (μg)	Vitamin B12 (μg)	Vitamin D (μg)	Calcium (mg)	Potassium (mg)	Sodium (mg)	Iron (mg)	Iodine (μg)	Zinc (mg)
Estonia	**National Dietary Survey 2014–2015**								
Female	166	5.8	4.3	648	3037	1801	10.8	108	8.4
Male	198	8.0	5.7	767	3761	2562	13.6	134	11.4
Hungary	**Hungarian Dietary Survey 2009**								
Female	131	2.8	2.0	651	2600	5086	9.5		7.5
Male	161	3.7	2.6	701	3140	7100	12.5		10.2
Latvia	**Latvian National Food Consumption Survey 2007–2009**								
Female	214	3.7	1.9	457	2250	2283	9.1	53	7.2
Male	214	3.7	1.9	555	2868	3598	12.1	68	10.1
Lithuania	**Study and Evaluation of Actual Nutrition and Nutrition Habits of Lithuanian Adult Population 2013–2014**								
Female	366	1.0	3.1	506	2322	2348	8.9	28	7.0
Male	643	1.5	3.7	576	2887	2538	12.2	33	9.6
Turkey	**Turkey Nutrition and Health Survey 2010 (TNHS)**								
Female	320	2.5	0.8	583	2242	1625	10.0	58	8.2
Male	393	4.0	1.2	704	2608	2552	12.3	69	10.7
CEEC TOTAL Female	**298**	**2.6**	**1.1**	**586**	**2292**	**2019**	**9.9**	**58**	**8.1**
CEEC TOTAL Male	**370**	**3.9**	**1.5**	**698**	**2692**	**3041**	**12.3**	**69**	**10.6**
Denmark	**Danish Dietary Habits 2011–2013**								
Female	329	5.6	4.3	1038	3200	3200	10.0	227	10.5
Male	370	8.0	5.3	1188	3900	4400	13.0	268	14.1
Finland	**The National FINDIET 2012 Survey**								
Female	231	5.0	8.7	1040	3352	2492	10.0	186	10.2
Male	266	7.0	11.8	1178	4037	3400	12.4	228	12.7
Iceland	**The Diet of Icelanders—a National Dietary Survey 2010–2011**								
Female	249	5.5	6.6	820	2632	2600	9.4	142	8.8
Male	304	8.4	9.7	1034	3433	3773	12.5	195	12.4
Norway	**Norkost3 2010–2011**								
Female	231	6.0	4.9	811	3374	2510	10.0		
Male	279	8.8	6.7	1038	4263	3558	12.5		
Sweden	**Riksmaten 2010–2011 Swedish Adult Dietary Survey**								
Female	252	5.0	6.4	825	2887	2766	9.6		
Male	266	6.0	7.6	945	3410	3591	11.5		
NORTH TOTAL Female	**260**	**5.3**	**6.1**	**912**	**3142**	**2751**	**9.8**	**205**	**10.3**
NORTH TOTAL Male	**291**	**7.2**	**7.8**	**1064**	**3812**	**3721**	**12.2**	**247**	**13.4**
Andorra	**Evaluation of the Nutritional Status of the Andorran Population 2004–2005**								
Female	241	5.4	2.6	790	2867	2495	10.8		8.1
Male	255	7.4	4.1	831	3126	3086	13.3		9.9
Austria	**Austrian Nutrition Report 2010–2012**								
Female	206	4.1	2.8	771	2504	3027	10.6	133	9.3
Male	209	4.9	3.9	821	2775	3532	11.4	144	11.0
Belgium	**The Belgian Food Consumption Survey 2014–2015**								

Female	190	3.7	3.5	720		2062	8.6	127	
Male	226	5.2	4.2	821		2739	11.1	174	
France	**INCA2 2006–07**								
Female	268	5.1	2.4	850	2681	2533	11.5	117	9.1
Male	307	6.5	2.7	984	3287	3447	14.9	136	12.4
Germany	**German National Nutrition Survey II 2005–2007**								
Female	285	4.4	3.0	1020	3272	2502	12.4	196	9.5
Male	327	6.4	3.9	1115	3779	3418	15.0	248	12.1
Ireland	**National Adult Nutrition Survey 2008–2010**								
Female	342	7.8	4.7	851	2694	2231	13.7		9.2
Male	410	7.2	4.7	1038	3426	3060	15.5		11.6
Italy	**The third Italian National Food Consumption Survey INRAN-SCAI 2005–2006**								
Female		5.3	2.2	735	2853		10.3		10.5
Male		6.6	2.6	803	3231		12.7		12.5
The Netherlands	**Dutch National Food Consumption Survey (DNFCS) 2007–2010**								
Female	252	4.3	3.1	993	3086	2386	9.9	158	9.5
Male	308	5.5	4.1	1151	3895	3165	11.9	201	12.3
Portugal	**National Food and Physical Activity Survey (IAN-AF) 2015–2016**								
Female	248	4.7	3.5	730	2999	2647	10.8		9.2
Male	281	5.5	4.0	816	3845	3605	14.0		11.9
Spain **	**ENIDE 2011**								
Female	266	6.1	3.7	835	2865	2347	13.7	85	8.7
Male	296	7.9	4.3	884	3049	2702	16.1	100	10.4
UK	**National Diet and Nutrition Survey (NDNS) Y1-4 2008–2012**								
Female	231	4.8	2.7	743	2558	2148	9.6	146	7.6
Male	289	6.1	3.3	896	3044	2793	11.6	187	9.6
WEST TOTAL Female	259	5.0	2.8	846	2869	2405	11.3	143	9.1
WEST TOTAL Male	302	6.5	3.5	951	3349	3153	13.8	178	11.5
EUROPE TOTAL Female	268	4.5	2.7	799	2771	2341	10.9	127	8.9
EUROPE TOTAL Male	316	6.0	3.3	908	3245	3163	13.4	156	11.4

* For each country, weighted means were calculated for each nutrient by multiplying the male/female mean for each age group by the number of men/women in that age group, then dividing the total by the total number of men/women in the country in question. For each nutrient regional weighted means were calculated by multiplying the male/female mean for each country by the total national population (16), adding this figure for each country and dividing by the total sum of the national populations in that region. For each nutrient total European weighted means were calculated by multiplying the male/female mean for each age country by the total national population (16), adding this figure for each country and dividing by the total sum of the national populations in all three European regions. ** Figures for Spain are based on median rather than mean values.

4.3.2 Energy and Nutrient Intakes

4.3.2.1 Energy

Energy intakes reported from the NDS have previously been documented (5). Briefly, daily mean/median energy intakes were higher in adult males and decreased with age for all age groups in all 21 countries; however, age groupings reported were not consistent across countries (see Figures 1–3).

Figure 1. Mean/median* adult energy intake (MJ/day) for Western European countries (excluding supplements). * Figures for Spain are based on median rather than mean values.

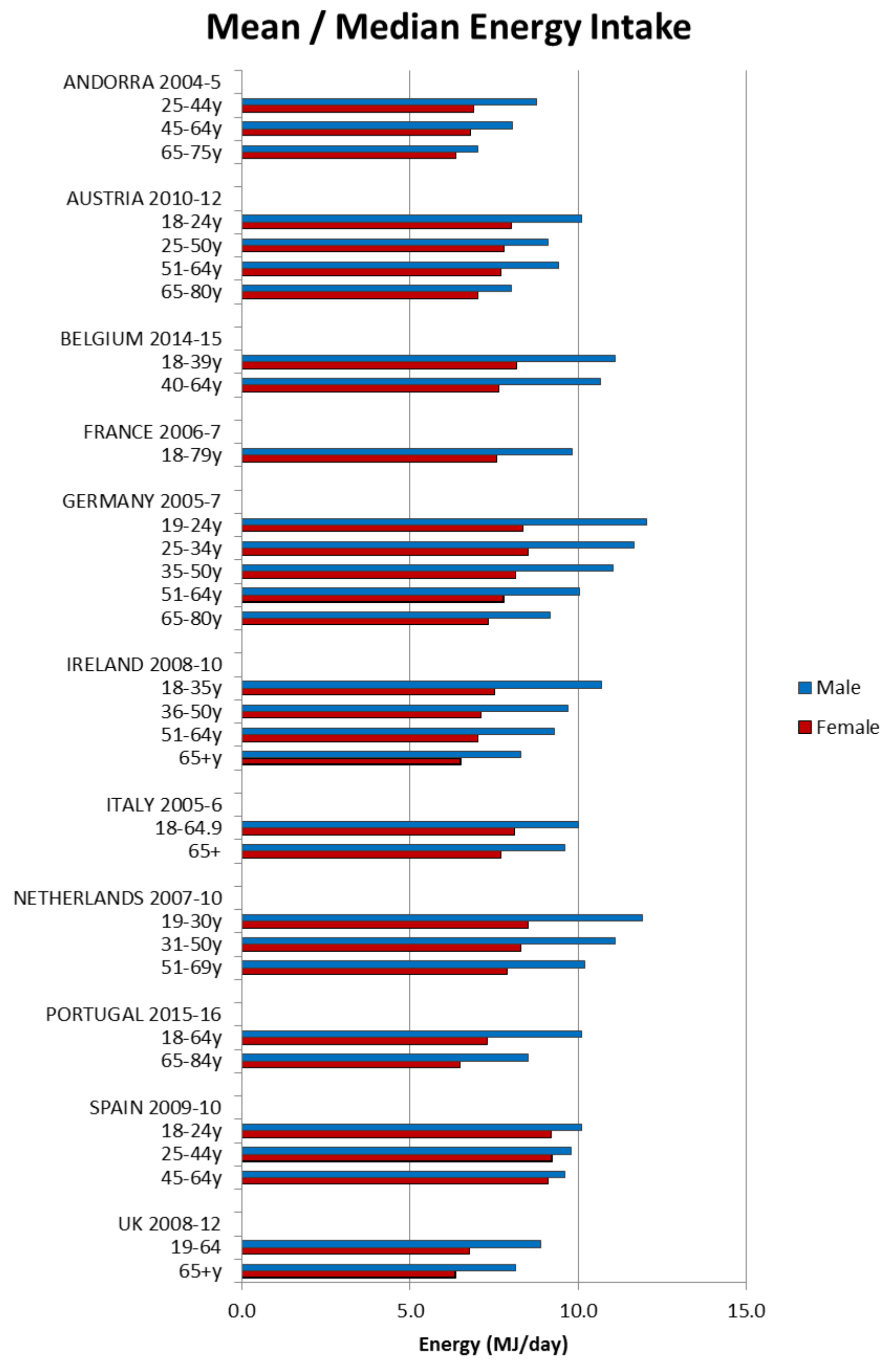


Figure 2. Mean/median adult energy intake (MJ/day) for Northern European countries (excluding supplements).

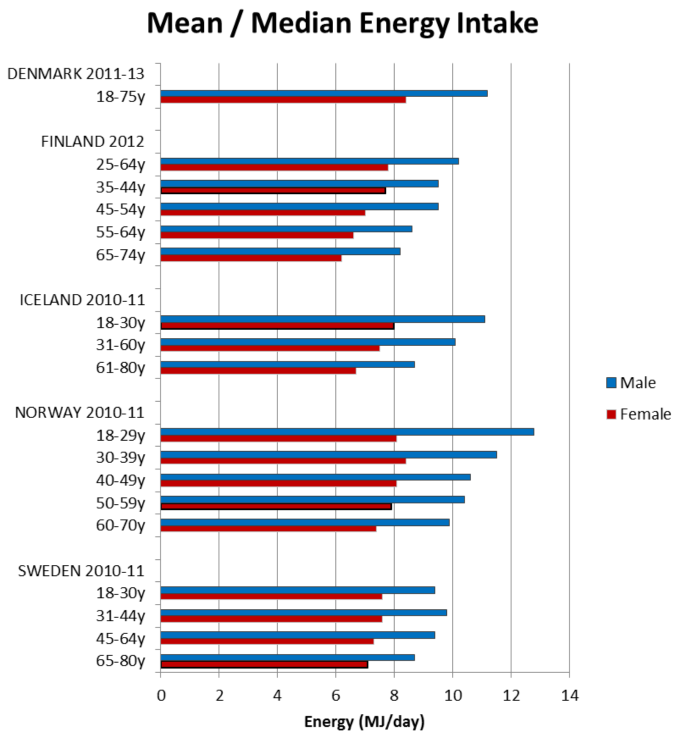
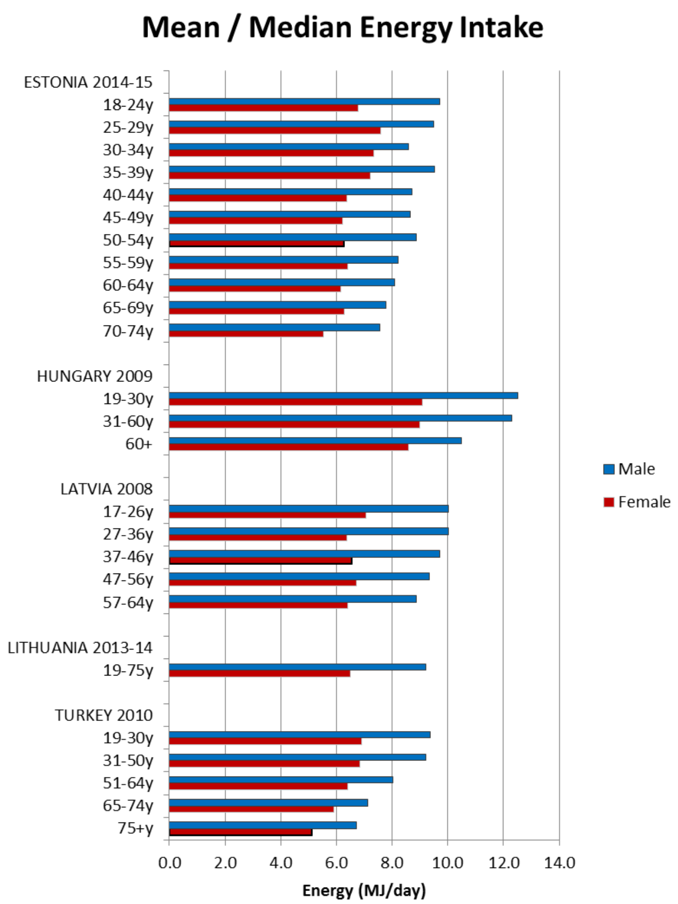


Figure 3. Mean/median adult energy intake (MJ/day) for Central & Eastern European countries (excluding supplements).



4.3.2.2 Macronutrients

For all macronutrients, with the exception of sugars and fibre in older age groups, males tended to have a higher intake than females in all countries across all age groups. In this section means reported are estimated weighted European means (see Tables 4 and 5 for total weighted means by nutrient and broken down by country) and those in brackets are the ranges of gender and age group means provided in the country reports.

Attainment of the WHO macronutrient RNIs (10) was generally poor across all regions and marginally worse in CEEC. All age groups in all countries were comfortably over the lower 10%E protein RNI in men and women. Just over half of countries met or exceeded the upper RNI of 15%E, though there was no regional pattern. No country met the lower carbohydrate RNI of 55%E in any age group (Figure 4). The mean carbohydrate intake was 209 g, (range 156–265 g) for women and 264 g (range 173–342 g) for men. Most countries fell short of the fibre RNI in all ages; only Norway (all ages), Germany (women aged 51–64 and men across the lifespan) and Hungary (non-elderly men) met the 25 g target (Figure 5). Mean fibre intakes were 19 g (range 13–26 g) for women and 21 g (range 15–29 g) in men. All countries that reported added sugars (*n* = 7) were over the 5% recommended RNI, although only Estonian and Finnish women were above the 10% maximum (Figure 6). Mean added sugar intakes were 41 g (range 30–49 g) for women and 48 g (38–69 g) in men.

All countries exceeded the WHO upper fat limit of 30%E except Portuguese elderly men (Figure 7). The mean total fat intake was 73 g (51–95 g) in women and 94 g (61–127 g) in men. The majority of countries were also above the 10%E RNI for saturates; only Portuguese elderly men were below (Figure 8). The mean saturates intake was 25 g (16–33 g) for women and 32 g (20–45 g) for men. Only Lithuanian men exceeded the upper PUFA RNI of 10%E and just under half the countries were below the lower RNI of 6%E, leaving around half of countries with optimum intakes between the two RNIs; there was no regional pattern. The greatest WHO RNI compliance was in TFAs, where only Icelandic elderly men exceeded the <1%E limit with intakes at 1%E. However, only nine countries reported TFAs; the CEEC region had fewest countries reporting intakes.

Omega fats RNI attainment was mixed; 60% of countries that reported n-3 intakes were between the 1%–2%E RNI bands, mostly in Northern Europe, whilst 4 countries did not meet the lower RNI. Turkey and Hungary exceeded the upper n-6 limit of 8%E but fewer countries achieved intakes within the lower and upper RNI bands in the majority of age/gender groups than for n-3. There was no age or gender pattern but Northern European countries had higher n-3 and lower n-6 intakes.

Figure 4. Mean/median* adult carbohydrate intake (%E) (excluding supplements). * Figures for Spain are based on median rather than mean values.

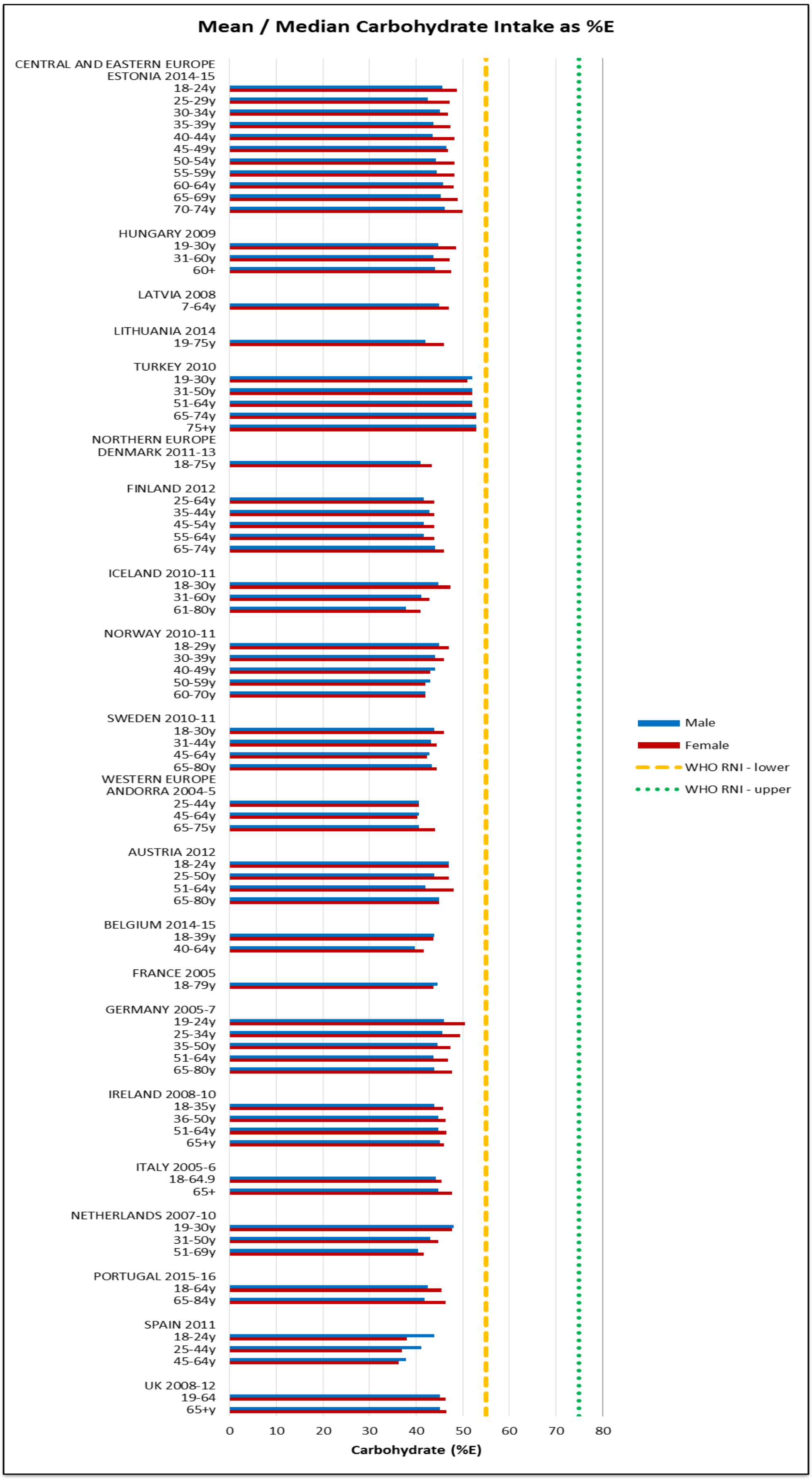


**Figure 5. Mean/median* adult fibre intake (g/day) (excluding supplements).
* Figures for Spain are based on median rather than mean values.**

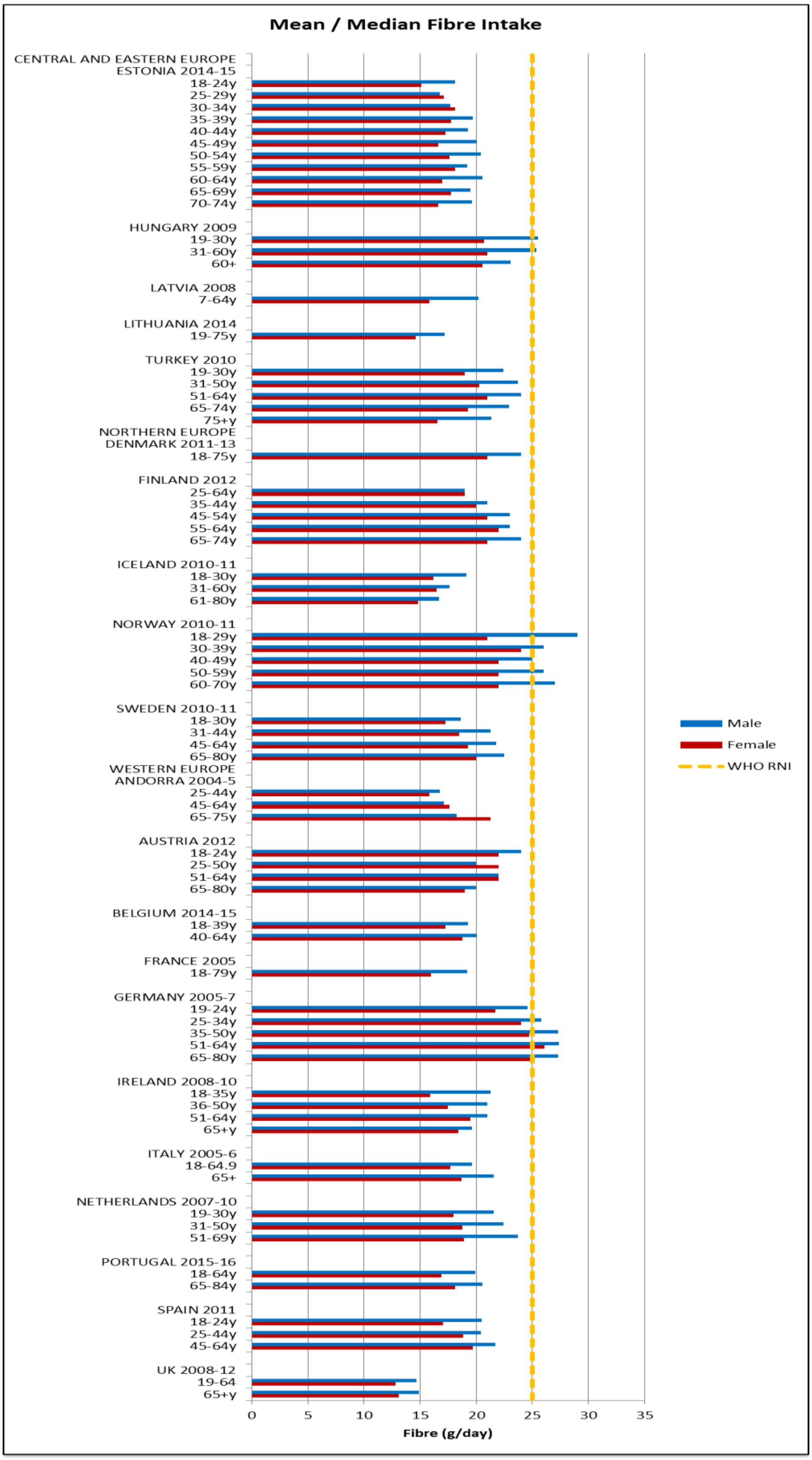


Figure 6. Mean/median adult added sugars intake (%E) (excluding supplements).

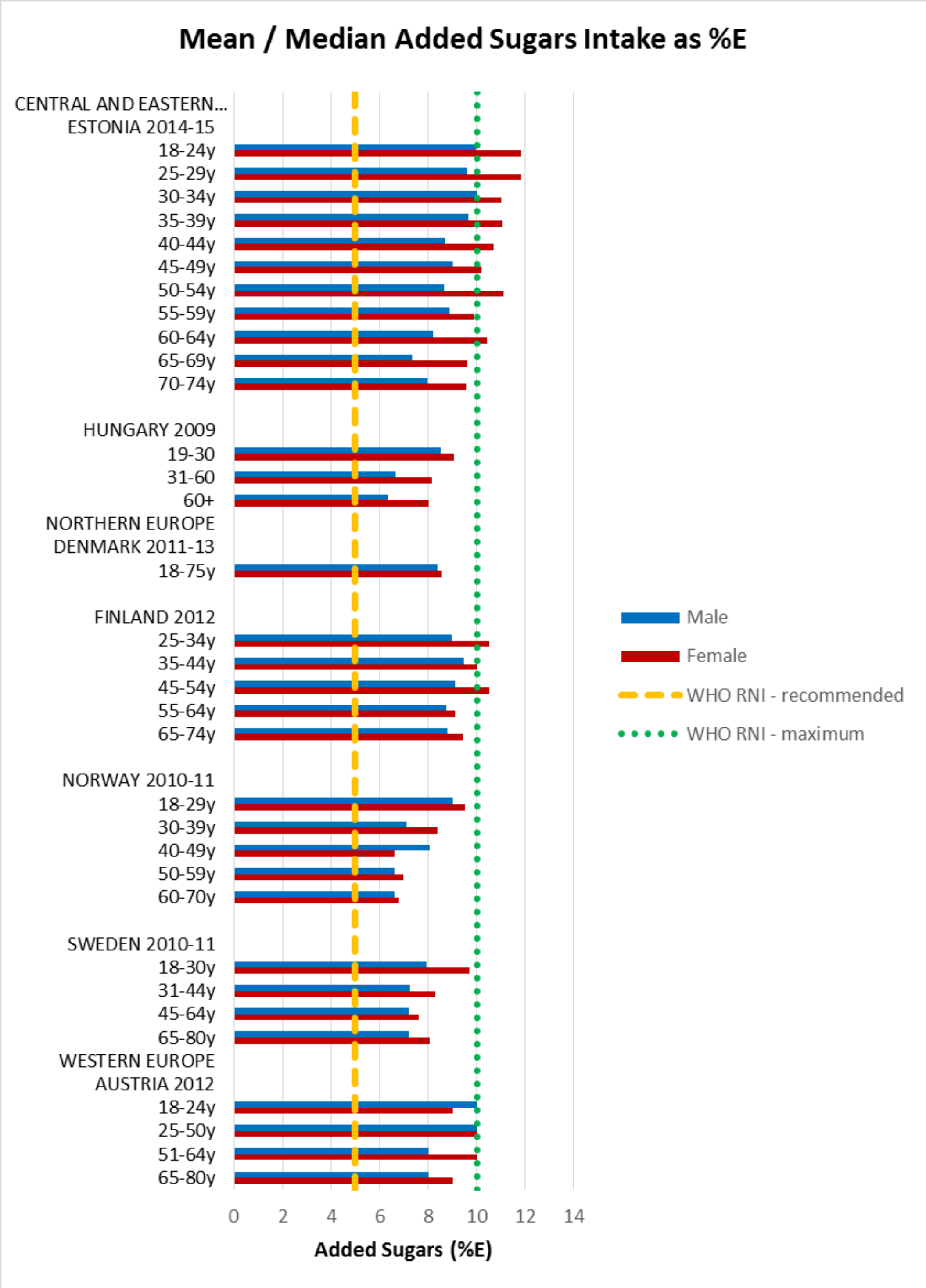


Figure 7. Mean/median* adult fat intake (%E) (excluding supplements). * Figures for Spain are based on median rather than mean values.

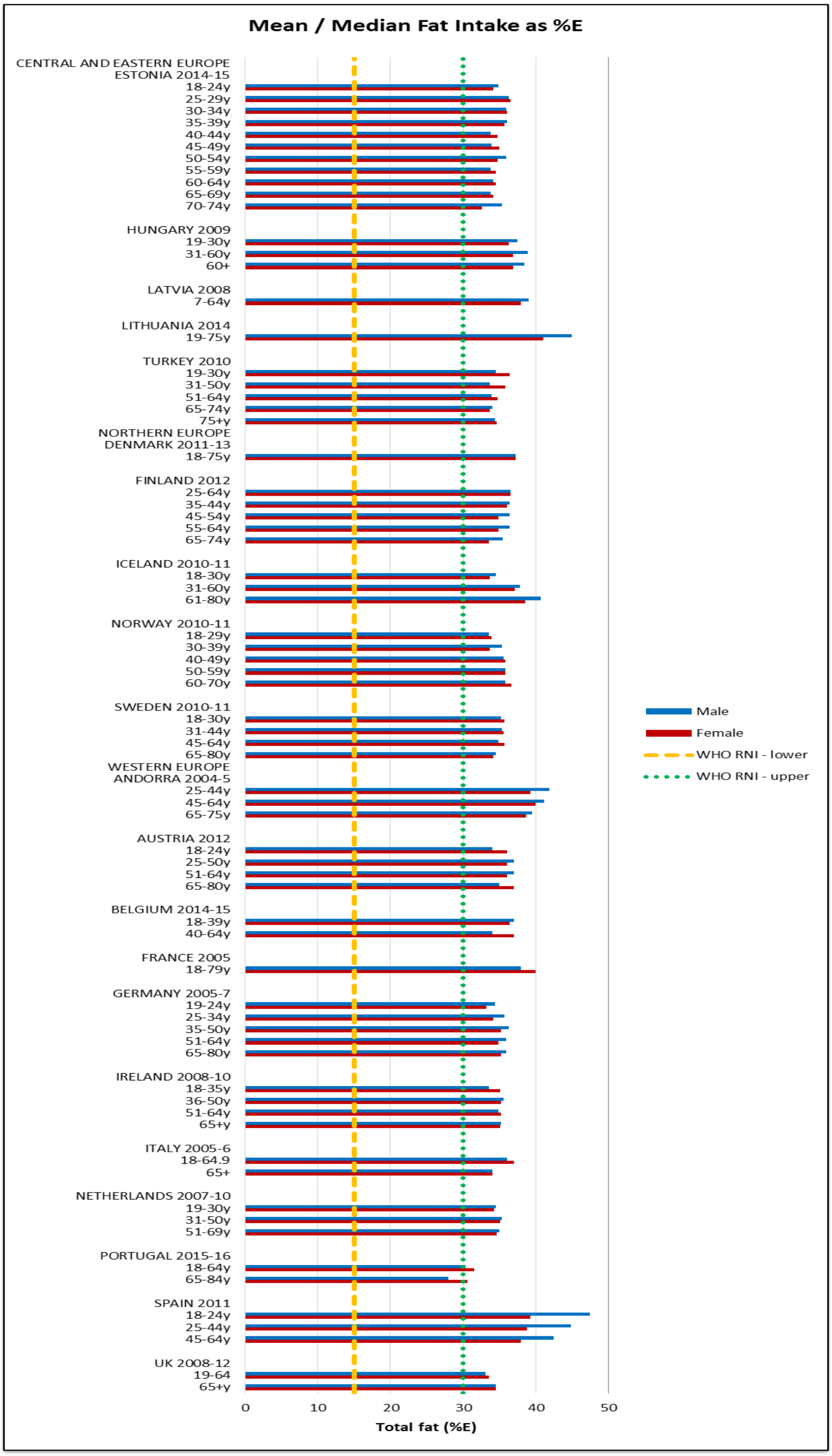
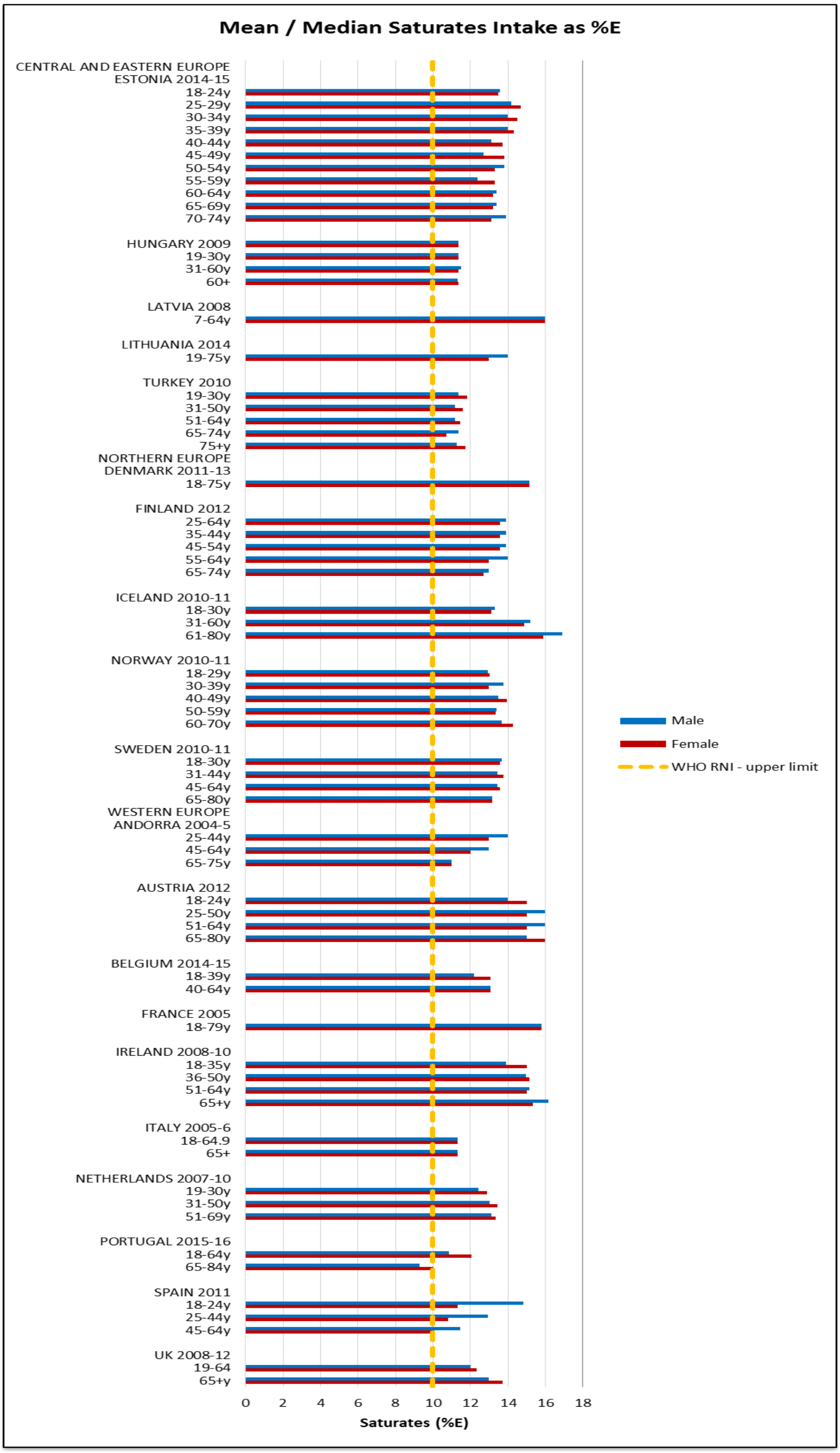


Figure 8. Mean/median* adult saturates intake (%E) (excluding supplements). * Figures for Spain are based on median rather than mean values.



4.3.2.3 Micronutrients

Micronutrient RNI (11-13) attainment was slightly better than macronutrient, though the variation in male/female intake patterns was higher and there were no clear age patterns.

All countries comfortably met the 4.9 mg female and 7 mg male RNI for zinc. The majority of countries met the 2.4 µg RNI for vitamin B12; only Lithuanian and Turkish older and elderly women and elderly men fell short. Fulfilment of iron, iodine and potassium RNIs was mixed and women generally had poorer attainment—particularly younger women (Figures 9–11 respectively). For iron, only younger Irish women met the 14.8 mg UK RNI (15) for women aged 19–50, though all countries met the 8.7 mg RNI for women aged 51–65 y and 65+ y except elderly Turkish women. All countries met the 8.7 mg male RNI for iron. Mean intakes were 10.9 mg (8.1–15.1 mg) in women and 13.4 mg (9.9–18.1 mg) in men.

Just under half of countries that reported iodine met the 150 µg RNI; more men and younger age groups exceeded the RNI but there were no regional patterns. The mean iodine intake was 127 µg (28–227 µg) in women and 156 µg (33–268 µg) in men. No countries met the 3510 mg RNI for potassium in women; half of countries met the RNI in at least some male age groups, though there was no regional pattern between countries. Mean intakes were 2771 mg (1855–3500 mg) in women and 3245 mg (2192–4300 mg) in men.

Few countries and no women of any nationality met the 400 µg RNI for folic acid; only young and elderly Irish men and middle-aged Lithuanian and Turkish men had adequate intakes (Figure 12). The mean folic acid intake was 268 µg (129–399 µg) in women and 318 µg (142–643 µg) in men. The majority of countries over-consumed sodium; all male age groups exceeded the 3000 mg RNI and in women only the UK and younger Estonian and Latvian women did not (Figure 13). Mean sodium intakes were 2341 mg (1426–5200 mg) in women and 3163 mg (1811–7400 mg) in men.

Assessing RNI attainment in vitamin D and calcium (Figures 14 and 15) is made more difficult by different ages having different RNIs—where age groupings span

RNI categories it cannot be specified whether or not the RNI is met. Where this could be assessed, few countries met the RNI for the age range in question, particularly in women and the elderly, where no countries met the RNI. Mean vitamin D intakes were 2.7 μg (0.5–9.1 μg) in women and 3.3 μg (0.6–13.4 μg) in men. Mean calcium intakes were 799 mg (457–1206 mg) for women and 908 mg (555–1424 mg) in men.

Figure 9. Mean/median* adult iron intake (mg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.

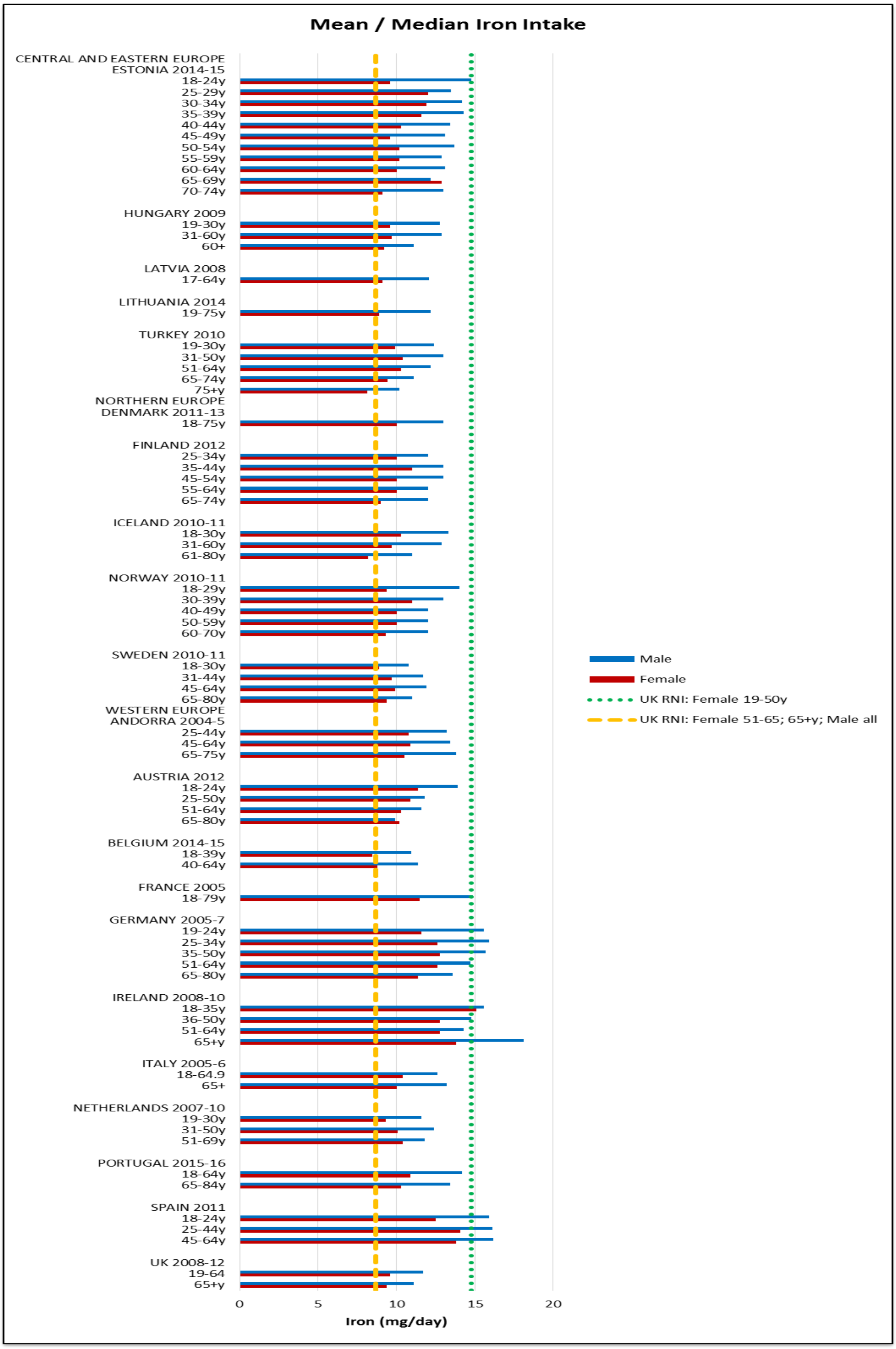


Figure 10. Mean/median* adult iodine intake (µg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.

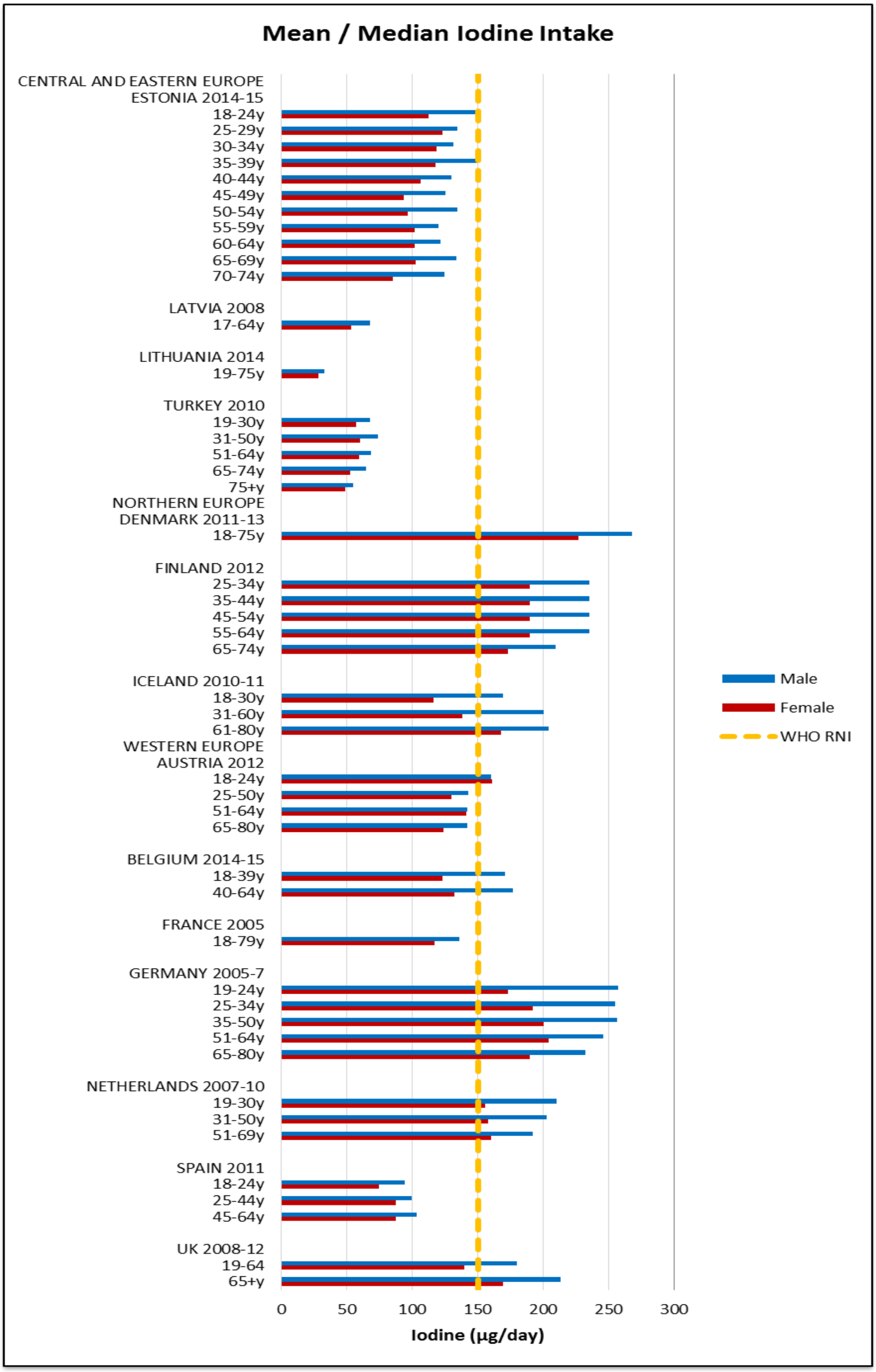


Figure 11. Mean/median* adult potassium intake (mg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.

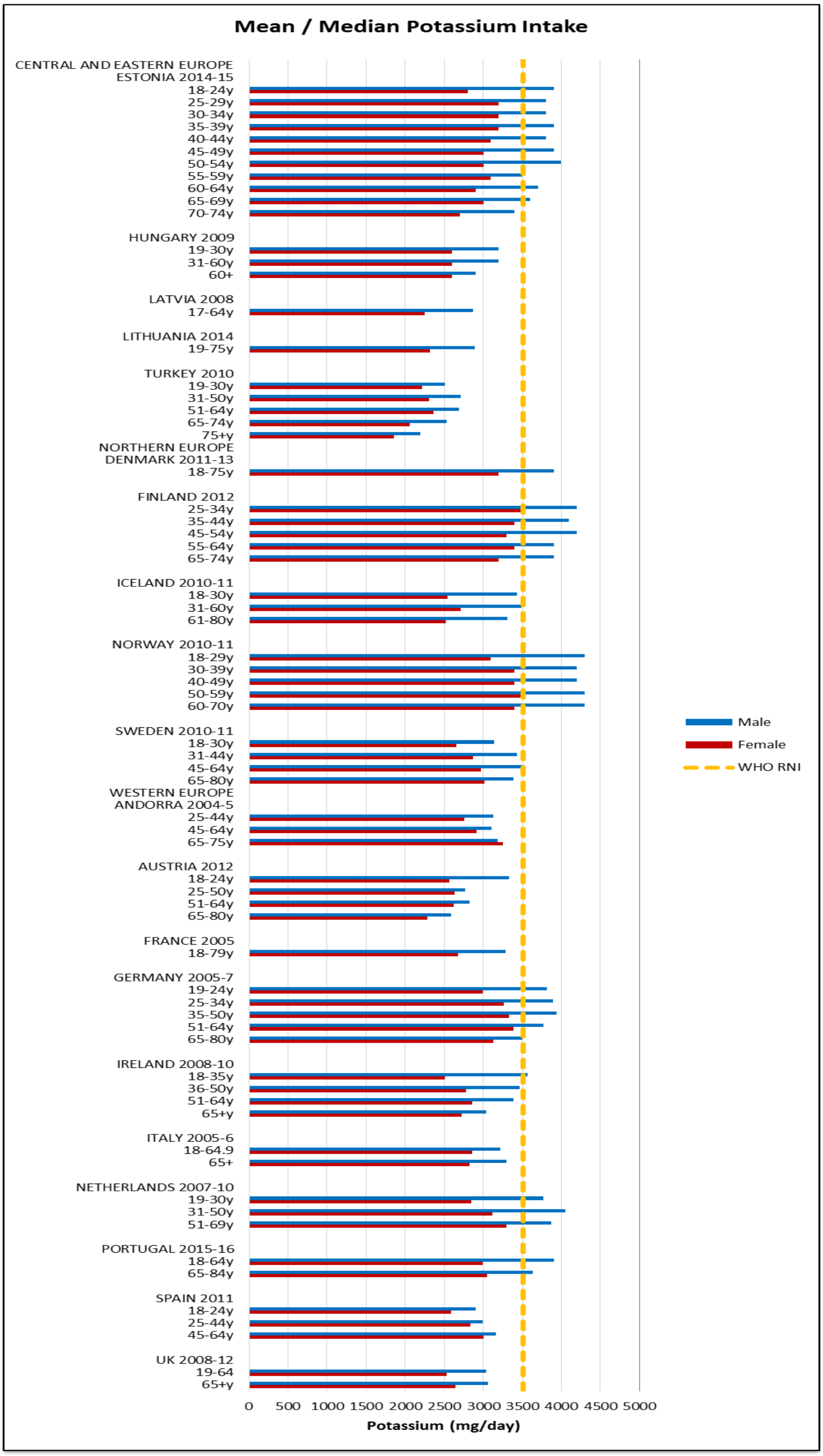


Figure 12. Mean/median* adult folic acid intake (µg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.

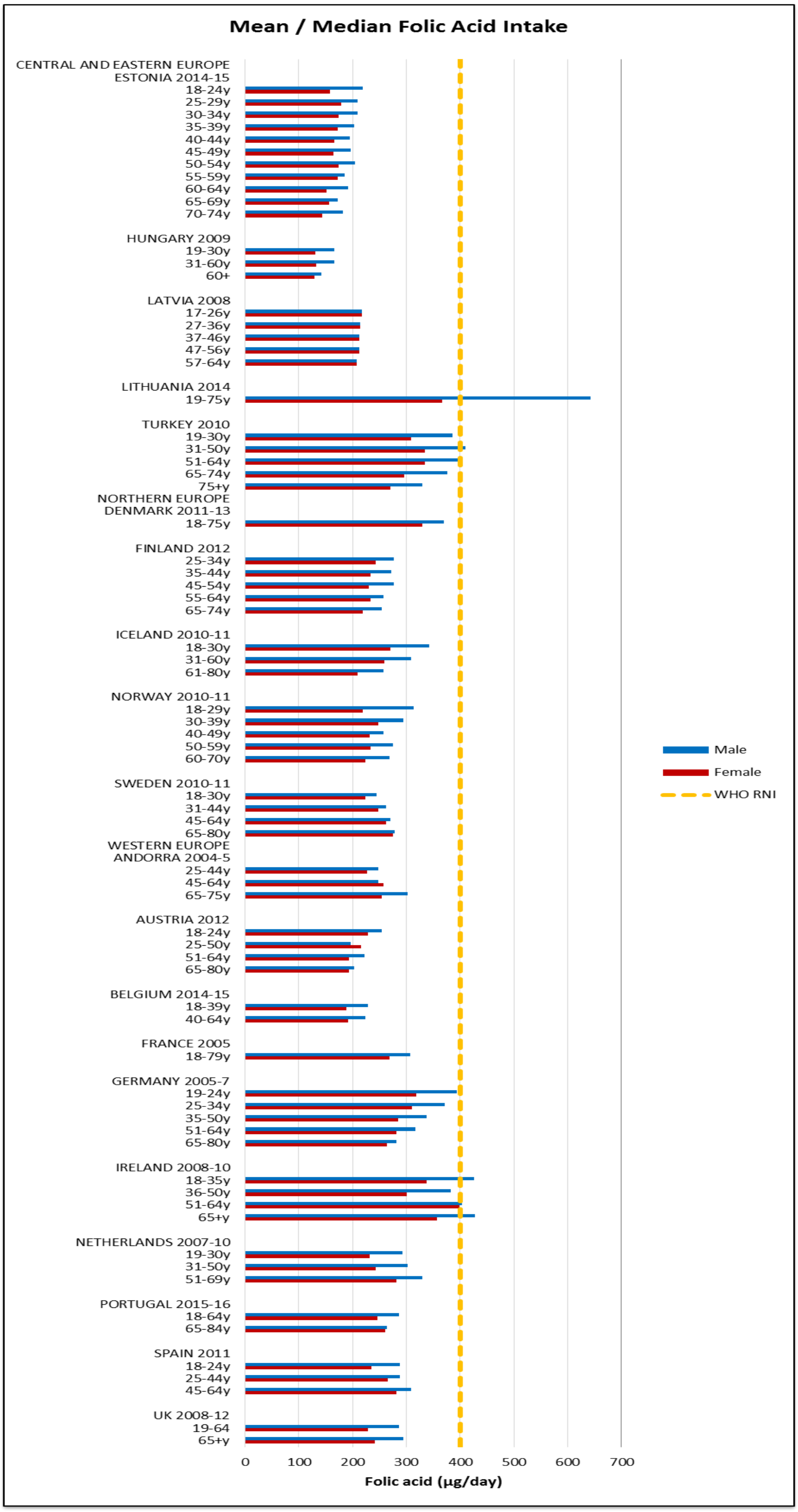


Figure 13. Mean/median* adult sodium intake (mg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.

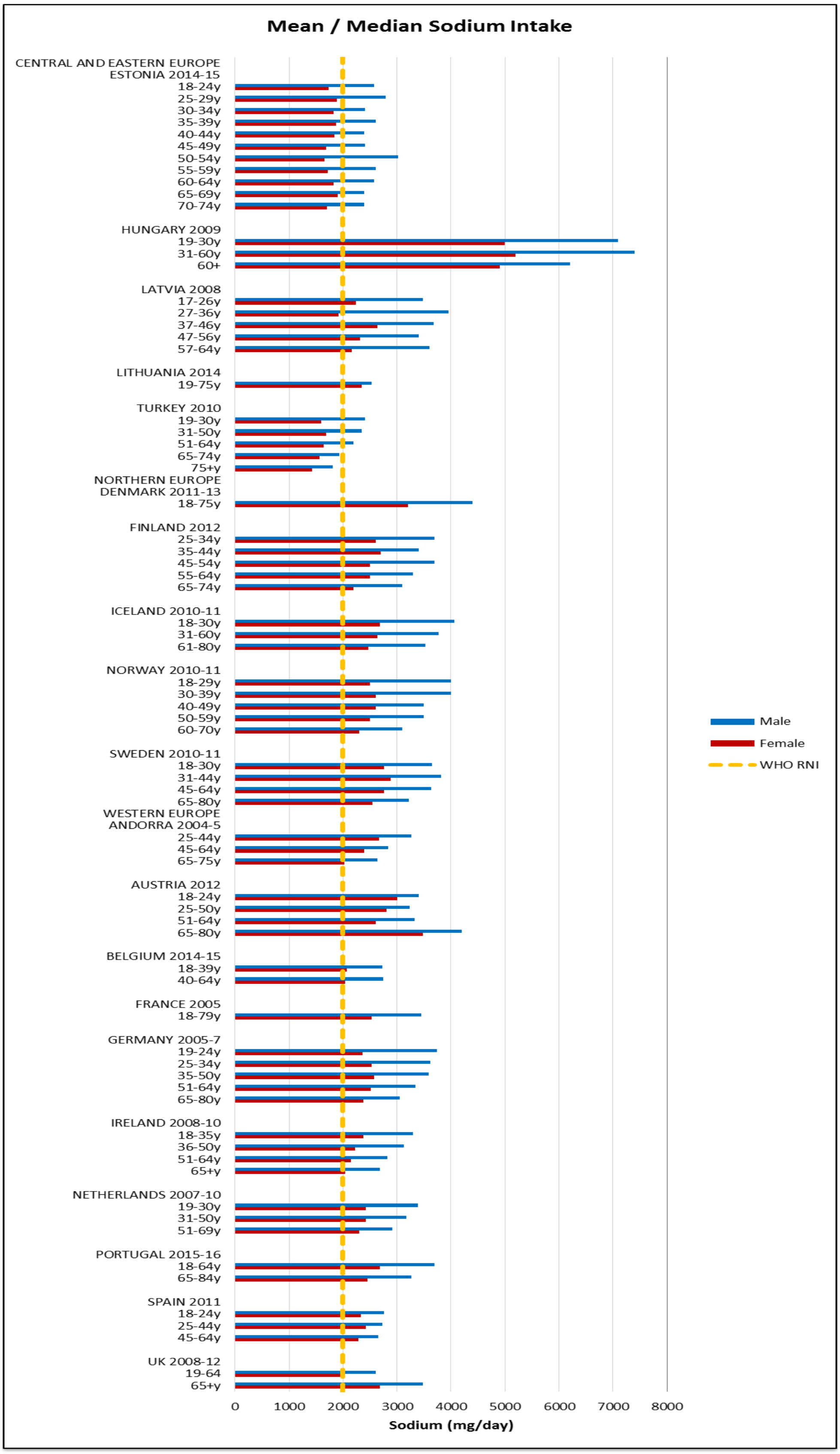


Figure 14. Mean/median* adult vitamin D intake (µg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.

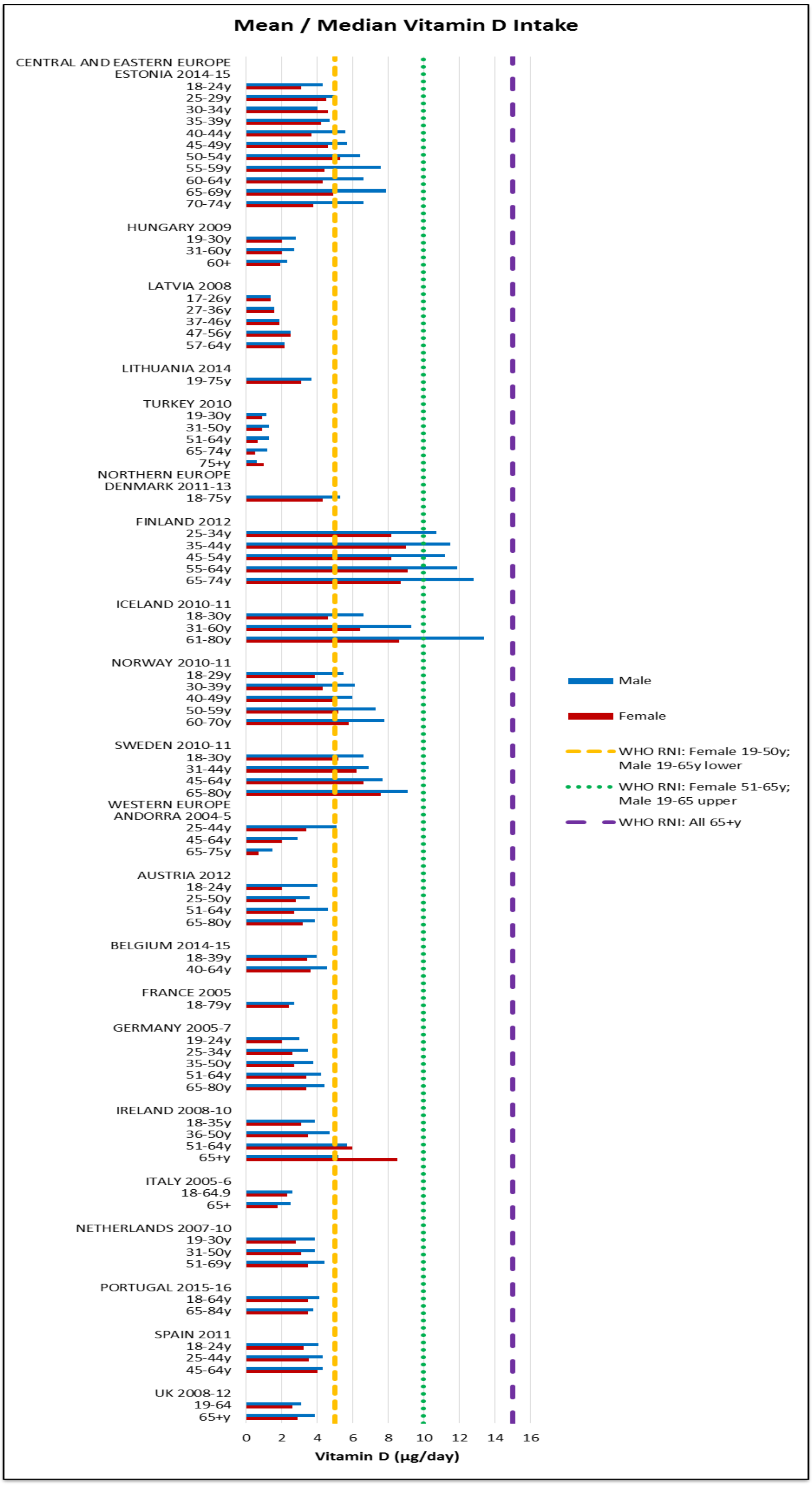
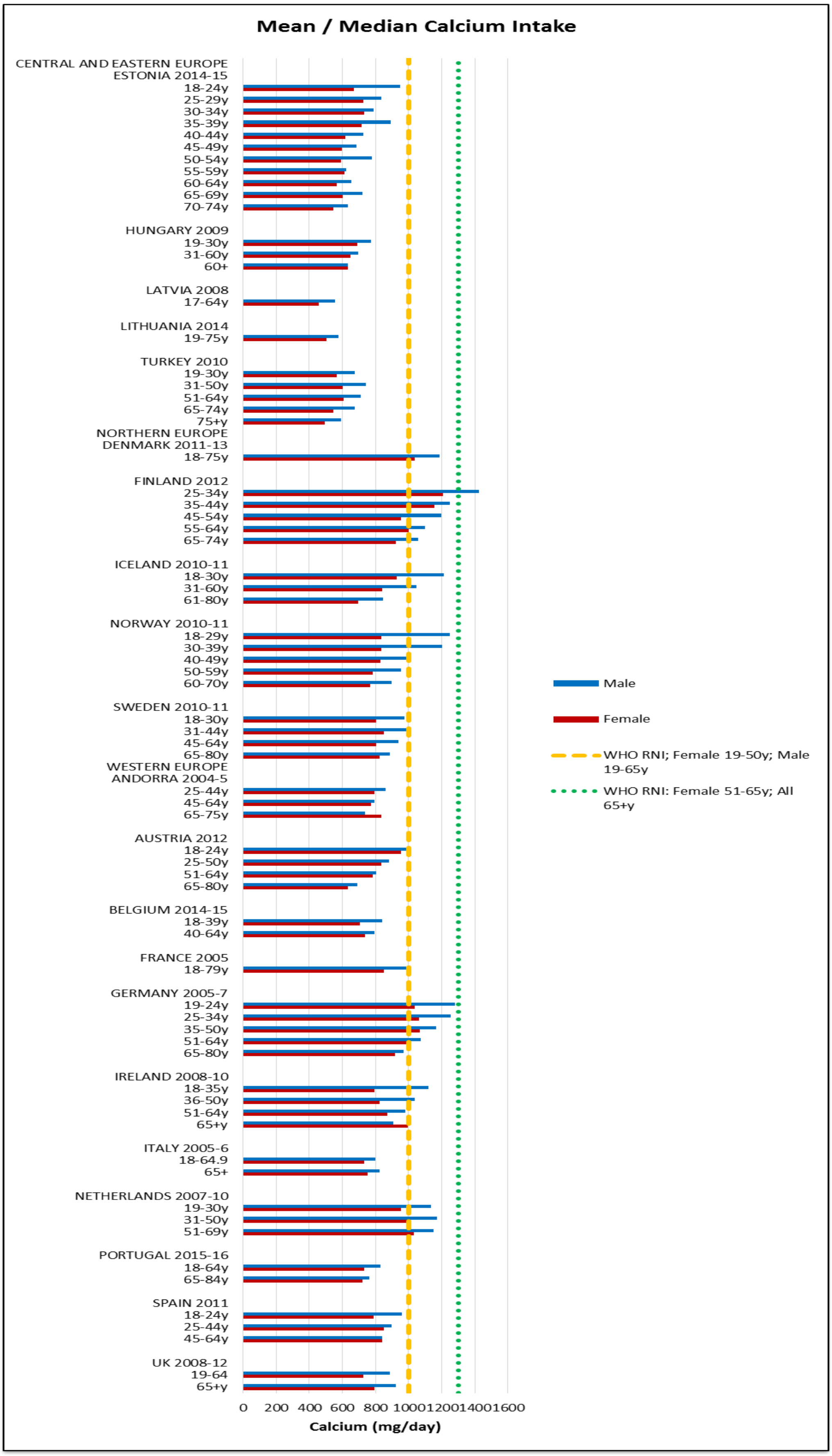


Figure 15. Mean/median* adult calcium intake (mg/day) (excluding supplements). * Figures for Spain are based on median rather than mean values.



4.4 Discussion

4.4.1 Data Extracted

This review details the provision of energy and nutrient intake data in nationally representative surveys across the 53 countries of the WHO Europe region for nutrients of particular concern to the WHO European Region (1). Only 40% (*n* = 21) of countries provided intake data by gender and age group for adults; the majority of these were Western and Northern European countries. This implies that nutrition policies in the remaining 60% of countries without intake data may be based on limited evidence, particularly in CEEC. This is a concern, as overweight and obesity have tripled in some of these countries since 1980 and NCD prevalence rates are reaching those of Western Europe (1). Additionally, unknown pockets of micronutrient deficiencies may exist in some countries.

Although the surveys used different dietary methodologies, we felt it important to report intakes in their publicly available format. Of the 21 surveys for which intakes were extracted, energy, macro and micronutrients were generally well represented and there were no apparent regional patterns in nutrient intake gaps. This provides a good basis for assessing population status and identifying vulnerable gender/age groups in these countries (see Appendices A & B). The biggest gaps in macronutrient provision were TFA, omega fatty acids and sugar, the latter particularly in CEEC, which have been identified as nutrients of concern (1, 49). These are therefore important knowledge gaps, as without intake data, population and subgroup status cannot be known or appropriate policies devised. Iodine was reported by the least surveys; deficiencies remain frequent in WHO Europe (1) and even mild-moderate maternal deficiency is associated with decreased cognitive function in children (50). This gap therefore limits effective policy formation to address population groups most in need.

A third of countries, or just 13% of the 53 WHO Europe countries, reported energy and nutrient intakes by SEG (Table 3). This is concerning, as whilst NDS could be used to identify subgroups lacking nutrients based on gender and age, few can gauge the potential for NDS to capture socio-economic inequalities. In addition, different, often multiple variables were used to represent SEG, making inter-country comparisons difficult. Consequently, vulnerable groups across

Europe may be at risk of malnutrition through under or over-nutrition and related NCDs, with limited means for governments and health bodies to measure, monitor or address in policy.

4.4.2 Energy Intakes

Energy intakes did not vary substantially by European region, although the different dietary assessment methodologies employed by surveys may make inter-country comparisons unreliable. In addition, under-reporting is associated with all dietary assessment methods, including the 24 h recall and food diaries used by the surveys in question (51), which could impact on the validity of intake data and the conclusions derived from it. Most surveys either included under-reporters or did not specify—only Belgium explicitly excluded under-reporters, which may elevate Belgian intakes compared to the other countries.

4.4.3 Nutrient Intakes and WHO RNI Status

WHO RNI attainment was low across all regions—only Finland and The Netherlands met more than a third of WHO RNIs in all gender/age groups, suggesting that nutritional concerns exist across WHO Europe and that population groups within countries are not impacted equally. Turkey had the lowest intakes in most nutrients, potentially because it reported the oldest age grouping (75+ y) who may be likely to consume less than younger adults. However, the Turkish 65–74 y group also had low intakes for multiple nutrients compared to equivalent age groups in other countries.

4.4.4 Carbohydrates and Fats

The majority of countries did not meet the carbohydrate, sugar or fiber guidelines. This suggests a potential under-consumption of complex carbohydrates, going against established dietary advice (10), particularly The Netherlands, which had a lower fibre but high sugar intake.

Most countries exceeded fat and saturates guidelines. Andorra and Lithuania had modest absolute but high %E intakes, suggesting a diet with an unfavorable fatty acid composition, particularly in Andorra, which does not have the high %E in PUFA evident in Lithuania. This could lead to increased susceptibility to NCDs like coronary heart disease (CHD) (52). Similarly, Denmark, Norway and Iceland had a high saturates intakes without correspondingly high unsaturated fat intakes. This suggests that Northern European countries may have higher saturated fat intakes as a proportion of total fat, possibly reflecting unfavorable national dietary patterns, though diet is one of many contributors to disease susceptibility.

Spain, Italy and Andorra had high MUFA intakes, which could indicate a Mediterranean diet pattern, linked to reduced all-cause mortality and NCD risk (53, 54). Hungary, Lithuania and Turkey had high PUFA intakes, which could indicate a regional influence based on CEEC diet patterns, particularly in Turkey, which had low intakes for most macronutrients other than PUFA. This pattern is also evident in n-6 intakes—both Turkey and Hungary exceeded the upper WHO RNI. TFAs had the greatest RNI compliance, possibly due to a combination of health bodies like WHO calling for a wholesale TFA reduction (1) and widespread TFA-reduction policies across Europe, including bans, labelling initiatives and voluntary product reformulation (55-58).

Of those reporting omega fats, Northern European countries had higher n-3 but lower n-6 intakes. This could potentially be a function of national diet patterns such as high oily fish consumption in Scandinavia; of the five European countries participating in the European Food Consumption Validation Project (EFCOVAL), Norway had the highest fish consumption (59). Although some countries reported different n-3 and n-6 variants, the highest intakes were not necessarily those that included multiple variants. Therefore, although amalgamated n-3 and n-6 levels may not represent the full population omega intake, this does not necessarily invalidate inferences made. It does, however, highlight the need for a common methodological approach to conducting dietary surveys and gathering nutrient intake data.

4.4.5 Micronutrients

The percentage of CEEC that surveyed micronutrients generally had lower micronutrient intakes than the other regions, particularly Lithuania and Turkey—exceptions were relatively high Lithuanian folate and Hungarian, particularly male, sodium intakes. This suggests the potential for population groups to have suboptimum diets with excessive or inadequate intakes of particular nutrients. More research is necessary to determine whether this is a function of typical regional diet patterns and to inform debate on potential solutions such as food-based compared to fortification and/or supplementation for specific at-risk groups.

The majority of countries not meeting the iodine RNI were CEEC (Figure 10); this could be attributed to regional differences in salt iodization practices. However, patterns are difficult to elucidate, as salt-iodization programs are not uniform within or between countries and even where countries have policies, household coverage may be low (60). For sodium only the UK and CEEC females did not exceed the RNI, although sodium intakes from dietary records may be unreliable. This could reflect generally low CEEC intakes and also the UK being an early adopter of a comprehensive voluntary salt reduction program since 2008 (61, 62), which is credited with facilitating a reduction in salt intakes (63). However, care must be taken when considering salt reduction, as salt iodization is a primary means of improving iodine intakes (64). European iodine status is concerning; of the WHO regions Europe has the highest deficiency level. Potential solutions for compatibility, such as increasing the concentration of iodine in salt or using alternative vehicles, may need to be considered in countries where iodine status is poor.

Nordic countries had higher mineral intakes, whilst different national fortification practices may explain some variations in vitamin intake. Scandinavian vitamin D intakes were relatively high, with the exception of Denmark and Swedish vitamin D fortification is more extensive than Danish (65). Northern European countries have less sunlight, meaning populations are likely to need more vitamin D from food, so where fortification is low, intakes are likely to be lower. This review includes fortification in base diet, as most countries' food composition databases do not separate this out (66).

Our findings support the identification of iodine, iron and vitamin D by WHO as nutrients of concern (1), particularly in CEEC, women and the female elderly respectively. Women and the female elderly appear to be the most vulnerable groups across the countries, with additional risk of potassium, calcium and folate deficiency. The latter is of particular concern in women of reproduction age as it can prevent neural tube defects in offspring (67). Nutrients of universal concern were carbohydrates, fats and sodium. In addition to improving micronutrient intakes, increasing complex carbohydrate and fiber consumption and reduction of sodium, fat and saturates should be a priority across the majority of European population groups.

4.4.6 Strengths and Limitations

The strengths of this review are that it provides a unique, current account of reported energy and nutrient intakes for adults across whole populations and subgroups in Europe, with reference to WHO RNI attainment. The review will help identify where there is a need to improve diets and could enable governments and health bodies to better use NDS to reduce NCDs and related conditions across Europe. It also details where surveys report nutrient intakes by SEG—future work could present and assess intakes by SEG in more detail.

A limitation is that inconsistent age groupings across countries made inter-country comparisons difficult. In Andorra, the youngest age group spanned both adults and children, invalidating conclusions regarding adults aged 18–24. Further investigations using raw data could obtain more reliable conclusions via consistent age groups. Differences in dietary assessment methodologies present further limiting factors when making inter-country comparisons. For example, mean energy intakes in young Norwegian men were 3.4MJ higher than in the same age group in Sweden, despite being neighboring countries whose NDS were conducted in the same years. These differences could therefore be either due to the different methodological approaches employed, or a genuine intake disparity. In addition, collection over more days better reflects usual intake due to greater control over day-to-day variation (68). However, most countries did not employ usual intake procedures such as the Statistical Programme to Assess Dietary Exposure (SPADE) (68). This could affect intakes, although the impact would be greater on the distribution rather than the mean values. Some countries did not report overall country means for nutrients by gender, so a consistent weighting method was used for all countries. However, the overall country means we tabled are approximations based on the assumption that the numbers in each age group are proportionate to those in the total population. Due to availability, we used total national population numbers, which included adults and children, to calculate weighted regional and overall European means; therefore, means of countries with larger proportions of children in their populations may be given more weighting than required in these approximations.

Lack of alignment and completeness of national food composition databases and classification systems represents a further limitation. Sweden used sucrose as a proxy for added sugar (45), whilst others did not specify, so the number of mono and disaccharides included may differ and intake levels be incomparable. In this review, sucrose was equated with added sugars. If differences like these exist in other countries, estimated intake levels may vary as a result. Different composition databases may represent nutrients to different degrees; of the 14 countries reporting iodine, for example, not all may have iodine values for all foods. Consequently, intake values for particular nutrient in certain countries may be less accurate. In addition, the nutrient values underpinning food composition databases may be derived from different analytical methods, as with folate, preventing true data harmonization and potentially skewing intakes. This could explain the particularly low UK fiber intakes; the UK survey used the Englyst method, whereas other countries may have used AOAC or other methods. Whilst there is good agreement between methods in most foods, the Englyst method produces lower results in certain cereals, fruits, white beans and peanuts, which may affect fiber intake levels (69). Additionally, food composition databases may not accurately reflect fortification—not all countries' food composition databases account for iodine fortification, potentially depressing intake estimates (70). Some food composition databases may not be updated to account for reformulated products; for instance, TFA values reported may be higher than those found in purchased products (71).

Future research could investigate how methodological differences impact on intake estimates in European populations—low Turkish intakes may have been due to either socioeconomic or methodological factors, using only a single 24 h recall (70). Ireland had high vitamin intakes and was the only country that used weighed intake; the majority of countries used 24 h recall (5), which Holmes & Nelson (72) rank as less likely than weighed intakes to generate accurate portion size data.

4.5 Conclusions

This review has found that adult energy and nutrient intakes could only be extracted from 21 (40%) of the 53 WHO Europe countries and that methodological and other differences make inter-country comparisons difficult. The main gaps lie in CEEC, where nutrition policies may therefore be based on limited evidence, with a lack of data meaning potential unknown nutrient deficiencies may exist. Macro and micronutrients of interest were reported by most countries with intake data, though TFAs, omega fats, sugars and iodine had the least coverage. WHO RNI attainment was generally poor, particularly for macronutrients and was most notably lacking in women. Concerning micronutrients, the same was seen and was most prominent amongst the elderly female population and CEEC. Only 13% of WHO Europe countries reported intakes by SEG and by different methods. Consequently, the majority of WHO Europe countries are unable to adequately assess and address nutrient deficiencies in vulnerable SEGs. Future efforts should encourage WHO Europe countries to report a full range of nutrient intakes, including by SEG, in a uniform way.

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Appendix A. Mean Macronutrient Intakes across Dietary Surveys.

COUNTRY	SURVEY	YEAR	Energy (MJ)	Energy (Kcal)	Protein (g)	CHO (g)	Sugar (g)	Sucrose (g)	Starch (g)	Fiber (g)	Total Fat (g)	Saturates (g)	MUFA (g)	PUFA (g)	TFA (g)	n-3 (g)	n-6 (g)
Andorra	**Evaluation of the nutritional status of the Andorran population**	2004–2005															
	female: 25–44 y		6.9	1650	83	165	75			15.8	73	23.4	32.5	10.2			
	female: 45–64 y		6.8	1628	81	162	77			17.6	73	22.3	32.8	10.6			
	female: 65–75 y		6.4	1518	71	165	83			21.3	65	18.3	31.2	8.6			
	male: 25–44 y		8.8	2093	100	205	88			16.8	85	30.7	42.7	13.8			
	male: 45–64 y		8.0	1919	90	188	84			17.1	86	26.5	39.3	12.1			
	male: 65–75 y		7.0	1679	83	173	80			18.3	74	20.8	34.9	12.0			
Austria	**Austrian nutrition report**	2010–2012															
	female: 18–24 y		8.0	1917	72	225		43		22.0	77	32.0	25.6	14.9		1.5	12.6
	female: 25–50 y		7.8	1854	70	218		46		22.0	74	30.9	24.7	12.4		1.5	12.2
	female: 51–64 y		7.7	1826	64	219		46		22.0	73	30.4	22.3	14.2		1.5	12.0
	female: 65–80 y		7.0	1675	63	188		38		19.0	69	29.8	22.3	13.0		1.4	10.4
	male: 18–24 y		10.1	2403	90	282		60		24.0	91	37.4	29.4	16.0		1.6	13.9
	male: 25–50 y		9.1	2172	81	239		54		20.0	89	38.6	29.0	14.5		1.5	12.5
	male: 51–64 y		9.4	2245	84	236		45		22.0	92	39.9	29.9	15.0		1.5	13.0
	male: 65–80 y		8.0	1920	67	216		38		20.0	75	32.0	23.5	12.8		1.4	11.1
Belgium	**The Belgian food consumption survey 2014–2015**	2014–2015															
	female: 18–39 y		8.2	1955	71	214	99		116	17.3	79	29.0	29.0	14.0	0.8		
	female: 40–64 y		7.6	1826	71	190	89		100	18.8	75	27.0	26.0	14.0	0.8		

	male: 18–39 y		11.1	2652	95	291	131		155	19.3	100	36.0	38.0	18.0	1.0		
	male: 40–64 y		10.7	2547	96	253	115		137	20.1	104	37.0	36.0	19.0	1.1		
Denmark	**Danish Dietary habits 2011–2013**	2011–2013															
	female: 18–75 y		8.4	2008	76	211		43		21.0	83	33.0	31.0	13.0	1.3		
	male: 18–75 y		11.2	2677	101	269		56		24.0	111	45.0	41.0	17.0	1.7		
Estonia	**National Dietary Survey**	2014–2015															
	female: 18–24 y		6.8	1625	64	200		48		15.1	64	25.5	22.8	10.9	0.5	1.6	8.6
	female: 25–29 y		7.6	1818	71	217		54		17.1	76	30.5	27.2	12.1	0.6	1.9	9.2
	female: 30–34 y		7.3	1762	71	210		49		18.1	73	29.6	26.4	11.6	0.6	1.8	8.9
	female: 35–39 y		7.2	1730	68	205		48		17.8	72	29.1	26.4	11.9	0.6	2.2	9.1
	female: 40–44 y		6.4	1529	60	188		41		17.3	61	24.4	21.8	10.4	0.5	1.8	7.7
	female: 45–49 y		6.2	1488	59	177		38		16.6	60	23.6	21.9	10.3	0.5	1.8	7.7
	female: 50–54 y		6.3	1505	60	183		42		17.6	61	23.3	22.3	10.8	0.5	1.8	7.8
	female: 55–59 y		6.4	1537	64	185		38		18.1	62	24.6	22.6	10.7	0.5	1.5	8.0
	female: 60–64 y		6.2	1474	61	179		39		17.0	59	22.5	22	10.2	0.5	1.7	7.6
	female: 65–69 y		6.3	1509	62	186		36		17.8	59	23.3	21.4	10.3	0.5	1.9	7.5
	female: 70–74 y		5.5	1330	55	168		32		16.6	51	20.3	18.3	8.9	0.4	1.5	6.7
	male: 18–24 y		9.7	2326	102	266		58		18.1	92	35.8	34.4	16.4	0.6	2.8	13.2
	male: 25–29 y		9.5	2277	94	239		55		16.8	93	36.9	35.2	14.7	0.8	3.5	11.4
	male: 30–34 y		8.6	2058	85	234		52		17.7	84	33	31.3	14.4	0.7	2.6	11.2
	male: 35–39 y		9.5	2279	94	252		55		19.7	94	36.9	34.7	16.8	0.6	4.4	12.3
	male: 40–44 y		8.7	2085	89	229		45		19.3	81	31.8	30.9	13.4	0.6	3.0	10.0
	male: 45–49 y		8.6	2068	79	242		47		20.1	80	29.7	31.3	14	0.6	3.6	10.5
	male: 50–54 y		8.9	2125	89	233		46		20.4	89	33.9	33.8	14.9	0.6	4.6	11.1
	male: 55–59 y		8.2	1965	75	221		44		19.2	76	27.6	29	14	0.5	3.5	10.5

	male: 60–64 y		8.1	1941	81	226		40		20.6	75	29.6	28.1	12.6	0.6	2.9	9.3
	male: 65–69 y		7.8	1865	78	213		34		19.5	74	29.8	27.4	12.4	0.6	2.6	9.0
	male: 70–74 y		7.6	1814	75	213		36		19.6	73	29.1	27.5	12.7	0.5	2.4	9.4
Finland	**The national FINDIET 2012 survey**	2012															
	female: 25–34 y		7.8	1864	76	199		49		19.0	78	31.0	27.0	13.4	1.0	3.0	9.8
	female: 35–44 y		7.7	1840	77	195		46		20.0	75	29.0	27.0	13.0	0.9	2.9	9.6
	female: 45–54 y		7.0	1673	68	180		44		21.0	67	26.0	24.0	11.6	0.8	2.7	8.4
	female: 55–64 y		6.6	1577	67	171		36		22.0	63	24.0	22.0	11.6	0.7	2.8	8.5
	female: 65–74 y		6.2	1482	62	166		35		21.0	57	22.0	20.0	10.6	0.7	2.5	7.6
	male: 25–34 y		10.2	2449	106	249		55		19.0	102	40.0	37.0	16.9	1.3	3.7	12.5
	male: 35–44 y		9.5	2275	96	237		54		21.0	93	36.0	34.0	15.6	1.1	3.5	11.4
	male: 45–54 y		9.5	2282	96	237		52		23.0	93	36.0	34.0	16.2	1.1	3.6	11.8
	male: 55–64 y		8.6	2053	85	207		45		23.0	86	33.0	30.0	14.9	1.0	3.5	10.8
	male: 65–74 y		8.2	1954	80	212		43		24.0	77	29.0	28.0	13.7	0.9	3.4	9.7
France	**INCA2**	2006–2007															
	female: 18–79 y		7.6	1809	74	199	89		105	16.0	80	32.1	28.6	12.3			
	male: 18–79 y		9.8	2348	100	262	101		153	19.2	100	41.2	35.7	14.5			
Germany	**German National Nutrition Survey II**	2005–2007															
	female: 19–24 y		8.4	1996	65	252				21.7	74						
	female: 25–34 y		8.5	2031	70	251				24.0	77						
	female: 35–50 y		8.2	1948	69	231				24.7	76						
	female: 51–64 y		7.8	1856	67	217				26.1	72						
	female: 65–80 y		7.3	1753	62	209				24.9	69						
	male: 19–24 y		12.0	2872	102	331				24.6	110						
	male: 325–34 y		11.6	2783	99	318				25.8	110						

	male: 35–50 y		11.0	2640	94	294				27.3	106						
	male: 51–64 y		10.0	2400	86	262				27.4	96						
	male: 65–80 y		9.2	2191	78	241				27.3	88						
	Hungarian Dietary Survey 2009																
	female: 19–30 y		9.1	2175	81	265		49		20.7	88	26.2	26.8	22.8		0.9	22.1
	female: 31–60 y		9.0	2151	81	254		44		21.0	88	25.9	27.1	22.7		0.9	22.0
Hungary	female: 60+	2009	8.6	2055	75	245		41		20.6	84	25.0	26.3	21.2		0.9	20.4
	male: 19–30 y		12.5	2988	112	334		64		25.5	124	37.5	39.8	30.0		1.2	29.1
	male: 31–60 y		12.3	2940	109	322		49		25.4	127	37.6	41.4	30.4		1.2	29.5
	male: 60+		10.5	2510	92	277		40		23.1	107	31.7	35.1	25.5		1.0	24.6
	The Diet of Icelanders—a national dietary survey 2010–2011																
	female: 18–30 y		8.0	1895	75	222	108			16.2	71	27.6	23.2	12.4	1.3	2.6	9.7
Iceland	female: 31–60 y	2010–2011	7.5	1795	76	190	86			16.5	74	29.7	23.4	12.5	1.6	3.0	9.4
	female: 61–80 y		6.7	1610	71	161	74			14.8	69	28.4	21.9	10.7	1.6	2.9	7.6
	male: 18–30 y		11.1	2635	116	288	129			19.1	101	38.9	32.5	17.1	2.1	3.5	13.6
	male: 31–60 y		10.1	2402	107	242	105			17.6	101	40.5	32.3	16.2	2.2	3.9	12.3
	male: 61–80 y		8.7	2081	97	192	80			16.7	94	39.1	30.1	13.7	2.3	4.0	9.5
	National adult nutrition survey																
	female: 18–64 y		7.2	1721	70	200	81		115	17.3	68	28.9	27.4	13.9	1.1	1.6	
	female: 18–35 y		7.5	1793	69	206	84		117	15.9	70	29.9	29.4	14.8	1.1	1.6	
Ireland	female: 36–50 y	2008–2010	7.1	1697	71	197	77		115	17.5	67	28.6	26.4	13.2	1.0	1.6	
	female: 51–64 y		7.0	1673	73	195	83		109	19.5	65	27.9	25.8	13.5	1.0	1.8	
	female: 65+ y		6.5	1554	69	187	80		103	18.4	61	26.5	22.6	11.7	1.0	1.7	
	male: 18–64 y		10.1	2414	100	266	102		160	21.1	92	38.7	36.4	16.9	1.6	2.0	

	male: 18–35 y		10.7	2557	105	281	108		167	21.3	95	39.5	38.3	17.9	1.7	2.0
	male: 36–50 y		9.7	2318	99	259	98		157	21.0	92	38.6	35.6	16.2	1.5	1.9
	male: 51–64 y		9.3	2223	93	249	98		148	21.0	86	37.4	33.6	15.9	1.5	2.0
	male: 65+ y		8.3	1984	85	226	89		133	19.6	78	35.6	29.8	13.1	1.4	1.6
	The third Italian National food consumption survey INRAN-SCAI															
Italy	female: 18–64.9	2005–2006	8.1	1939	76	237	80		142	17.7	79	24.4	38.3	10.0		
	female: 65+		7.7	1834	71	234	79		139	18.7	70	22.2	34.1	8.0		
	male: 18–64.9		10.0	2390	93	283	86		179	19.6	95	29.7	45.9	12.2		
	male: 65+		9.6	2296	88	275	82		174	21.6	87	26.8	43.5	10.4		
	Latvian National Food Consumption Survey 2007–2009															
	female: ALL		6.7	1613	55	190				15.8	68	28.1	24.0	10.8		
	male: ALL		9.1	2171	79	246				20.2	93	38.1	33.4	14.8		
	female: 17–26 y		7.1	1690												
	female: 27–36 y		6.4	1523												
Latvia	female: 37–46 y	2007–2009	6.5	1562												
	female: 47–56 y		6.7	1608												
	female: 57–64 y		6.4	1530												
	male: 17–26 y		10.0	2394												
	male: 27–36 y		10.0	2393												
	male: 37–46 y		9.7	2319												
	male: 47–56 y		9.3	2230												
	male: 57–64 y		8.9	2121												
Lithuania	**Study and evaluation of**															

	actual nutrition and nutrition habits of Lithuanian adult population																
	female: 19–75 y		6.5	1561	56	178	56			14.6	71	21.9	26.8	15.5			
	male: 19–75 y	2013–2014	9.2	2188	75	224	55			17.2	108	33.5	41.1	23.8			
	all: 19–34 y		8.1	1936	65	209	58			15.4	92	28.4	34.8	20.1			
	all: 35–49 y		7.8	1855	66	197	56			16.1	90	27.7	34.0	19.7			
	all: 50–64 y		7.4	1763	63	191	55			15.8	83	25.9	31.7	18.3			
	all: 65–75 y		6.7	1600	57	183	51			15.1	72	22.3	27.3	15.8			
	Dutch National Food Consumption Survey (DNFCS) 2007–2010																
	female: 19–30 y		8.5	2028	73	242	121			18.0	77	29.0	26.9	14.8	1.3	1.5	12.3
The Netherlands	female: 31–50 y	2007–2010	8.3	1983	75	222	104			18.9	77	29.6	26.6	14.6	1.3	1.7	11.9
	female: 51–69 y		7.9	1874	77	195	92			18.8	72	27.8	24.0	13.8	1.4	1.8	11.3
	male: 19–30 y		11.9	2847	98	342	152			22.4	109	39.3	39.1	21.7	1.7	2.3	18.1
	male: 31–50 y		11.1	2651	97	285	126			23.7	104	38.3	36.2	21.0	1.6	2.3	17.4
	male: 51–69 y		10.2	2425	97	246	107			21.6	94	35.4	32.2	18.6	1.6	2.2	15.4
	Norkost3																
	female: 18–70 y		8.0	1912	81	205		36		22.0	75	29.0	25.0	13.0			
	male: 18–70 y		10.9	2605	112	278		48		26.0	102	39.0	34.0	18.0			
	female: 18–29 y		8.1	1936	80	221		46		21.0	73	28.0	25.0	13.0			
Norway	female: 30–39 y	2010–2011	8.4	2008	83	232		42		24.0	75	29.0	25.0	14.0			
	female: 40–49 y		8.1	1936	83	202		32		22.0	77	30.0	26.0	14.0			
	female: 50–59 y		7.9	1888	81	194		33		22.0	75	28.0	26.0	14.0			
	female: 60–70 y		7.4	1769	77	182		30		22.0	72	28.0	24.0	13.0			
	male: 18–29 y		12.8	3059	130	339		69		29.0	114	44.0	38.0	21.0			

	male: 30–39 y		11.5	2749	118	298		49	26.0	108	42.0	37.0	19.0			
	male: 40–49 y		10.6	2533	107	275		51	25.0	100	38.0	34.0	19.0			
	male: 50–59 y		10.4	2486	109	259		41	26.0	99	37.0	33.0	18.0			
	male: 60–70 y		9.9	2366	102	247		39	27.0	94	36.0	31.0	17.0			
Portugal	**National Food and Physical Activity Survey (IAN-AF)**	2015–2016														
	female: 18–64 y		7.3	1747	80	199	78		16.9	61	23.4	25.2	11.1	0.9		9.9
	female: 65–84 y		6.5	1555	70	180	73		18.1	53	17.3	21.7	9.1	0.6		7.9
	male: 18–64 y		10.1	2398	111	255	89		19.9	81	28.9	33.9	13.7	1.1		13.1
	male: 65–84 y		8.5	2030	91	212	71		20.6	63	20.9	26.4	10.8	0.7		9.6
Spain	**ENIDE 2011**	2009–2010														
	female: 18–24 y		9.2	2186	88	209			17.1	95	27.5	40.1	13.0			
	female: 25–44 y		9.2	2187	88	202			18.9	94	26.2	38.9	12.4			
	female: 45–64 y		9.1	2162	88	193			19.7	91	24.2	38.1	12.6			
	male: 18–24 y		10.1	2402	117	275			20.5	127	39.6	53.3	17.1			
	male: 25–44 y		9.8	2340	109	248			20.4	117	33.6	49.1	15.7			
	male: 45–64 y		9.6	2281	106	222			21.7	108	29.0	45.1	14.5			
Sweden	**Riksmaten 2010–11 Swedish Adult Dietary Survey**	2010–2011														
	female: 18–30 y		7.6	1819	69	205		44	17.3	72	27.4	27.1	12.0		2.4	9.2
	female: 31–44 y		7.6	1820	73	199		38	18.5	72	27.8	26.9	11.6		2.4	8.7
	female: 45–64 y		7.3	1755	73	182		34	19.3	70	26.5	26.0	11.7		2.5	8.7
	female: 65–80 y		7.1	1703	70	186		34	20.0	65	24.9	23.9	10.6		2.6	7.6
	male: 18–30 y		9.4	2246	95	241		45	18.6	88	34.1	32.8	14.0		2.7	10.6
	male: 31–44 y		9.8	2343	95	250		43	21.3	92	35.0	34.9	14.9		2.9	11.4
	male: 45–64 y		9.4	2254	93	237		41	21.8	87	33.7	32.8	13.9		2.9	10.3

	male: 65–80 y		8.7	2083	84	223		38		22.5	80	30.5	29.6	13.4		3.1	9.7
	Turkey nutrition and health survey 2010 (TNHS)																
Turkey	female: 19–30 y	2010	6.9	1649	52	204				19.0	67	21.7	23.1	17.4		1.2	16.1
	female: 31–50 y		6.9	1638	52	205				20.3	65	21.1	22.4	17.3		1.2	16.0
	female: 51–64 y		6.4	1533	49	195				21.0	59	19.5	21.5	14.2		1.1	13.1
	female: 65–74 y		5.9	1409	46	183				19.3	53	16.8	19.0	13.4		0.9	12.4
	female: 75+ y		5.1	1223	39	156				16.5	47	16.0	17.2	10.7		0.8	9.8
	male: 19–30 y		9.4	2242	71	282				22.4	86	28.3	30.0	21.9		1.6	20.2
	male: 31–50 y		9.2	2203	73	278				23.7	83	27.4	29.3	20.4		1.5	18.8
	male: 51–64 y		8.0	1919	64	242				24.0	72	23.8	26.5	17.1		1.3	15.7
	male: 65–74 y		7.1	1705	56	220				22.9	64	21.5	23.4	15.0		1.1	13.7
	male: 75+ y		6.7	1606	52	207				21.4	61	20.1	24.0	13.0		1.1	11.9
	National Diet and Nutrition Survey (NDNS) Years 1–4																
UK	female: 19–64	2008–2012	6.8	1613	65	197	85		113	12.8	60	22.1	21.7	10.6	1.1	1.8	8.8
	female: 65+ y		6.4	1510	64	187	88		98	13.1	58	23.0	19.6	9.5	1.2	1.8	7.7
	male: 19–64		8.9	2111	85	251	106		146	14.7	78	28.4	28.5	13.4	1.5	2.2	11.2
	male: 65+ y		8.1	1935	78	231	102		129	14.9	74	28.7	25.8	12.4	1.5	2.3	10.1
	all: 19–64		7.8	1861	75	224	95		129	13.7	69	25.2	25.1	12.0	1.3	2.0	10.0
	all: 65+ y		7.1	1697	70	206	95		112	13.9	65	25.5	22.3	10.7	1.3	2.0	8.7

Appendix B. Mean Micronutrient Intakes across Dietary Surveys.

COUNTRY	SURVEY	YEAR	Folic Acid (µg)	Vitamin B12 (µg)	Vitamin D (µg)	Calcium (mg)	Potassium (mg)	Sodium (mg)	Iron (mg)	Iodine (µg)	Zinc (mg)
Andorra	**Evaluation of the nutritional status of the Andorran population**	2004–2005									
	female: 25–44 y		227	5.3	3.4	793	2751	2662	10.8		8.4
	female: 45–64 y		258	5.8	2.0	772	2912	2401	10.9		7.9
	female: 65–75 y		254	4.6	0.7	834	3252	2030	10.5		7.4
	male: 25–44 y		248	7.1	5.1	863	3124	3272	13.2		10.4
	male: 45–64 y		248	8.1	2.9	797	3102	2835	13.4		9.7
	male: 65–75 y		302	7.4	1.5	737	3179	2644	13.8		7.8
Austria	**Austrian nutrition report**	2010–2012									
	female: 18–24 y		229	3.6	2.0	956	2562	3000	11.4	161	10.4
	female: 25–50 y		216	4.0	2.8	838	2632	2800	10.9	130	9.7
	female: 51–64 y		193	3.3	2.7	786	2623	2600	10.3	141	9.1
	female: 65–80 y		194	4.8	3.2	632	2288	3480	10.2	124	8.6
	male: 18–24 y		255	5.5	4.0	991	3329	3400	13.9	160	12.4
	male: 25–50 y		197	5.3	3.6	881	2768	3240	11.8	143	11.4
	male: 51–64 y		222	5.0	4.6	802	2820	3320	11.6	142	11.9
	male: 65–80 y		203	4.0	3.9	692	2593	4200	9.9	142	9.2
Belgium	**The Belgian food consumption survey 2014–2015**	2014–2015									
	female: 18–39 y		189	3.6	3.4	704		2076	8.5	123	
	female: 40–64 y		191	3.7	3.6	737		2047	8.8	132	
	male: 18–39 y		228	5.0	4.0	842		2731	11.0	171	
	male: 40–64 y		224	5.5	4.6	795		2748	11.4	177	
Denmark	**Danish Dietary habits 2011–2013**	2011–2013									

	female: 18–75 y		329	5.6	4.3	1038	3200	3200	10.0	227	10.5
	male: 18–75 y		370	8.0	5.3	1188	3900	4400	13.0	268	14.1
	National Dietary Survey										
	female: 18–24 y		159	4.4	3.1	671	2800	1737	9.6	112	7.8
	female: 25–29 y		178	5.8	4.5	729	3200	1890	12.0	123	9.2
	female: 30–34 y		174	5.6	4.6	730	3200	1820	11.9	119	9.3
	female: 35–39 y		172	6.2	4.2	715	3200	1878	11.6	117	9.0
	female: 40–44 y		167	5.5	3.7	620	3100	1847	10.3	107	8.0
	female: 45–49 y		164	5.9	4.6	595	3000	1687	9.6	93	7.7
	female: 50–54 y		175	7.4	5.3	591	3000	1657	10.2	96	7.9
	female: 55–59 y		173	5.7	4.4	614	3100	1718	10.2	102	8.4
	female: 60–64 y		152	5.5	4.3	566	2900	1827	10.0	102	8.0
	female: 65–69 y		156	7.5	4.9	601	3000	1909	12.9	102	8.3
Estonia	female: 70–74 y	2014–2015	143	5.0	3.8	545	2700	1700	9.1	85	7.4
	male: 18–24 y		219	6.6	4.3	950	3900	2571	14.8	149	12.1
	male: 25–29 y		210	7.6	5.0	833	3800	2798	13.5	134	11.7
	male: 30–34 y		209	9.1	4.0	788	3800	2412	14.2	132	11.1
	male: 35–39 y		203	7.8	4.7	894	3900	2608	14.3	151	12.4
	male: 40–44 y		194	7.5	5.6	729	3800	2396	13.4	130	11.5
	male: 45–49 y		196	5.9	5.7	685	3900	2416	13.1	125	11.2
	male: 50–54 y		205	10.9	6.4	777	4000	3014	13.7	135	12.0
	male: 55–59 y		186	7.0	7.6	621	3500	2607	12.9	120	10.4
	male: 60–64 y		191	9.7	6.6	652	3700	2580	13.1	121	11.1
	male: 65–69 y		173	7.9	7.9	720	3600	2396	12.2	134	10.4
	male: 70–74 y		182	8.4	6.6	636	3400	2395	13.0	125	10.8
Finland	**The national FINDIET 2012 survey**	2012									

	female: 25–34 y		243	5.3	8.2	1206	3500	2600	10.0	190	11.0
	female: 35–44 y		233	5.1	9.0	1155	3400	2700	11.0	190	11.0
	female: 45–54 y		230	4.9	8.2	952	3300	2500	10.0	190	10.0
	female: 55–64 y		233	4.7	9.1	1002	3400	2500	10.0	190	10.0
	female: 65–74 y		219	5.1	8.7	921	3200	2200	9.0	173	9.0
	male: 25–34 y		277	6.9	10.7	1424	4200	3700	12.0	235	14.0
	male: 35–44 y		272	7.3	11.5	1251	4100	3400	13.0	235	13.0
	male: 45–54 y		277	8.0	11.2	1195	4200	3700	13.0	235	13.0
	male: 55–64 y		257	6.4	11.9	1099	3900	3300	12.0	235	12.0
	male: 65–74 y		255	6.7	12.8	1056	3900	3100	12.0	209	12.0
	INCA2										
France	female: 18–79 y	2006–2007	268	5.1	2.4	850	2681	2533	11.5	117	9.1
	male: 18–79 y		307	6.5	2.7	984	3287	3447	14.9	136	12.4
	German National Nutrition Survey II										
	female: 19–24 y		318	4.0	2.0	1039	2997	2355	11.6	173	9.1
	female: 25–34 y		311	4.4	2.6	1061	3260	2533	12.6	192	9.8
	female: 35–50 y		285	4.4	2.7	1067	3331	2579	12.8	200	9.8
	female: 51–64 y		281	4.6	3.4	1011	3391	2522	12.6	204	9.6
Germany	female: 65–80 y	2005–2007	264	4.3	3.4	918	3125	2376	11.4	190	8.8
	male: 19–24 y		394	6.9	3.0	1281	3812	3739	15.6	257	13.2
	male: 325–34 y		372	6.9	3.5	1252	3890	3620	15.9	255	13.2
	male: 35–50 y		337	6.5	3.8	1167	3939	3582	15.7	256	12.7
	male: 51–64 y		316	6.4	4.2	1071	3769	3346	14.7	246	11.7
	male: 65–80 y		282	5.9	4.4	970	3498	3058	13.6	232	10.9
	Hungarian Dietary Survey 2009										
Hungary	female: 19–30 y	2009	130	3.1	2.0	691	2600	5000	9.6		7.9

	female: 31–60 y		133	2.9	2.0	647	2600	5200	9.7		7.7
	female: 60+		129	2.6	1.9	636	2600	4900	9.2		7.0
	male: 19–30 y		167	3.6	2.8	772	3200	7100	12.8		10.6
	male: 31–60 y		166	3.9	2.7	698	3200	7400	12.9		10.5
	male: 60+		142	3.0	2.3	635	2900	6200	11.1		8.8
Iceland	**The Diet of Icelanders—a national dietary survey 2010–2011**	2010–2011									
	female: 18–30 y		270	4.6	4.6	930	2543	2677	10.3	116	9.4
	female: 31–60 y		259	5.3	6.4	840	2708	2631	9.7	138	9.1
	female: 61–80 y		209	6.6	8.6	694	2517	2474	8.2	168	7.8
	male: 18–30 y		343	7.5	6.6	1215	3429	4057	13.3	169	13.9
	male: 31–60 y		309	7.7	9.3	1047	3489	3775	12.9	200	12.4
	male: 61–80 y		258	10.8	13.4	847	3308	3520	11.0	204	11.2
Ireland	**National adult nutrition survey**	2008–2010									
	female: 18–64 y		339	8.0	3.9	824	2690	2268	13.7		9.0
	female: 18–35 y		337	11.1	3.1	794	2507	2385	15.1		8.5
	female: 36–50 y		301	5.4	3.5	824	2781	2220	12.8		8.7
	female: 51–64 y		399	6.9	6.0	874	2855	2145	12.8		10.1
	female: 65+ y		357	6.5	8.5	995	2721	2035	13.8		10.7
	male: 18–64 y		407	7.3	4.6	1060	3491	3122	15.1		11.8
	male: 18–35 y		426	7.4	3.9	1122	3568	3291	15.6		12.4
	male: 36–50 y		383	7.4	4.7	1036	3463	3123	14.8		11.6
	male: 51–64 y		404	7.2	5.7	981	3388	2817	14.3		11.2
	male: 65+ y		427	6.4	5.2	908	3038	2689	18.1		10.2
Italy	**The third Italian National food consumption survey INRAN-SCAI**	2005–2006									
	female: 18–64.9			5.5	2.3	730	2861		10.4		10.6

	female: 65+			4.4	1.8	754	2822		10.0		9.9
	male: 18–64.9			6.6	2.6	799	3218		12.6		12.6
	male: 65+			6.5	2.5	825	3300		13.2		12.2
Latvia	**Latvian National Food Consumption Survey 2007–2009**	2007–2009									
	female: ALL					457	2250		9.1	53	7.2
	male: ALL					555	2868		12.1	68	10.1
	female: 17–26 y		218	3.3	1.4			2240			
	female: 27–36 y		214	3.6	1.6			1920			
	female: 37–46 y		213	3.9	1.9			2640			
	female: 47–56 y		212	3.7	2.5			2320			
	female: 57–64 y		208	4.5	2.2			2160			
	male: 17–26 y		218	3.3	1.4			3480			
	male: 27–36 y		214	3.6	1.6			3960			
	male: 37–46 y		213	3.9	1.9			3680			
	male: 47–56 y		212	3.7	2.5			3400			
	male: 57–64 y		208	4.5	2.2			3600			
Lithuania	**Study and evaluation of actual nutrition and nutrition habits of Lithuanian adult population**	2013–2014									
	female: 19–75 y		481	1.2	3.4	535	2556	2842	10.3	30	8.1
	male: 19–75 y		366	1.0	3.1	506	2322	2348	8.9	28	7.0
	all: 19–34 y		643	1.5	3.7	576	2887	2538	12.2	33	9.6
	all: 35–49 y		350	1.4	3.2	575	2654	245	10.7	30	8.6
	all: 50–64 y		459	1.0	1.5	531	2625	2935	10.7	32	8.3
	all: 65–75 y		669	1.2	4.9	518	2519	2882	10.0	30	7.7
The Netherlands	**Dutch National Food Consumption Survey (DNFCS) 2007–2010**	2007–2010									
	female: 19–30 y		232	3.9	2.8	954	2847	2429	9.3	156	9.2

	female: 31–50 y		243	4.3	3.1	993	3112	2428	10.1	158	9.5
	female: 51–69 y		281	4.8	3.5	1031	3296	2301	10.4	160	9.9
	male: 19–30 y		293	5.3	3.9	1133	3774	3394	11.6	210	12.0
	male: 31–50 y		302	5.4	3.9	1171	4048	3177	12.4	202	12.5
	male: 51–69 y		330	5.8	4.4	1149	3866	2920	11.8	192	12.3
Norway	**Norkost3**	2010–2011									
	female: 18–70 y		231	6.0	4.9	811	3400	2500	9.9		
	male: 18–70 y		279	8.9	6.7	1038	4200	3600	13.0		
	female: 18–29 y		219	5.7	3.9	834	3100	2500	9.4		
	female: 30–39 y		247	5.3	4.3	836	3400	2600	11.0		
	female: 40–49 y		231	6.1	5.0	828	3400	2600	10.0		
	female: 50–59 y		233	6.4	5.2	784	3500	2500	10.0		
	female: 60–70 y		224	6.4	5.8	768	3400	2300	9.3		
	male: 18–29 y		314	8.9	5.5	1248	4300	4000	14.0		
	male: 30–39 y		295	8.9	6.1	1202	4200	4000	13.0		
	male: 40–49 y		257	8.4	6.0	1009	4200	3500	12.0		
	male: 50–59 y		275	8.9	7.3	955	4300	3500	12.0		
	male: 60–70 y		269	9.1	7.8	900	4300	3100	12.0		
Portugal	**National Food and Physical Activity Survey (IAN-AF)**	2015–2016									
	female: 18–64 y		245.7	4.8	3.5	731	2990	2690	10.9		9.4
	female: 65–84 y		260.1	4.2	3.5	724	3044	2449	10.3		8.3
	male: 18–64 y		285.7	5.7	4.1	830	3901	3700	14.2		12.4
	male: 65–84 y		264.6	4.8	3.8	764	3639	3260	13.4		10.2
Spain	**ENIDE 2011**	2009–2010									
	female: 18–24 y		234	5.2	3.2	789	2590	2328	12.5	75	8.6
	female: 25–44 y		265	5.8	3.5	851	2838	2420	14.1	87	8.8

	female: 45–64 y		281	6.7	4.0	839	3007	2283	13.8	87	8.7
	male: 18–24 y		287	7.7	4.1	958	2905	2756	15.9	95	11.2
	male: 25–44 y		288	7.9	4.3	898	2998	2730	16.1	100	10.4
	male: 45–64 y		309	8.1	4.3	840	3160	2652	16.2	103	10.1
Sweden	**Riksmaten 2010–11 Swedish Adult Dietary Survey**	2010–2011									
	female: 18–30 y		223	4.0	5.2	806	2659	2767	8.9		9.2
	female: 31–44 y		247	4.8	6.2	849	2865	2876	9.7		9.9
	female: 45–64 y		263	5.0	6.6	805	2971	2755	9.9		9.7
	female: 65–80 y		275	6.4	7.6	826	3013	2546	9.4		9.1
	male: 18–30 y		244	5.8	6.6	975	3139	3649	10.8		12.6
	male: 31–44 y		263	5.5	6.9	991	3433	3819	11.7		13.0
	male: 45–64 y		271	6.1	7.7	937	3523	3638	11.9		12.6
	male: 65–80 y		279	6.6	9.1	885	3392	3214	11.0		10.9
Turkey	**Turkey nutrition and health survey 2010 (TNHS)**	2010									
	female: 19–30 y		308	3.1	0.9	566	2211	1596	9.9	57	8.4
	female: 31–50 y		334	2.7	0.9	605	2311	1686	10.4	60	8.6
	female: 51–64 y		335	2.3	0.7	606	2357	1636	10.3	59	8.2
	female: 65–74 y		296	2.0	0.5	547	2063	1572	9.5	53	7.6
	female: 75+ y		271	2.0	1.0	495	1855	1426	8.1	49	6.3
	male: 19–30 y		385	4.4	1.1	676	2511	2411	12.4	67	11.2
	male: 31–50 y		410	4.7	1.3	744	2717	2353	13.0	74	11.5
	male: 51–64 y		400	3.7	1.3	713	2687	2197	12.2	68	10.3
	male: 65–74 y		375	2.8	1.2	677	2537	1938	11.1	64	9.2
	male: 75+ y		329	2.3	0.6	593	2192	1811	10.2	55	8.4
UK	**National Diet and Nutrition Survey (NDNS) Years 1–4**	2008–2012									

female: 19–64	228	4.6	2.6	728	2532	1995	9.6	140	7.6
female: 65+ y	241	5.5	2.9	796	2649	2680	9.4	169	7.6
male: 19–64	287	5.7	3.1	888	3039	2600	11.7	180	9.7
male: 65+ y	295	7.6	3.9	924	3063	3480	11.1	213	9.2
all: 19–64	258	5.1	2.8	807	2785	2297	10.7	160	8.6
all: 65+ y	265	6.4	3.3	852	2831	3040	10.2	188	8.3

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Chapter 5 Child and adolescent nutrient intakes from current national dietary surveys of European populations

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5.1 Abstract

The World Health Organisation (WHO) encourages national diet survey (NDS) implementation to obtain relevant data to inform policies addressing all forms of malnutrition, which remains a pressing issue throughout Europe. This paper provides an up-to-date review on energy, macro and selected micronutrient intakes in children across WHO Europe using the latest available NDS intakes. It assesses these against WHO Recommended Nutrient Intakes (RNIs) to highlight vulnerable groups and areas of concern. Dietary survey information was gathered by internet searches, contacting survey authors and nutrition experts. Survey characteristics, energy and nutrient intakes were extracted and weighted means calculated and presented by region. Child energy and nutrient intakes were extracted from 21 NDS across a third (n=18) of the 53 WHO Europe countries. Of these, 38% (n=6) reported intakes by socio-economic group (SEG), but by various indicators. Energy and macronutrients, where boys and older children had higher intakes, were more widely reported than micronutrients. Most countries met under half of the WHO RNIs for nutrients reported in their NDS. Micronutrient attainment was higher than macronutrients, but worst in girls and older children. Only a third, mainly Western, WHO European member states provided published data on child nutrient intakes. Gaps in provision mean dietary inadequacies may go unidentified, preventing evidence-based policy formation. WHO RNI attainment was poor, particularly in girls and older children. Inconsistent age groups, dietary methodologies, nutrient composition databases and under-reporting hinder inter-country comparisons. Future efforts should encourage countries to conduct NDS in a standardised format by age and socio-demographic variables.

5.2 Introduction

The burden of malnutrition in the form of overweight and obesity, nutrient deficiency and preventable diet-related noncommunicable diseases (NCDs) is significant and worsening worldwide (1, 2). In particular, unhealthy diet is one of the four major behavioural risk factors for noncommunicable diseases (NCDs) in all WHO regions (3), with the European region proportionately suffering the greatest NCD burden. In Europe, the four most common NCDs account for 77% of disease and almost 86% premature mortality (1) and overweight and obesity affects a third of children aged 11y (4). Childhood obesity has negative health impacts and is associated with educational underachievement, low self-esteem, and increased obesity risk in adulthood (5).

National diet surveys (NDS) have an important role in assessing dietary patterns and intakes in the whole population and informing relevant policy decisions; the WHO European Food & Nutrition Action Plan (1) explicitly encourages member states to 'strengthen and expand nationally representative diet and nutrition surveys'. However, NDS provision across Europe is inconsistent. A recent review found that less than two thirds (34/53) of WHO Europe countries have nationally representative NDS, and that the majority of gaps lie in Central & Eastern European countries (CEEC) (6). This is concerning, as nutrition policies in these countries may therefore lack an appropriate evidence base.

Novakovic et al. (7) examined selected micronutrient intakes in CEEC compared to other European countries and found that CEEC lacked intake data across all ages, particularly in children. The aforementioned recent review by Rippin et al. (6) showed that under a third (17/53) of European countries reported energy and nutrient intakes for children aged <18y from NDS conducted post-2000 (6). This finding is not surprising, as data of this kind is limited. The Global Dietary Database (GDD) houses information on food and nutrient consumption levels before 2010 in countries globally, but has limited nutrient data, includes some regional rather than national surveys and does not currently cover children (8). Merten et al. (9) reviewed methodological characteristics and heterogeneity in European NDS, but also included regional child surveys. However, the surveys were limited to European Union (EU) member states, only included surveys employing certain dietary assessment methods and did not discuss nutrient intakes.

Despite this lack of data, nutrition and health surveys remain the main source of information on dietary risk factors. For example, a systematic analysis of disease risk in 21 regions worldwide between 1990-2010 was conducted based on information collated from NDS (10). Such data is also used to inform policy and identify food and nutrients of most concern. For example, Volatier et al. (11) used NDS to compile a reference list of indicator foods to be used for the validation of nutrient profiling schemes – a policy tool to categorise foods according to their nutritional composition to aid disease prevention and health promotion. These examples demonstrate the importance and range of use NDS can have in monitoring population diet quality and health, and gathering information on which to base disease-risk prevention policies and address childhood obesity. NDS can help monitor NCD risk factors and malnutrition, identify specific areas of concern, highlight inequalities and evaluate policy impact, thereby ultimately contributing to the promotion of best practice for nutritional health across the region (1).

A comprehensive, up-to-date review of total nutrient intakes across different European child populations is therefore needed, which could identify where in Europe there is a need to improve diets and whether inequalities exist. In a manner consistent with that published for adults (12), this review aims to examine macro and selected micronutrient intakes in children across the WHO European Region via the latest NDS for which nutrient intake data is available, with reference to age-appropriate WHO Recommended Nutrient Intakes (RNIs).

5.3 Methods

5.3.1 Identifying National Diet Surveys (NDS)

The methods for identifying and accessing NDS have been reported (6). Briefly, authors of national surveys within the WHO European Region were identified using listed contact names and other information from two main reports of NDS (13, 14). Where no response was obtained from authors, further general internet searches were performed on organisations specialising in nutrition to find other potentially useful contact details. Additionally, country responses to WHO Global Nutrition Policy Review 2017 questionnaires were mined to obtain relevant references. Contacts identified were asked to complete a questionnaire to provide information on nationally representative dietary surveys conducted on adults or children at an individual level since 1990, including links or references to relevant reports. For countries without contact details, a systematic database search was performed across Web of Science, Medline and Scopus for nationally representative dietary surveys of adults and children that collected data at an individual level from 1990 to June 2016. Papers returned were screened for relevance according to the criteria in table 1.

We found 109 (6) (and have subsequently added recent releases to make 110) nationally representative surveys that collected data on whole diets at an individual level since 1990 across 34 of the 53 countries in WHO Europe; 69 included children, of which 49 were conducted since 2000. Further details of all surveys found are presented in Rippin et al. (6).

5.3.2 Data Extracted

Where available, estimated energy and nutrient intakes by gender and age group were extracted from the latest NDS collected after 2000. For NDS that provided results including *and* excluding supplements, the latter was used; where not specified, it was assumed that intakes excluded supplements. For children this was extracted from 21 surveys from 18 countries; the Netherlands had two and Ireland three surveys, which covered different child age groups. Mean values were reported in all cases except Dutch children aged 7-8y, which used medians – these were extracted and used instead. The 18 countries were grouped into regions – Western, Northern and Central & Eastern Europe. For some countries (France, Latvia, the Netherlands and Spain), more recent surveys had been conducted, but intake data was not yet available. Energy intakes reported in kcal were converted to MJ for consistency across studies. Appendices 1&2 list the availability of selected nutrients reported from the latest surveys collected after 2000.

All macronutrients reported by the 21 surveys were included in the data extraction, but micronutrients extracted (see table 2) were limited to those explicitly mentioned in the WHO European Food and Nutrition Action Plan (1) as being currently important to population health in the region. See appendices 1&2 for all nutrient intakes extracted.

WHO RNIs were used to assess intake adequacy in the population majority and highlight areas of concern in the absence of raw NDS data from sufficient countries to determine the prevalence of inadequacy in relation to the percentage of the population below the Estimated Average Requirements (EARs). The exception was energy, where RNIs changed in yearly increments, so were not sufficiently compatible with survey age groupings (15-20). Additionally, WHO RNIs for iron are given for different bioavailabilities, so UK Reference Nutrient Intakes (RNIs) were used instead (21). UK RNIs were also used for potassium and sodium, as WHO RNIs recommend downweighting values based on energy requirements for children relative to adults. The RNI for monounsaturated fats (MUFAs) is calculated by the difference between total fat and the sum of saturated fats (SFA), polyunsaturated fats (PUFA) and trans fats (TFAs), so has not been included. The WHO RNI for free sugars (19) has been adopted as the RNI for added sugars, as no WHO RNI exists for added sugars, yet the majority of surveys that reported sugars used the added rather than free sugar definition. The added sugars definition is similar but more restrictive to that of free sugars, meaning free sugar intake would not be overestimated. Depending on the nutrient, RNIs were variously maximum, minimum or target amounts (see table 2).

Energy and selected nutrient intakes reported by age group and gender in these latest surveys collected after 2000, were graphed. To harmonise the data where possible, units of measurement were converted to common standard units. Omega-3 and omega-6 fatty acids were reported variously in surveys, including omega-3, omega-6, linoleic acid and α-linolenic acid in g/day and percentage energy (%E) and eicosapentaenoic acid+docosahexaenoic acid (EPA+DHA) in mg/day. These were converted to grams and %E and grouped into omega-3 and omega-6 fatty acids for clarity. Added sugars is used as a proxy term for sucrose, as the countries reporting this nutrient typically referred to it as 'added sugars' or did not specify.

Additionally, estimated mean intakes by gender for two age groups split roughly by those aged <10y and ≥10y (to 18) were determined for each country, and also for European regions and Europe overall. This cut-off was chosen because 10y was a common boundary for RNIs split by age. Age ranges for reported and extracted means that spanned the 10y cut-off contained a larger proportion of ≥10 year olds in all cases, so were allocated to that group. This occurred in seven countries (Cyprus, Ireland, Latvia, the Netherlands, Spain, Turkey and the UK), where only Latvia included children aged <9y (7-16y). The UK 4-10y age group was included in the <10y group. Some countries did not separate by gender in the youngest ages – in these instances the same mean intake was used for both girls and boys. Where mean intakes were reported by a country for more than one age group <10 years, or more than one age group ≥10 years, the number of children/adolescents surveyed in the NDS in each age group were used to weight the reported means to produce estimated mean intakes for those aged <10y and ≥10y. For instance, mean intakes for Belgium were reported and extracted for 3-5y, 6-9y, 10-13y and 14-17 year olds; the mean intake reported for boys aged 3-5y was multiplied by the number of boys surveyed for that age group, and added to a similar calculation for the 6-9y olds; the sum of these was then divided by the total number of boys aged <10y to produce an estimated mean for <10y for Belgium. Where countries had multiple NDS (Ireland, the Netherlands), age ranges ran concurrently rather than overlapping, so the NDS were grouped and used to estimate the mean intakes for those aged <10y and ≥10y as described above. The mean intakes for each European region and Europe overall were estimated by multiplying the <10y or ≥10y means for each country and gender by the national population aged <19y for each country (22-24). The resulting figure for each country was summed and then divided by the total sum of the national child populations in each European region, then Europe as a whole. The same population figures were used for both the <10y and ≥10y group, assuming similar population ratios. These population weightings made the estimated means roughly generalizable to the European regions and Europe as a whole.

Characteristics of the 21 surveys were also extracted and tabled; these were: country name, survey name, year of survey (data collection), source, sample size, age range, dietary methodology and the nutrient reference database underpinning the survey. The number and percentage of WHO RNIs not met was recorded for the nutrients and gender/age groups for which they were reported. Where reported, surveys presenting nutrient intakes by socio-economic group (SEG) based on social class, income (continuous or grouped), occupation and education level were also noted.

5.4 Results

5.4.1 Data Extracted

The scope of NDS coverage across Europe has previously been documented (6). Energy and nutrient intakes (excluding supplements) for children aged <=18y were extracted from 21 surveys across 18 countries from three regions: two of five Northern European countries (Denmark, Norway); ten of 17 Western European countries (Austria, Belgium, France, Germany, Ireland, Italy, The Netherlands, Portugal, Spain, UK) and six of 31 CEEC (Bulgaria, Cyprus, Estonia, Latvia, Slovenia, Turkey). Table 3 shows the characteristics of these surveys. Child energy and nutrient intakes could not be extracted for 66% (35) of European countries for various reasons from lack of availability to incompatible age-group structure. 19 of these countries, mainly CEEC, had no identifiable nationally representative survey, making up over a third of WHO Europe countries. The Andorran NDS surveyed children, but the lowest age group (12-24y) spanned adults and children, so intake data was not included in the results or graphs.

All 21 NDS that reported nutrient intakes included energy; however Latvia reported no other macronutrients. The majority (n=20) reported protein, carbohydrate and fat intakes and most reported fibre intakes (n=19) (see table 4.1). Most NDS included intake data on saturated fats (n=19), and MUFAs and PUFAs (n=18). However, less than half (n=7) NDS included TFA intakes. Most

NDS (n=16) included either total or added sugars/sucrose; however, six NDS included neither. Just over half the countries included either omega-3 (n=7) or omega-6 (n=7) fatty acid intakes in some form; six NDS included both.

Micronutrients were less widely covered by the 21 surveys – Spain reported no micronutrient intakes and Latvia only included sodium (see table 4.2). Calcium and iron were reported by all but two surveys (Latvia and Spain did not), whilst vitamins B12 and D were reported by all but three (Latvia, Spain and Cyprus did not). Iodine was the least reported micronutrient, by just over half (n=11) surveys.

Of the 21 surveys for which energy and nutrient intakes were extracted, only 38% (n=8) reported intakes by SEG in addition to age and gender (Estonia, France, all three Irish surveys, Dutch DNFCS young children, Norway, UK).

5.4.2 Energy and Nutrient Intakes

Means reported here are estimated weighted means for Europe overall for children <10y and ≥10y (see tables 4.1-4.2 for estimated means by energy and nutrient broken down by country/survey); figures in brackets are ranges of gender and age group means provided in the survey reports. Of the 19 macro and micronutrients considered, no country other than Slovenia (44%) met more than half of the WHO RNIs in the nutrients and age/gender groups for which they were reported. Though patterns were evident across gender and age, there were no apparent regional trends across Europe.

5.4.2.1 Energy

Although age groupings were not consistent across countries, where boys and girls were presented separately boys' intakes were generally higher than girls' and older children had higher intakes (see figure 1). The mean energy intake was 6.0MJ (range 5.3–8.0MJ); 7.7MJ (range 6.6–9.4MJ) for girls <10y and ≥10y respectively and 6.3MJ (range 5.5–8.5MJ); 9.4MJ (range 8.2–12.7MJ) for boys.

5.4.2.2 Macronutrients

For all macronutrients, where age groups were split by gender, boys generally had higher intakes than girls in all countries except Slovenia, particularly in older children. WHO RNI (15, 21) attainment was universally poor in both genders across all ages in the majority of macronutrients. The TFA RNI had the highest compliance, with all countries that reported intakes falling below the maximum value. No country fell short of the 10%E minimum protein value and half the surveys fell between the 10-15%E minimum and maximum boundaries. Only Slovenian teenagers and Dutch young children met the lower 55%E carbohydrate RNI (figure 2.1). The mean carbohydrate intake was 183g (range 126–255g); 233g (range 192–379g) for girls aged <10y and ≥10y respectively, and 192g (range 126–258g); 281g (range 211–370g) for boys. Of the six countries that reported added sugars (n=6), Ireland (1y), Denmark (4-9y), Norway (4y) and Austrian boys (10-12, 13-14y) had intakes between the recommended 5%E and maximum 10%E RNI and all other children exceeded the maximum (figure 2.2). Mean added sugar intakes were 46g (range 25–56g); 58g (range 48–110g) for girls <10y and ≥10y respectively and 48g (range 25–61g); 63g (range 49–103g) for boys. Only Slovenian adolescents and German boys (14-18y) met the 25g fibre RNI (figure 2.3). Mean fibre intakes were 12g (range 8–19g); 17g (range 9–31g) for girls <10y and ≥10y respectively and 13g (range 8–21g); 18g (range 11–28g) for boys.

Total fat and saturated fats RNI compliance was particularly poor – all countries in all age groups exceeded the latter and only Slovenia and the Netherlands (2-3y) had fat intakes below the 30%E maximum RNI, but these were close to the upper boundary (figures 2.4-2.5). Mean fat intakes were 56g (range 38–80g); 71g (range 60–148g) for girls <10y and ≥10y respectively and 58g (range 38–80g); 86g (range 66–177g) for boys. For saturated fats this was 21g (range 14–32g); 25g (range 16–35g) for girls <10y and ≥10y respectively and 22g (range 14–34g); 30g (range 18–38g) for boys. PUFA RNI attainment was mixed, although all countries except Turkey that achieved the RNI were very close to the lower 6%E boundary (figure 2.6). Mean PUFA intakes were 10g (range 4–17g) for both genders aged <10y and 13g (range 9-19–g) for girls and 15g (range 10–21g) for boys aged ≥10y.

RNI attainment was relatively poor for the seven countries that reported omega fats intakes; only Estonian boys (14-17y) achieved the lower 1%E n-3 RNI (figure 2.7). Just over half of countries reporting n-6 achieved the lower 5%E RNI in some age categories (figure 2.8). Turkey was the only country to exceed the upper 8%E n-6 limit in any age group. Mean n-3 intakes were 1.0g (range 0.5–1.5g); 1.3g (range 0.5–1.6g) for girls <10y and ≥10y respectively and 1.0g (range 0.5–1.4g); 1.5g (range 0.5–2.5g) for boys. Mean n-6 intakes were 8.6g (range 3.0–15.6g); 11.4g (range 3.1–17.3g) for girls <10y and ≥10y respectively and 9.2g (range 2.9–15.6g); 13.1g (range 3.1–19.7g) for boys.

5.4.2.3 Micronutrients

Micronutrient RNI attainment (16-18) was better than for macronutrients. Micronutrient intakes are grouped according to RNI-compliance and described beginning with those with greatest compliance across the countries and ending with those that demonstrate the greatest shortfall. All micronutrients except vitamin D had age-specific RNIs; iron and zinc also had gender-specific RNIs for children aged 10-18y. RNI compliance was greater in boys and younger children aged <10y.

All countries met the vitamin B_{12} RNI across all ages, with the exception of Turkish adolescent girls. The majority of countries met the zinc RNI across the age groups surveyed; however, attainment gaps were most likely to be in adolescent girls. Potassium and iron intakes were mixed, but generally poorer in children aged ≥10y and girls, particularly for iron (figures 3.1-3.2). All countries (except France) fulfilled the potassium RNI in some age groups and only Slovenian adolescent girls and German and Estonian adolescent boys exceeded the upper 3500mg RNI. However, no country met the lower potassium RNI across all childhood stages. Mean intakes were 1974mg (range 1471–2700mg); 2481mg (range 1867–3770mg) for girls <10y and ≥10y respectively and 2062mg (range 1471–3000mg); 2768mg (range 2039–3800mg) for boys. Bulgaria and France did not achieve the UK iron RNI (21) in any age group. In other countries lack of compliance with the iron RNI was dominated by adolescent girls, where only Slovenia achieved the RNI. Boys had slightly higher intakes than girls – mean intakes were 6.6mg (range 5.0–10.9mg); 9.8mg (range 7.7–16.0mg) for girls

<10y and ≥10y respectively and 7.3mg (range 5.0–11.4mg); 11.8mg (range 9.0–16.0mg) for boys. However, boys have lower requirements, resulting in higher RNI attainment.

Calcium and iodine attainment was also mixed; 75% countries reporting calcium achieved the RNI in some age groups, though no country had adequate intakes in children aged ≥10y (figure 3.3). Mean calcium intakes were 691mg (range 26–1113mg); 755mg (range 545–1167mg) for girls <10y and ≥10y respectively and 729mg (range 515–966mg); 903mg (range 554–1277mg) for boys. Three of the 10 countries reporting iodine (Turkey; Austria; France) did not achieve the RNI in any age group (figure 3.4); of the remainder, attainment was spread across age groups. Mean intakes were 93µg (range 44–272µg); 109µg (range 52–213µg) for girls <10y and ≥10y respectively and 99µg (range 47–283µg); 137µg (range 53–249µg) for boys.

Irish boys (13-14y) were the only group aged >3y with adequate total folate intakes (figure 3.5). Mean intakes were 193µg (range 104–270µg); 259µg (range 137–340µg) for girls <10y and ≥10y respectively and 205µg (range 104–289µg); 304µg (range 143–410µg) for boys. The lowest RNI attainment was in vitamin D, where only French and Portuguese children aged <10y had sufficient intakes (figure 3.6). Mean intakes were 2.7µg (range 0.8–6.4µg); 2.0µg (range 0.8–4.0µg) for girls <10y and ≥10y respectively and 2.6µg (range 0.8–6.7µg); 2.4µg (range 1.0–4.3µg) for boys. Most countries over-consumed sodium – only Estonian girls aged ≥10y and Turkish adolescent girls did not exceed the 1600mg RNI (figure 3.7). Mean intakes were 1492mg (range 918–3320mg); 2095mg (range 1434–4191mg) for girls <10y and ≥10y respectively and 1702mg (range 918–3520mg); 2765mg (range 1599–4059mg) for boys.

5.5 Discussion

5.5.1 Data Extracted

This review details the reporting of child intake data for energy and selected nutrients of concern in nationally representative surveys across the 53 countries in the WHO Europe remit (1). Only a third of countries, mostly Western European, reported intake data by gender and age group. This is concerning, as potential micronutrient deficiencies may go unidentified and nutrition policies in two thirds of the WHO Europe region, particularly outside Western Europe, may be based on limited contextual evidence that can be critical in tailoring policies to local needs. This impacts on other NDS and has longer-term implications for obesity, over 60% children who are overweight before puberty are likely to remain so in adulthood (25). Although southern European countries have previously had the highest prevalence in children aged 6-9y (26, 27), there has been a particularly marked increase in childhood obesity in CEEC since 2002 (28). In addition, six of the top 10 countries for overweight and obesity in girls, and five of the top 10 countries for boys aged 7-9y in the Childhood Obesity Surveillance Initiative (COSI) round 4 were CEEC (29). This is concerning, as increased intakes of processed foods driven by food system changes induced by the nutrition transition in CEEC (30) could begin to impact later years. If dietary data is lacking, countries may struggle to advocate and design effective policies.

Energy, macro and micronutrients were generally widely reported in the 21 surveys across 18 countries from which intakes were extracted, though some gaps were evident. Energy was universally reported and macronutrients slightly better represented than micronutrients. This forms a good foundation for assessing child nutrient status and identifying vulnerable age/gender groups. The largest nutrient gaps in reported intakes were TFAs, omega fats, added sugars and iodine, all of which have been highlighted as of concern (1, 31). Iodine deficiency has been linked to reduced cognitive function in children (32) and remains an issue in the WHO European region. Andersson et al. (33) examined national (~65%) and subnational (~35%) data on urinary iodine concentration and found that 43.9% of European school-age children had insufficient intakes.

Omega 3 fatty acids have established links with reduced blood pressure and coronary heart disease (CHD) risk in adulthood, amongst other health benefits (34, 35), including brain development (36). Over-consumption of sugar, particularly in adolescents and often from sugar-sweetened beverages, is linked to overweight and obesity via elevated energy intake and can promote suboptimal diets by displacing nutrient-rich foods (28). Lack of intake data for these nutrients therefore hampers the identification of unfavourable intakes and policy-formulation to prevent subsequent problems in childhood that affect the lifespan. Although there were no regional patterns in nutrient reporting, Latvia only reported on energy and sodium intakes and Spain included no micronutrients. This has implications for national nutrition policies and identification of vulnerable groups in these countries.

Only a third of countries reported energy and nutrient intake by SEG, by one or more indicators including education, occupation, income and social class (table 3). This narrows opportunities to assess nutrient-based socio-economic inequalities in population subgroups, and prevents comparisons with countries that do include such stratification. Vulnerable groups may therefore be susceptible to malnutrition, with limited monitoring tools for preventative policy formation.

5.5.2 Energy Intakes

As expected, boys and older children had generally higher energy intakes. There were no obvious regional trends, though German and Slovenian adolescent boys had particularly high intakes, possibly due to the age range being limited to older adolescents. The literature suggests that under-reporting affects reported intakes to varying degrees across countries, making valid comparisons difficult, particularly considering that in different surveys children reported their own intake at different ages. Rothausen et al. (37) found that misreporting in Danish children aged 7-8y was ‘modest’, and greater in 12-13y, particularly in food diaries compared to 24hr recalls. Similarly, Lioret et al. (38) found greater under-reporting in French children aged ≥10y than in those aged <10y, and one study found under-reporting in British children aged 11-17y as high as 73% (39). This suggests that the energy differential between younger and older children may be higher than that reported.

5.5.3 Nutrient Intakes and WHO RNI Status

Countries in all WHO Europe regions had poor RNI attainment levels – only Slovenia met over half of the RNIs for those nutrients and age/gender groups reported (table 3). This is concerning, as it implies that nutritional issues affect children across Europe, to an extent that may be difficult to determine due to the limitations of the data available and the gaps in data for some countries and nutrients. Older adolescents in the ≥10y range are more likely to meet RNIs based on absolute levels rather than %E, such as fibre. This could explain why Slovenia had the highest percentage compliance (42%), having generally high intakes across the nutrients extracted. This could be due to the narrow adolescent age range surveyed (15-16y); Germany had a similar age range (14-18y) and also had relatively high intakes. However, other countries with similar age groupings had lower intakes, supporting the possibility of the differences being genuine.

5.5.3.1 Macronutrients

Most countries did not meet the carbohydrate, sugar or fibre RNIs in any age group. The only exceptions were German boys, who met the fibre RNI, and Slovenia, which met the total carbohydrate and fibre RNIs. However, both the German and Slovenian cohorts were limited to adolescents, giving them a greater chance of having intakes high enough to meet the fibre RNI, which represents an absolute amount rather than %E and is not a child-specific target. Northern European children <10y were more likely to meet the added sugar RNI, and other than Slovenian adolescents, Dutch children aged <10y were the only other group to meet the lower carbohydrate RNI. This suggests that in countries where sugar data was present, most children, particularly those aged ≥10y, could be at greater risk of the weight gain and associated risks linked to high sugar and low complex carbohydrate consumption (40).

Most countries had intakes indicating an unfavourable fatty acid balance across all age groups; all countries were over the upper RNI for saturated fats in all age groups and only Slovenia and very young Dutch children were below the maximum fat RNI. Dutch children aged 2-3y were the only group with a favourable fatty acid profile, achieving the PUFA in addition to the total fat RNI. Slovenian children neither achieved the PUFA RNI nor had a substantial MUFA intake compared to other children aged ≥10y. The Netherlands and Turkey met the PUFA and n-6 RNIs in all ages and Austria, the Netherlands and Portugal met the n-6 RNI in older children. Spain also met the PUFA RNI in all ages and Cyprus, Italy and Spain had relatively high MUFA intakes. The favourable intakes in these countries could indicate aspects of a Mediterranean diet pattern, which when adhered to in its complete form and supported by other factors such as physical activity, has been linked to reduced childhood obesity (41). Conversely, n-3 intakes were poor, with only Estonian adolescent boys achieving the RNI.

TFAs had the highest RNI compliance for those countries which reported it. This may reflect positive moves to reduce levels in the food supply following advice from health bodies like WHO (1), including bans, labelling legislation and voluntary product reformulation (42-44). However, the low number of countries reporting TFAs demonstrates the need for a common and comprehensive blueprint for conducting NDS and gathering nutrient intake data across Europe.

5.5.3.2 Micronutrients

As with macronutrients, there were no clear regional patterns in micronutrient intakes or RNI attainment. However, compliance was highest in boys and children aged <10y. Unlike macronutrients, micronutrient RNIs are based on absolute intakes rather than %E. Yet although most micronutrients have different RNIs for specific age groups, intakes in children aged ≥10y were generally not sufficient to meet RNIs for older children, particularly girls. Even in zinc and vitamin B12, where RNI attainment was high, shortfalls in adolescent girls were apparent, highlighting them as a vulnerable group.

Although not the worst in overall RNI attainment, iron was a particular issue for adolescent girls, with all countries except Slovenia having inadequate intakes. This is consistent with previous (non-national) European-based reviews and relates to higher requirements, primarily due to menstruation (45, 46). Adolescent girls are at greater risk of iron-deficiency anaemia and deficiency is associated with reduced intellectual, immune and other metabolic functions (46). Deficiency in this group may also be underestimated, as UK RNIs were used instead of WHO RNIs because the latter have different values for different bioavailabilities and menarchal status, which would be difficult to determine (16). However, although agreement between the UK and WHO RNIs was good for children aged <10y, WHO RNI requirements are much higher for girls post-menarche, even when using the RNI that assumes the highest bioavailability from diet (15%) (16, 21). The scale of European deficiency in this group may therefore be greater than previously thought, and policy initiatives may be required to improve iron intakes.

Calcium intakes were inadequate in older boys and girls. Calcium is needed for bone and tooth development, metabolic processes including muscle and nerve function and its metabolism is linked with vitamin D intake. Vitamin D intakes, assessed by a singular absolute amount, rather than age specific RNIs, were universally lacking other than in younger Portuguese children. This is an important issue, as in addition to roles in bone, muscle and immune function, deficiency is linked to rickets (47, 48). Although rickets was of relatively little concern in Europe in the latter half of the 20th century, in recent years prevalence has risen, particularly in the UK and Northern European countries and for individuals with darker skin or who cover up for religious and other reasons, as less can be synthesised on exposure to sunlight (49).

Total folate intakes were universally poor, with no children aged >3y achieving the RNI. Sodium intakes exceeded the RNI in all children except adolescent girls from Estonia and Turkey, which are both CEEC. This is despite the potential for under-reporting due to intakes being derived from self-assessed dietary methodologies rather than 24hr urinary biomarkers. Further efforts are needed to promote the consumption of low-salt, minimally processed foods and advance reformulation of foods commonly consumed by children – these will vary by country, but might include bread, cheeses and breakfast cereals. However, salt-iodisation is a primary means of increasing population iodine intakes, and iodine was the least reported micronutrient. Calls to reduce salt intake can lead to questions of compatibility with iodine intake goals, especially in CEEC. With almost half of European school-age children having insufficient intakes (33), which can cause reduced cognitive function (32), care is needed in approaches to tackle sodium over-consumption, especially where iodine RNI attainment is low and salt iodisation is practised (50). However, evidence is clear that appropriate sodium and iodine intakes can be achieved in the context of sodium reduction initiatives (18), as iodine concentration in salt can be increased or alternative vehicles for iodine sourced.

Of the micronutrients investigated, our findings show that iron, vitamin D, total folate and sodium would benefit from European-wide policy focus to improve intakes, particularly in girls and children aged ≥10y. Effective food-based approaches, including product reformulation and fortification, currently exist alongside targeted supplementation for at-risk groups. Aside from total folate, the WHO Europe Food and Nutrition Action Plan (1) identifies these as nutrients of concern, although this refers to all ages rather than specifically children. The Action Plan also highlights energy, saturated fat and sugar reduction as priorities and recommends a suite of policy options to address their excess intake, which our findings support. However, the plan does not discuss the increase of carbohydrate, fibre or omega fats, and our findings show that the RNIs for these were often not met. Countries across WHO Europe should also be encouraged to address this in policy and guidance, for example increased use of wholegrain in manufactured products or public education on sources of omega fats.

5.5.4 Strengths and Limitations

This review presents a much-needed up-to-date review of national child energy and nutrient intakes across Europe. It also reports intakes against WHO RNIs, enabling governments and policymakers to better use NDS to inform initiatives to improve diets and reduce diet-related diseases in groups and areas of greatest need. It is well documented that energy, macronutrient and sodium over-consumption is linked to childhood obesity and related NCDs (1) and poor micronutrient intakes continue to cause health problems in children (45, 46, 49). Blundell (51) found >10% inter-country variation in obesity prevalence and cited differences in national age profiles and socio-demographic patterns as key contributors. This review highlights both the scale and the potential hidden extent of such issues, showing that reported lack of compliance with WHO RNIs may be the tip of the iceberg, with many countries' intakes unknown. In addition to previous reviews, which document NDS provision across Europe (6, 12), this review also highlights whether and how surveys report nutrient intakes by SEG, helping to direct further research in this area.

A primary limitation is that intercountry comparisons are difficult, as age groupings were inconsistent. The most extreme example of this drawback was in Andorra, which could not be included in this review as the lowest age group included both adults and children. Age groupings also differed within countries; Bulgaria split children into four groups for energy, but two for other macro and micronutrients, making consistent and complete analysis difficult. In addition, several countries did not separate girls and boys in the youngest age groups. Raw survey data could be used in future work to create consistent age groups and obtain more reliable conclusions.

Differences in the reporting of nutrient intakes across and within countries further hindered comparisons and in some cases limited RNI assessment. For example, Estonia did not report nutrients in all age groups and the three Irish surveys reported different nutrients. Bulgaria reported some nutrients by %E and others with absolute values; because age groups for energy differed from other nutrients, the %E needed to assess macronutrient RNIs could not always be calculated, resulting in knowledge gaps. Age groups did not always correspond with RNI age boundaries, particularly in micronutrients, making it difficult to assess attainment. However, examples in the literature exist where international comparisons are made despite different age groupings (7). Using RNIs to assess nutrient intake adequacy also has limitations, as assertions are only as good as the data on which it is based, which may be incomplete. RNIs are estimates of the amount of a nutrient needed to ensure that the needs of the majority of a group (97.5%) are being met; therefore RNIs err on the side of caution and may over-estimate inadequacies. The proportion of intakes in a population group below the EAR is a more appropriate measure of nutrient inadequacy than the proportion below the RNI; however, lack of raw data from sufficient countries prevented this (16). Additionally, although the <10y and ≥10y age group splits were chosen to align with the RNI age cut-offs, different cut-offs will have produced different results. Despite these difficulties our review remains an important study that displays nutrient intakes in children, which WHO define as a vulnerable group (1). Any difficulties posed by lack of comparability serve to highlight the pressing need for harmonisation of methodologies and approaches.

The country means (tables 4.1-4.2) for the <10y or ≥10y groups are approximations that depend on the age ranges surveyed. For instance the Slovenian NDS covered a small age range (15-16y); reported mean intakes may therefore be less representative of the ≥10y group than countries that have surveyed a wider age range. Similarly, the contribution to the weighted estimated means for its region and Europe overall may be unrepresentative. The country-specific means for countries with multiple age groups above or below the 10y cut-off are approximations based on the assumption that the numbers surveyed in each age group are proportionate to those in the total child population, the latter being used due to availability. Additionally, in some countries age ranges spanned the 10y boundary, though broadly speaking the majority of children could be allocated to either the <10y or ≥10y group.

The different dietary assessment methodologies used by the surveys also limits the validity of comparisons. As under-reporting is common and varies across methods and is affected by multiple other factors, the impact on reported intakes differs across countries and compounds difficulties in making comparisons. This is exacerbated by the exclusion of under-reporters by some countries (Austria, France, Norway), whereas other countries include under-reporters (Cyprus, Denmark, Ireland, Italy, the Netherlands, Slovenia and the UK) and the remainder did not specify.

Discrepancies in national food composition databases creates further compatibility issues. This review used sucrose as a proxy for added sugars, as surveys typically did not distinguish between the two. Consequently, intakes may differ as the number of mono and di-saccharides included varies. Not all surveys had available user guides to determine the methods used to derive nutrient values. With fibre, the Englyst method usually generates lower results than the AOAC for certain cereals, fruits, white beans and peanuts (52). Certain micronutrients may also be derived from a narrow range of foods, making them less valid in representing population intakes. Similarly, databases do not address fortification in a common manner, as with iodine (53). This is problematic, as the severity of identified deficiencies may be misrepresented.

Future work could explore raw survey data to create common age groups and minimise the impact of inconsistencies. This would help determine whether extremes such as Slovenian macronutrient intakes are genuine differences or due to the age range covered. It would also allow the alignment of age groups with WHO RNIs, increasing the accuracy of identifying deficiencies.

5.6 Conclusion

This review reported macro and selected micronutrient intakes in children across WHO Europe using the latest available reported NDS intakes and assessed these against WHO RNIs. Energy and nutrient intakes were extracted from 21 surveys covering a third (18), mainly Western, WHO European countries. Most countries reported intakes from a good range of nutrients, particularly macronutrients, so where nutrient intakes were reported, countries generally had a sound basis to assess child nutrient status. However, TFAs, omega fats, added sugar and iodine were least reported. These gaps are concerning, as potential deficiencies could go undetected and nutrition policies implemented could be based on limited evidence. WHO RNI attainment was generally poor – most countries met under half of the RNIs for the nutrients and age/gender groups reported, implying that widespread nutrition issues could exist across Europe. Macronutrient RNI compliance was universally poor, and although micronutrients were slightly better, attainment was worse in girls and children ≥10y. Fat and saturated fats, vitamin D, sodium, total folate and iron had the lowest compliance. Only eight countries reported intakes by SEG and different indicators were used. This narrows opportunities to assess inequalities and vulnerable groups susceptible to malnutrition and limits the monitoring tools available for policy formation. Different age groups, methodologies, nutrient composition databases and under-reporting are the main limitations, potentially misrepresenting true intakes and preventing inter-country comparisons. Future work could use raw NDS data to conduct stratified analyses with consistent age groups. Governments and health bodies should continue efforts to encourage European countries to report a full range of nutrient intakes by various socio-demographic variables in a standardised format.

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Authors' Contributions

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Conflicts of Interest

The authors declare no conflict of interest. The co-authors Joao Breda and Jo Jewell are staff members of the World Health Organization Regional Office for Europe; however, the authors are responsible for the views expressed in this publication and they do not necessarily represent the decisions or stated policy of WHO.

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Figure 1: Mean/median child energy intake (MJ/day) (excluding supplements)

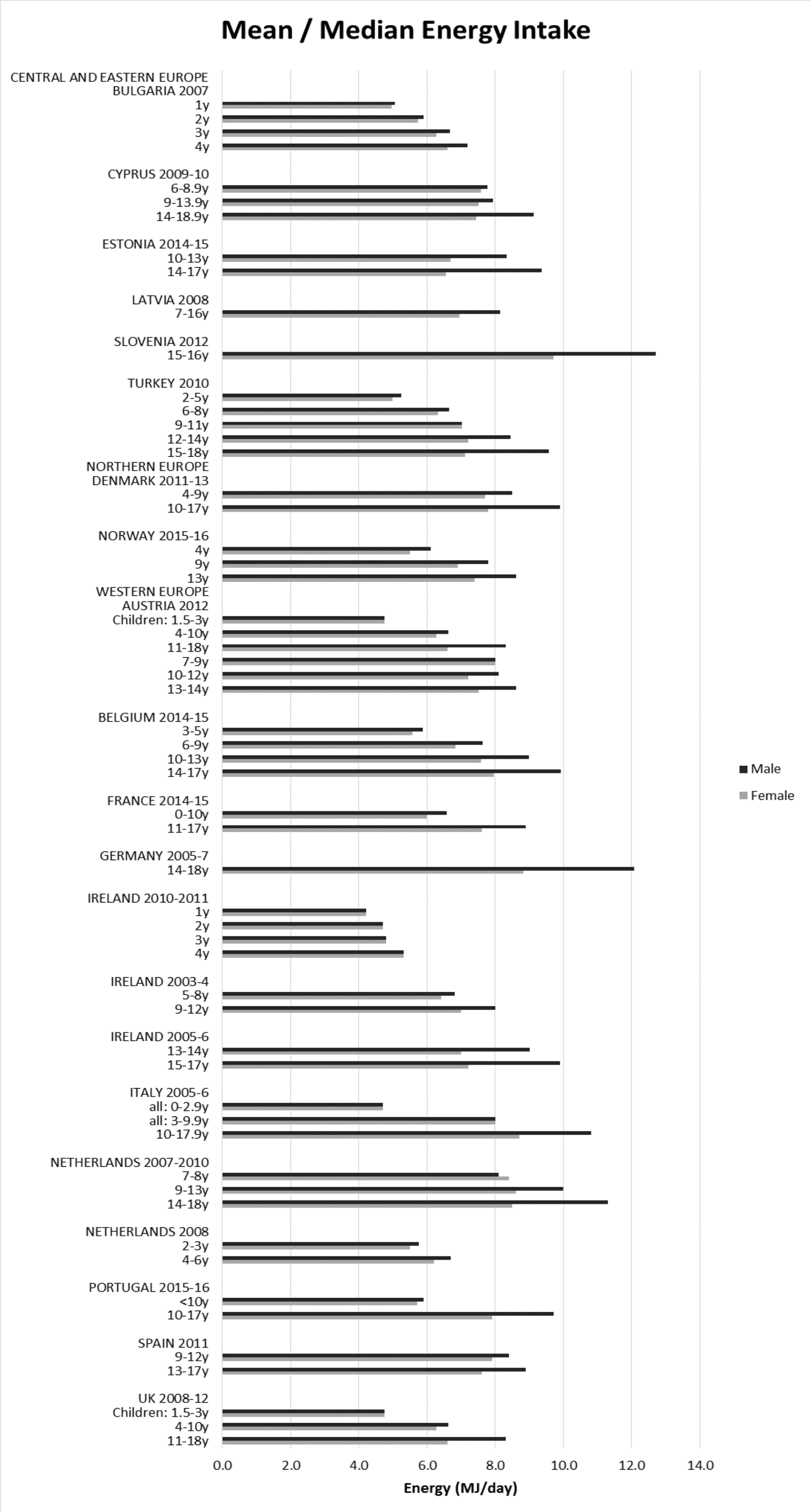

Figure 2.1: Mean/median child carbohydrate intake (%E) (excluding supplements)

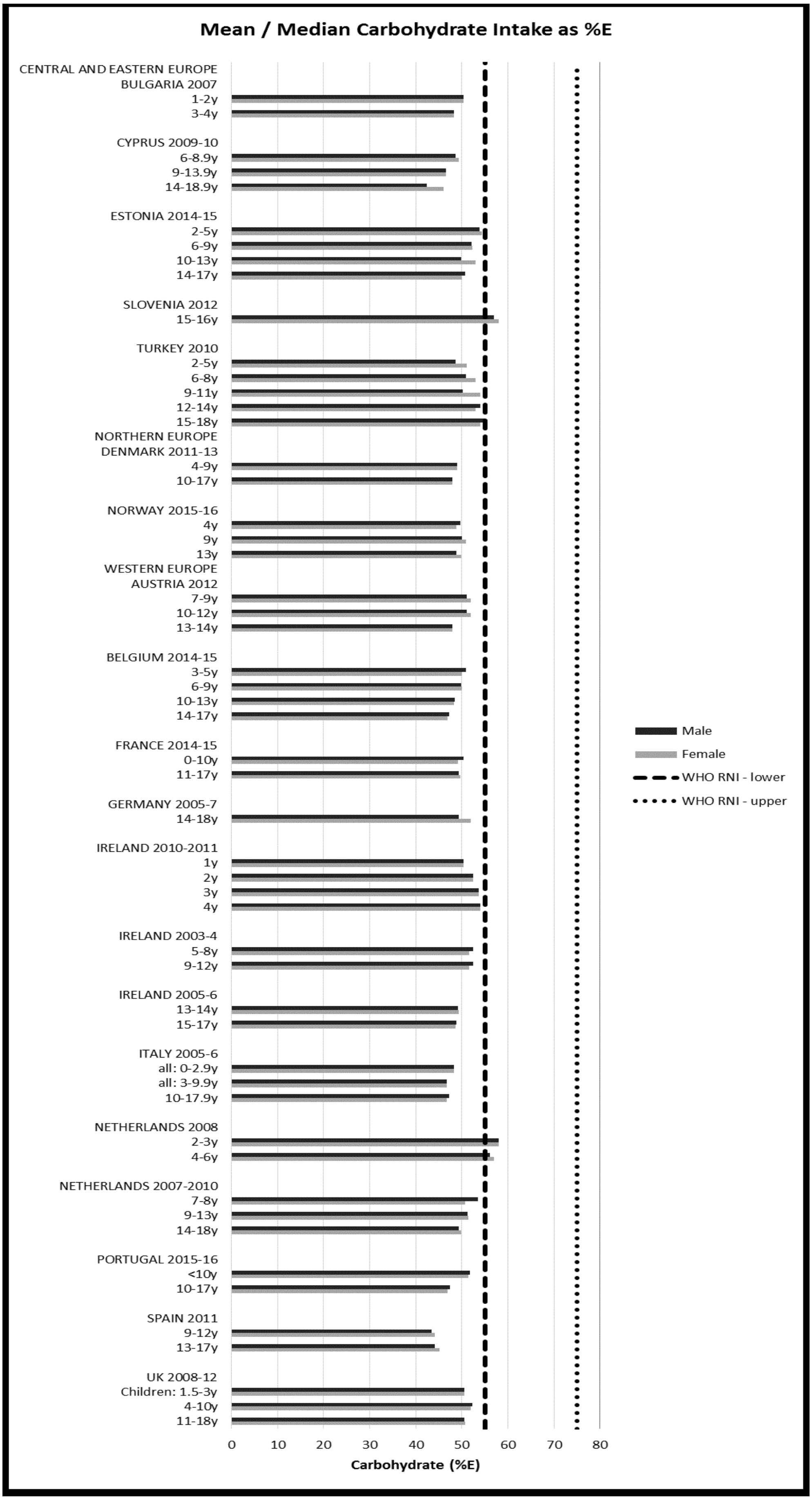

Figure 2.2: Mean/median child added sugars intake (%E) (excluding supplements)

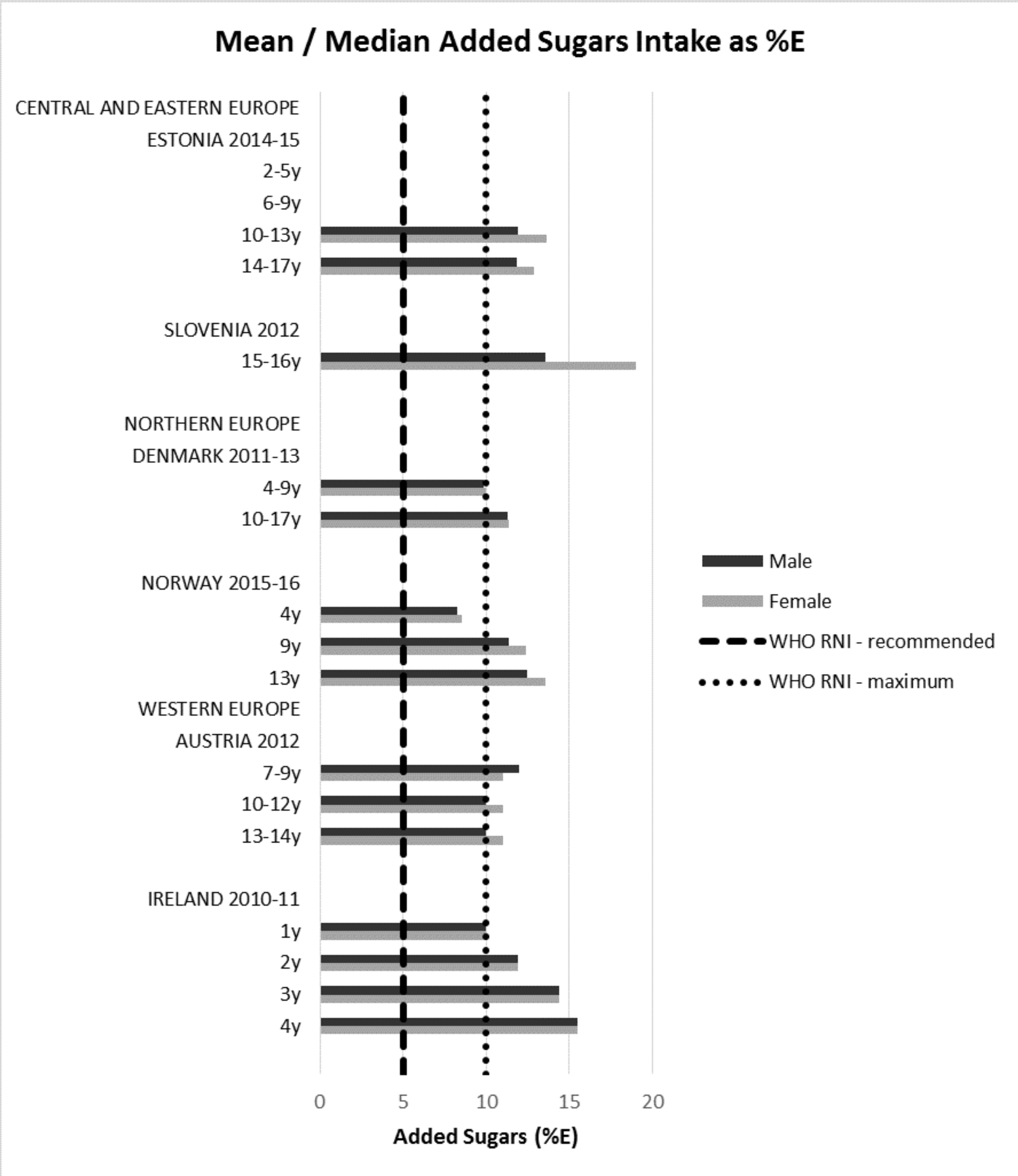

Figure 2.3: Mean/median child fibre intake (g/day) (excluding supplements)

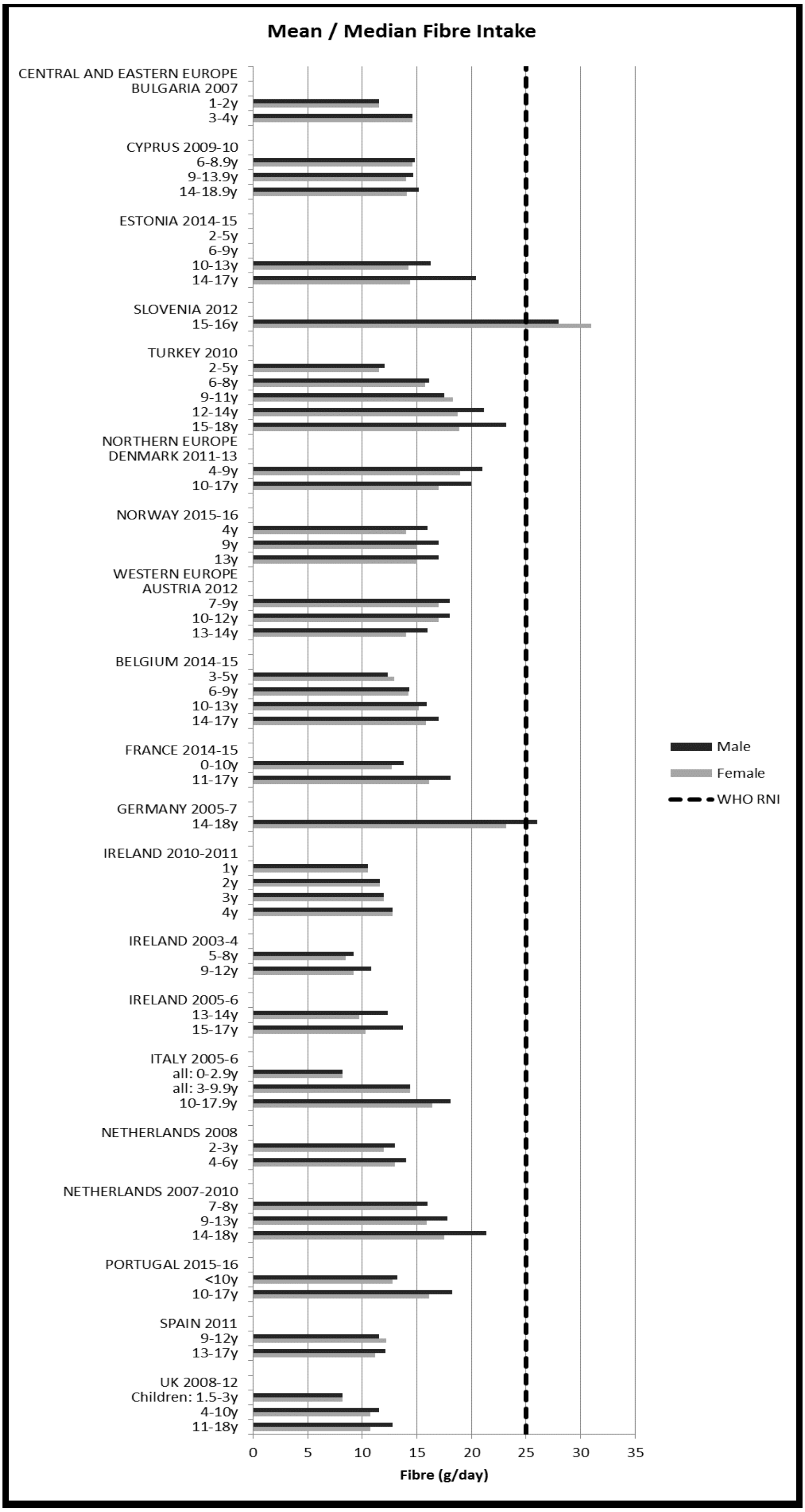

Figure 2.4: Mean/median child fat intake (%E) (excluding supplements)

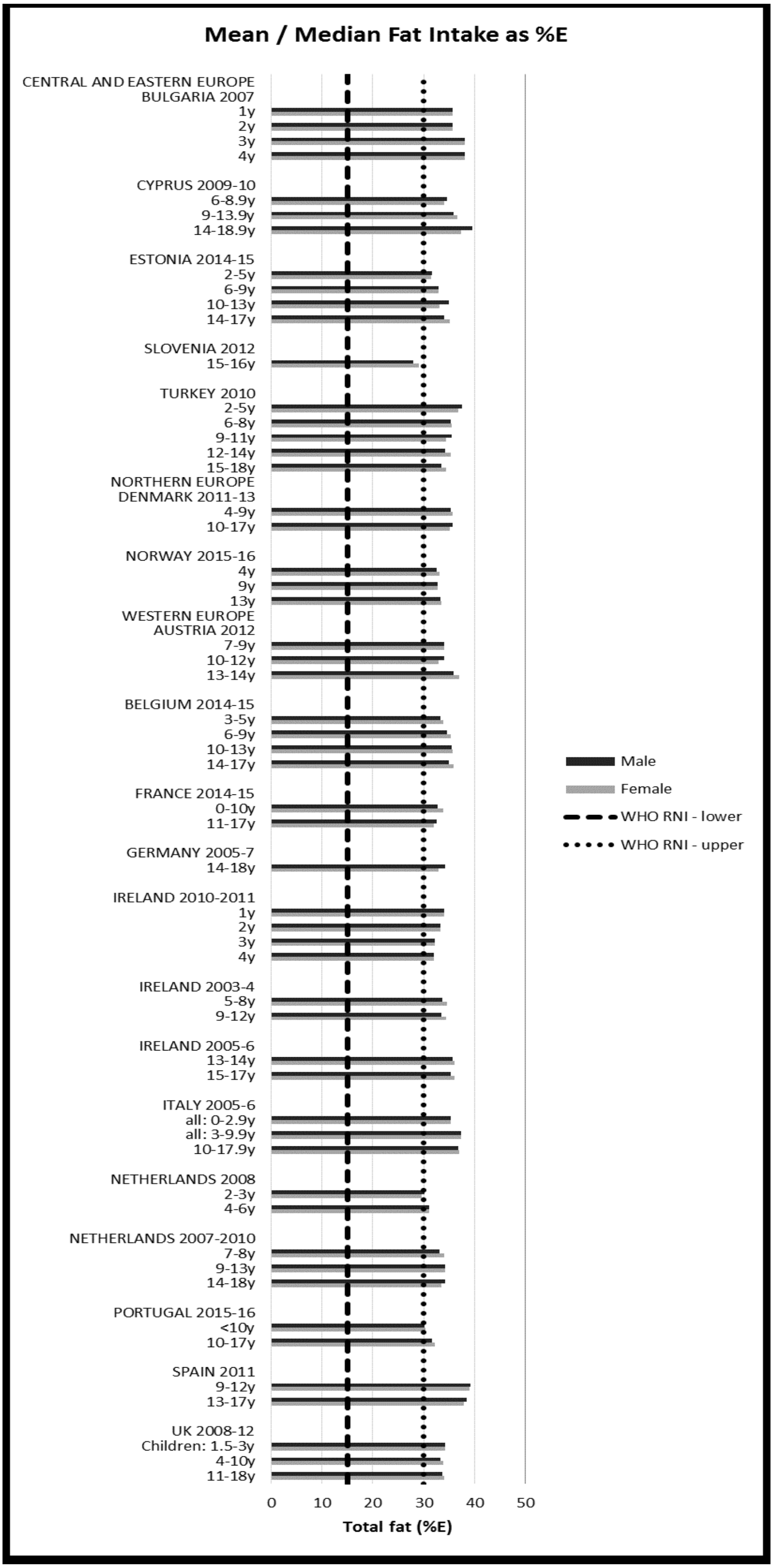

Figure 2.5: Mean/median child saturates intake (%E) (excluding supplements)

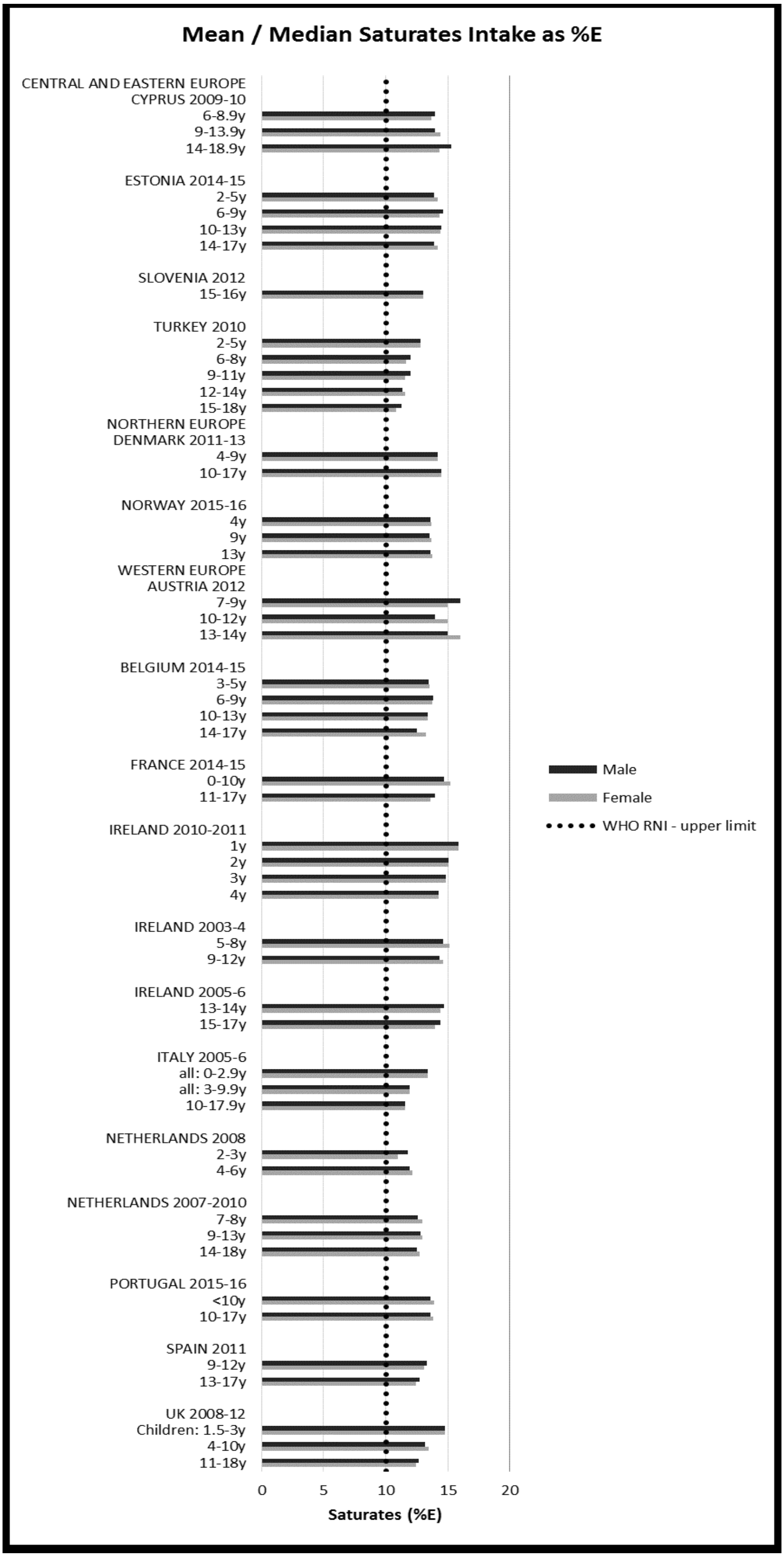

Figure 2.6: Mean/median child PUFA intake (%E) (excluding supplements)

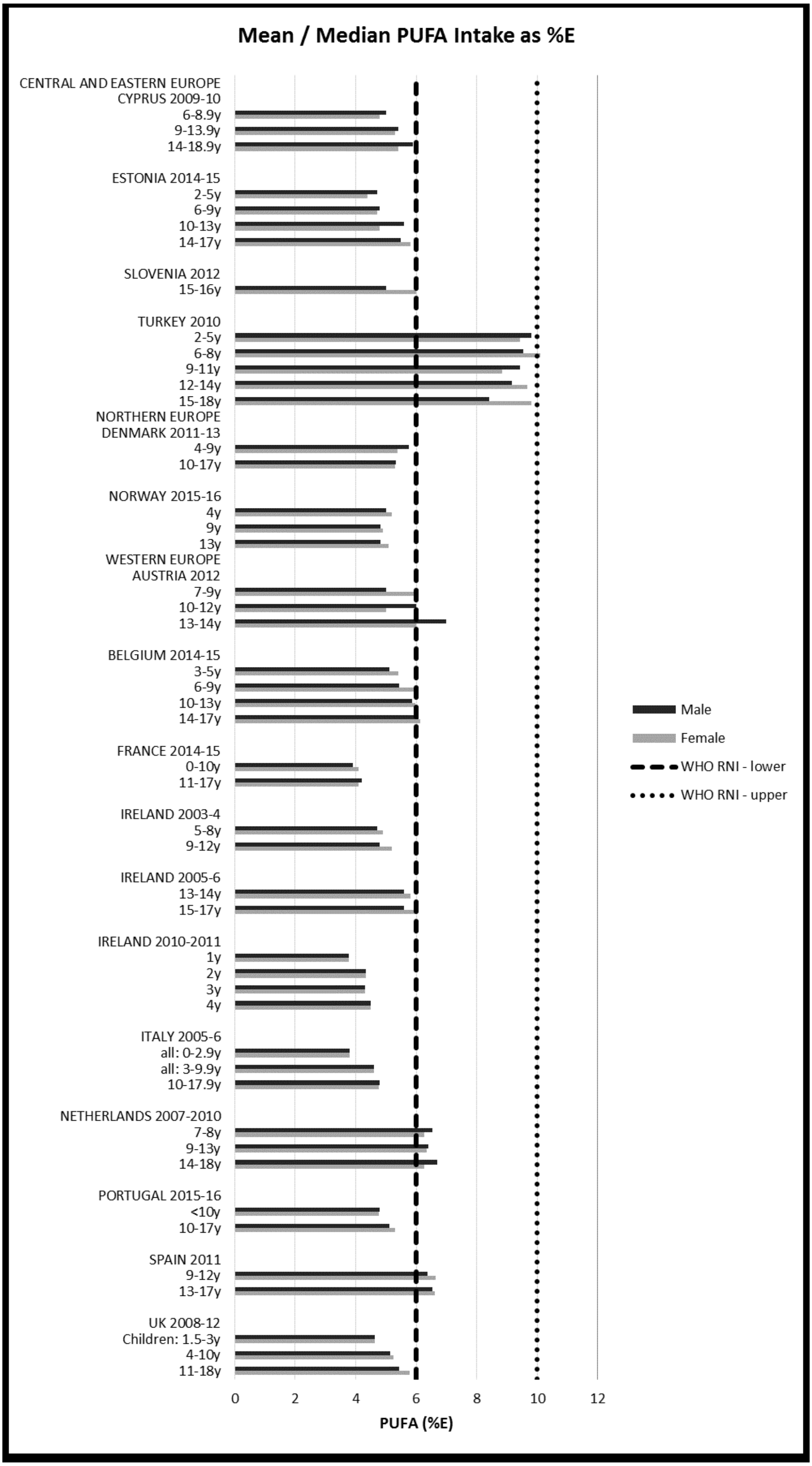

Figure 2.7: Mean/median child n-3 intake (%E) (excluding supplements)

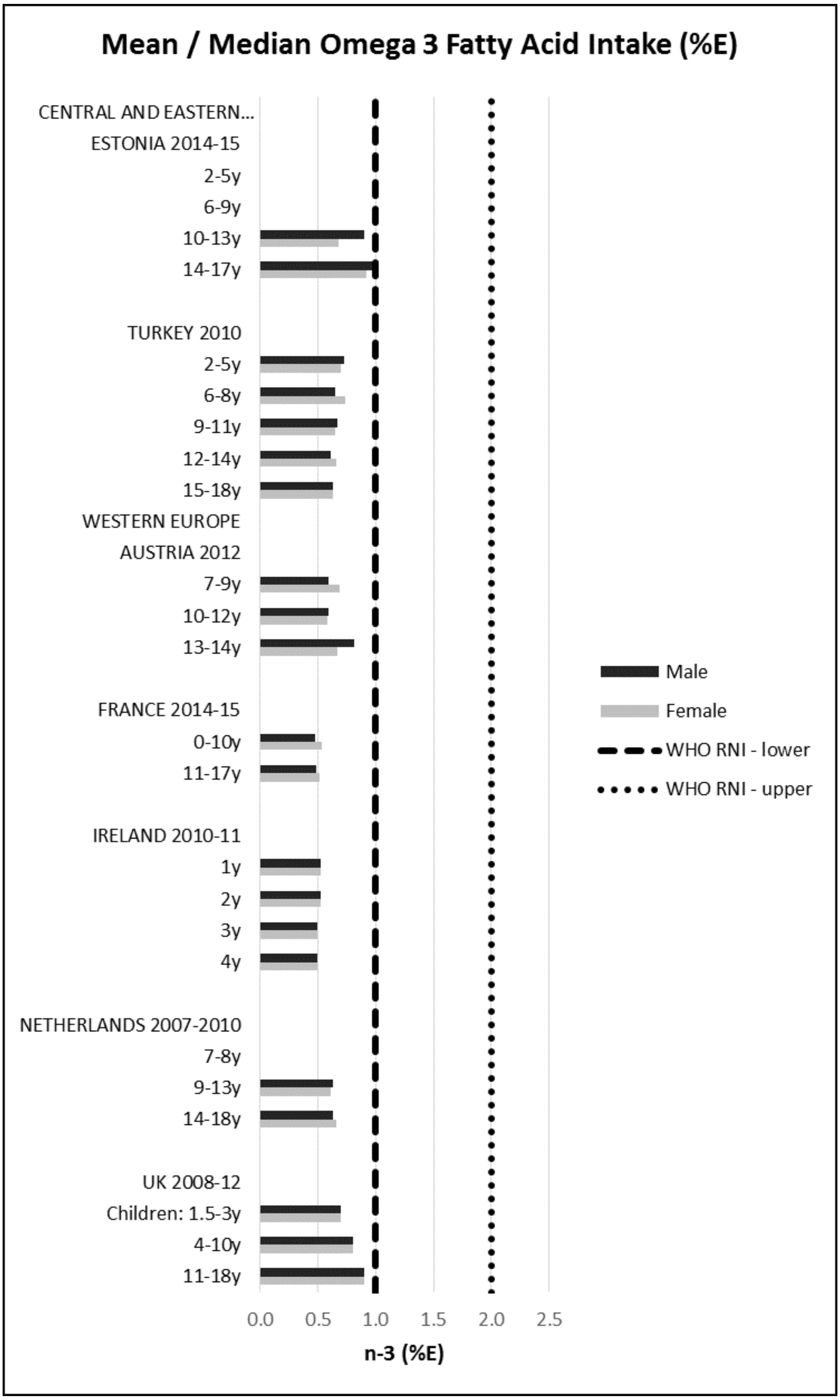

Figure 2.8: Mean/median child n-6 intake (%E) (excluding supplements)

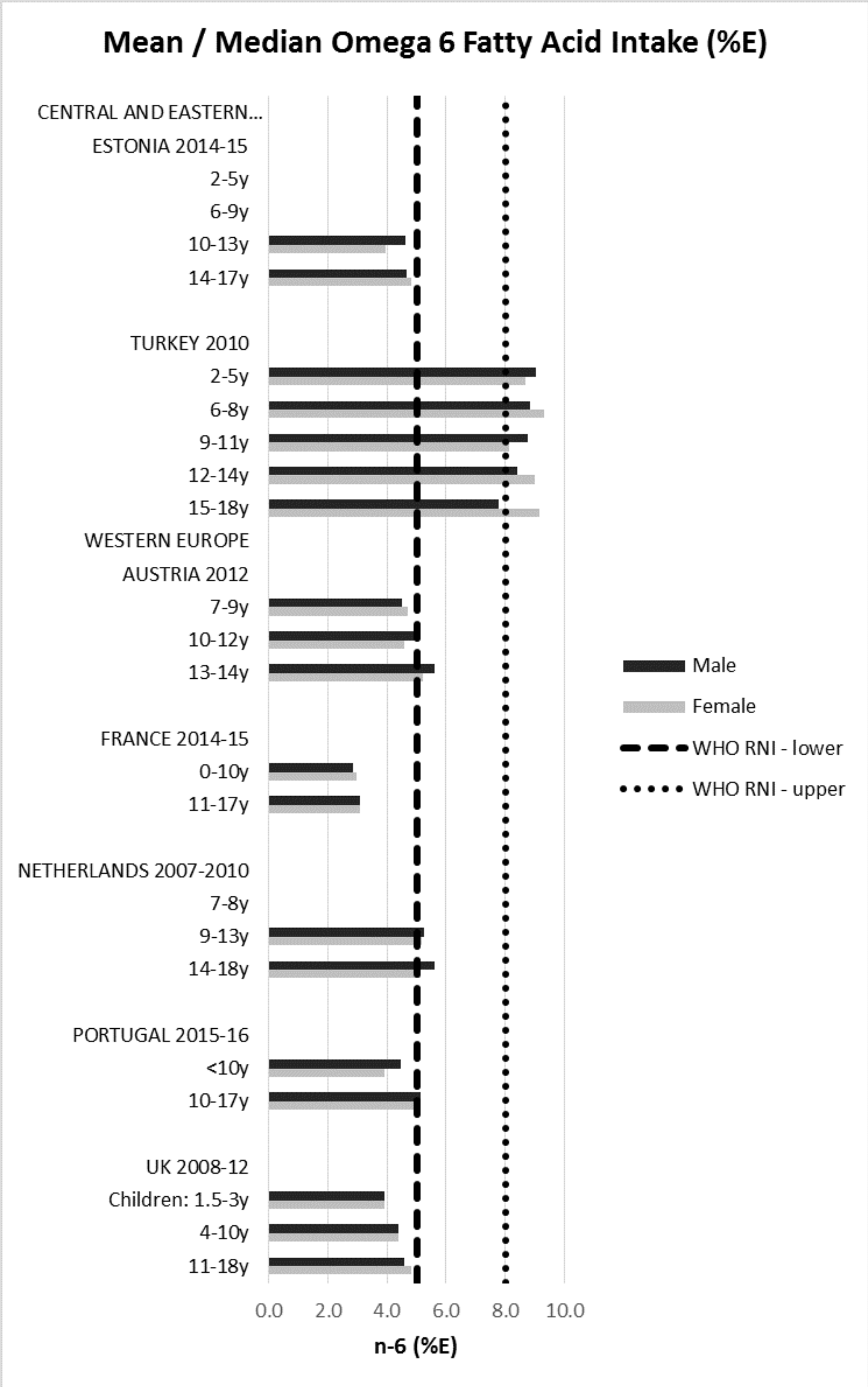

Figure 3.1: Mean/median child potassium intake (mg/day) (excluding supplements)

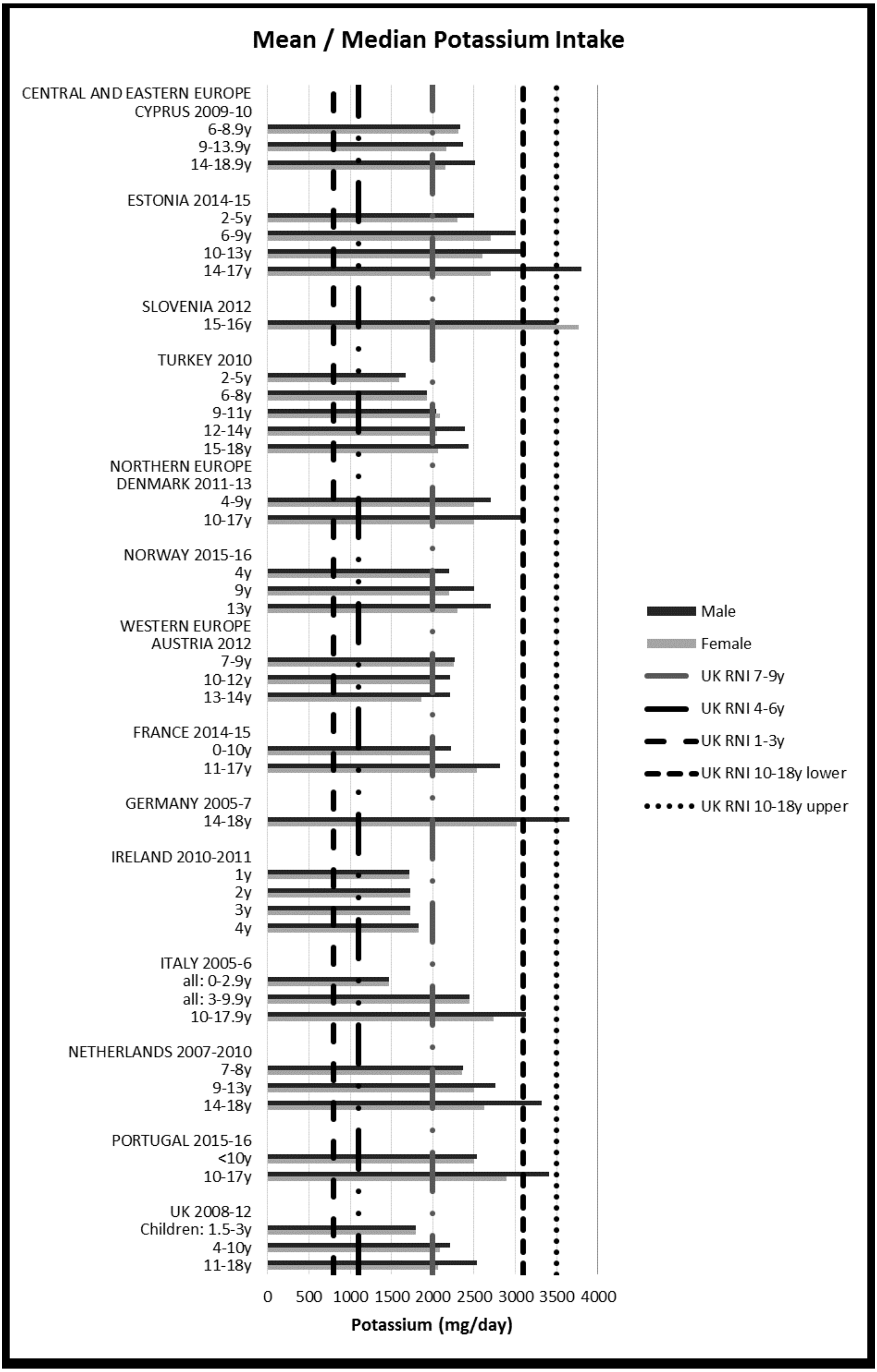

Figure 3.2: Mean/median child iron intake (mg/day) (excluding supplements)

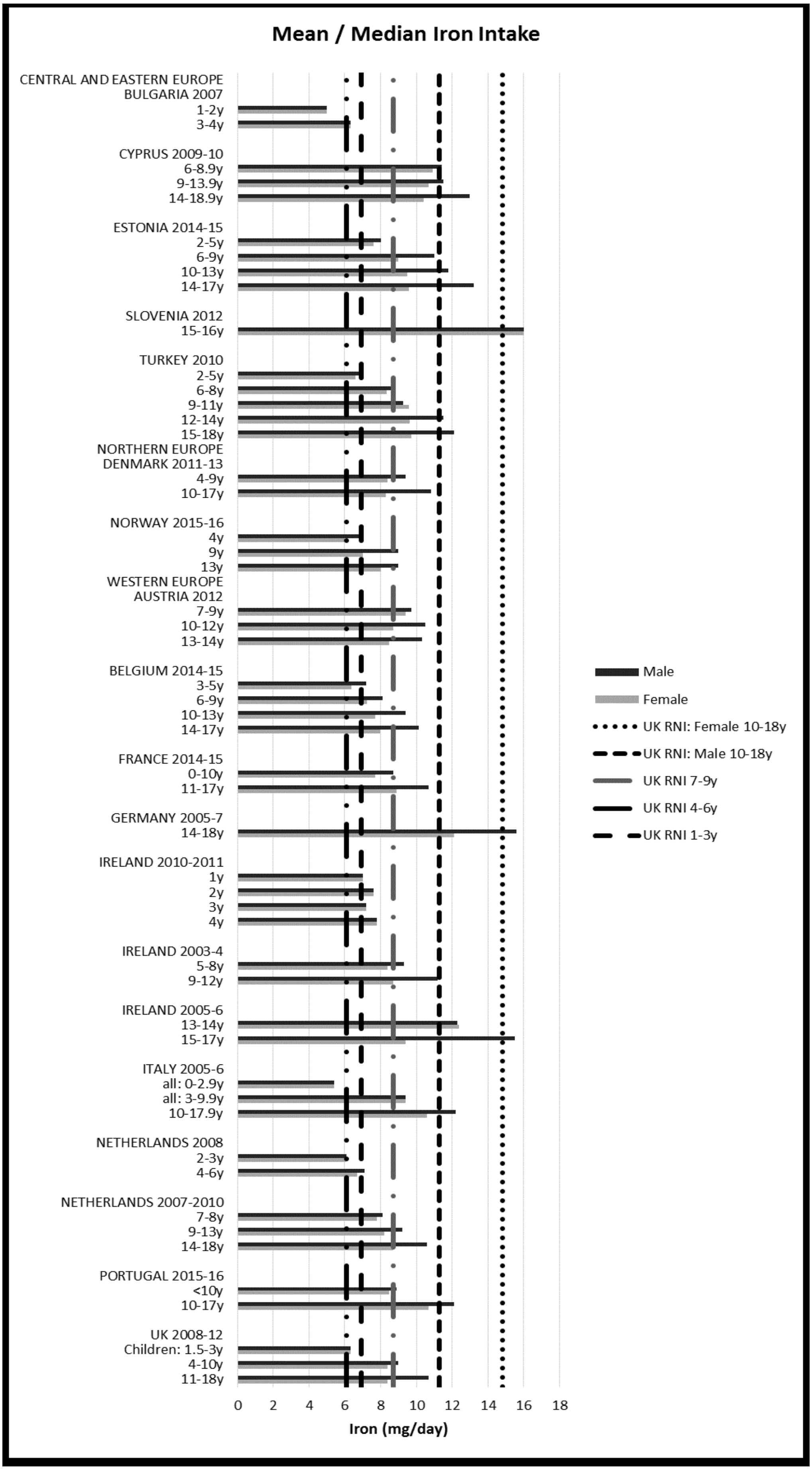

Figure 3.3: Mean/median child calcium intake (mg/day) (excluding supplements)

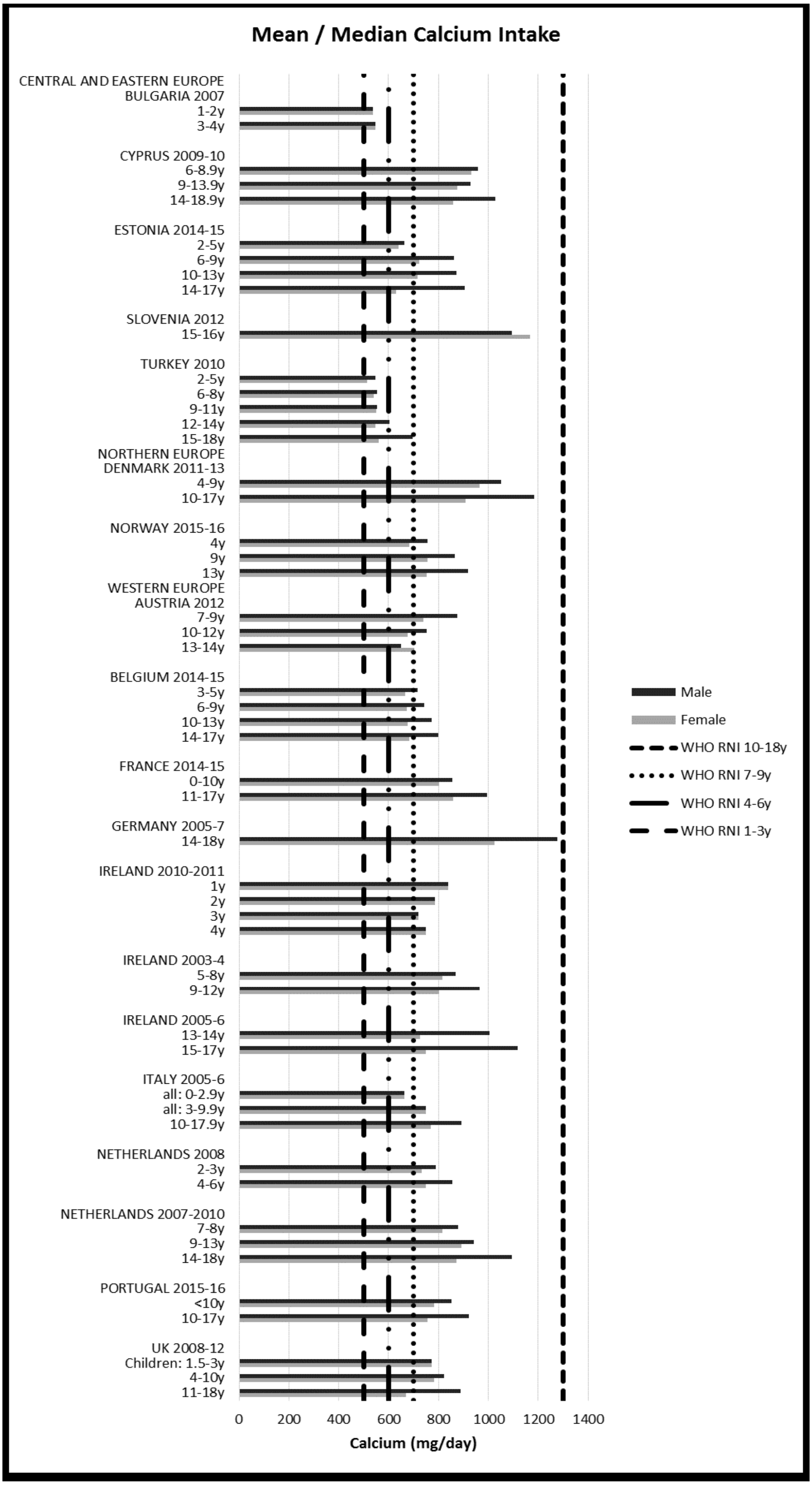

Figure 3.4: Mean/median child iodine intake (µg/day) (excluding supplements)

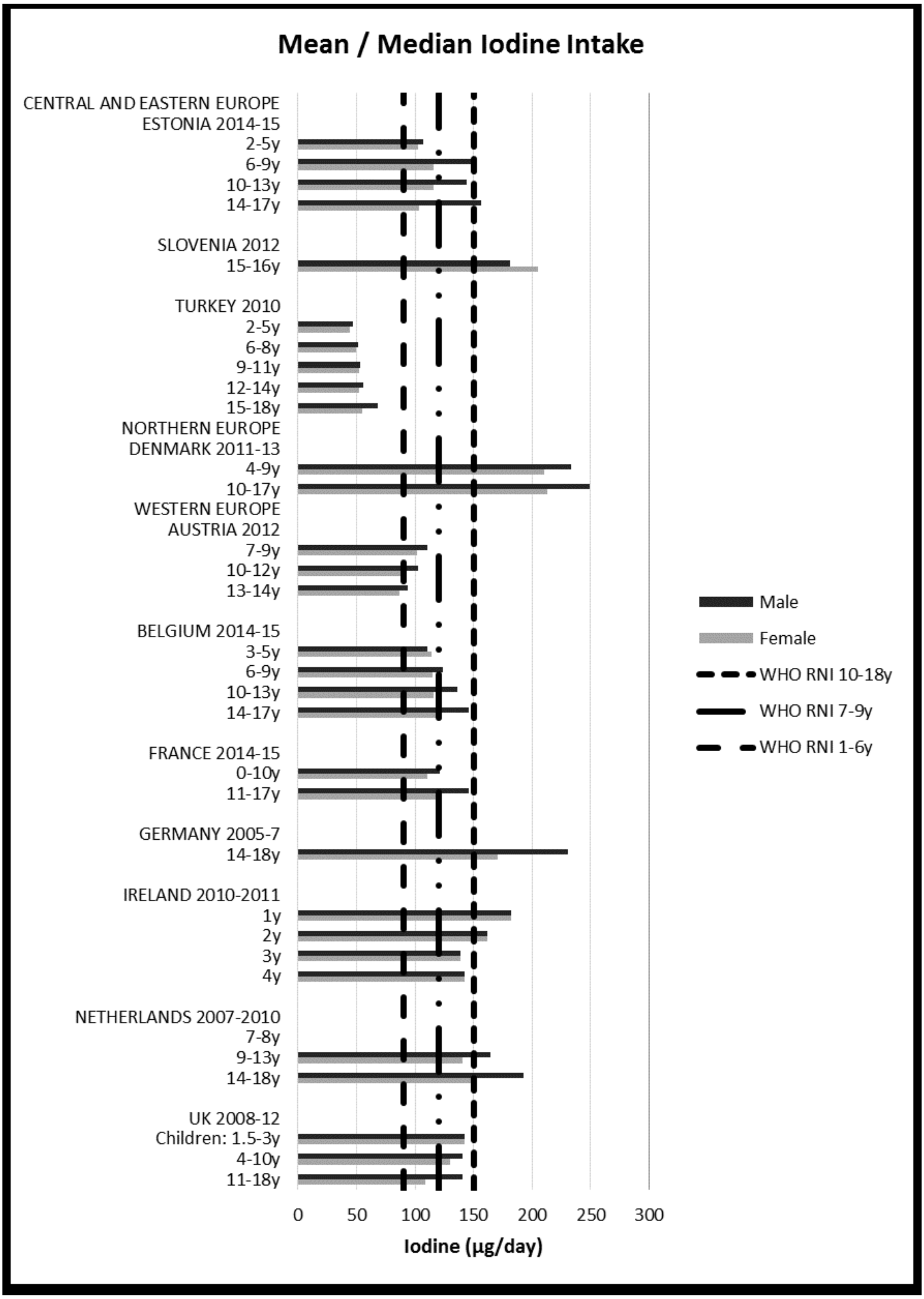

Figure 3.5: Mean/median child total folate intake (µg/day) (excluding supplements)

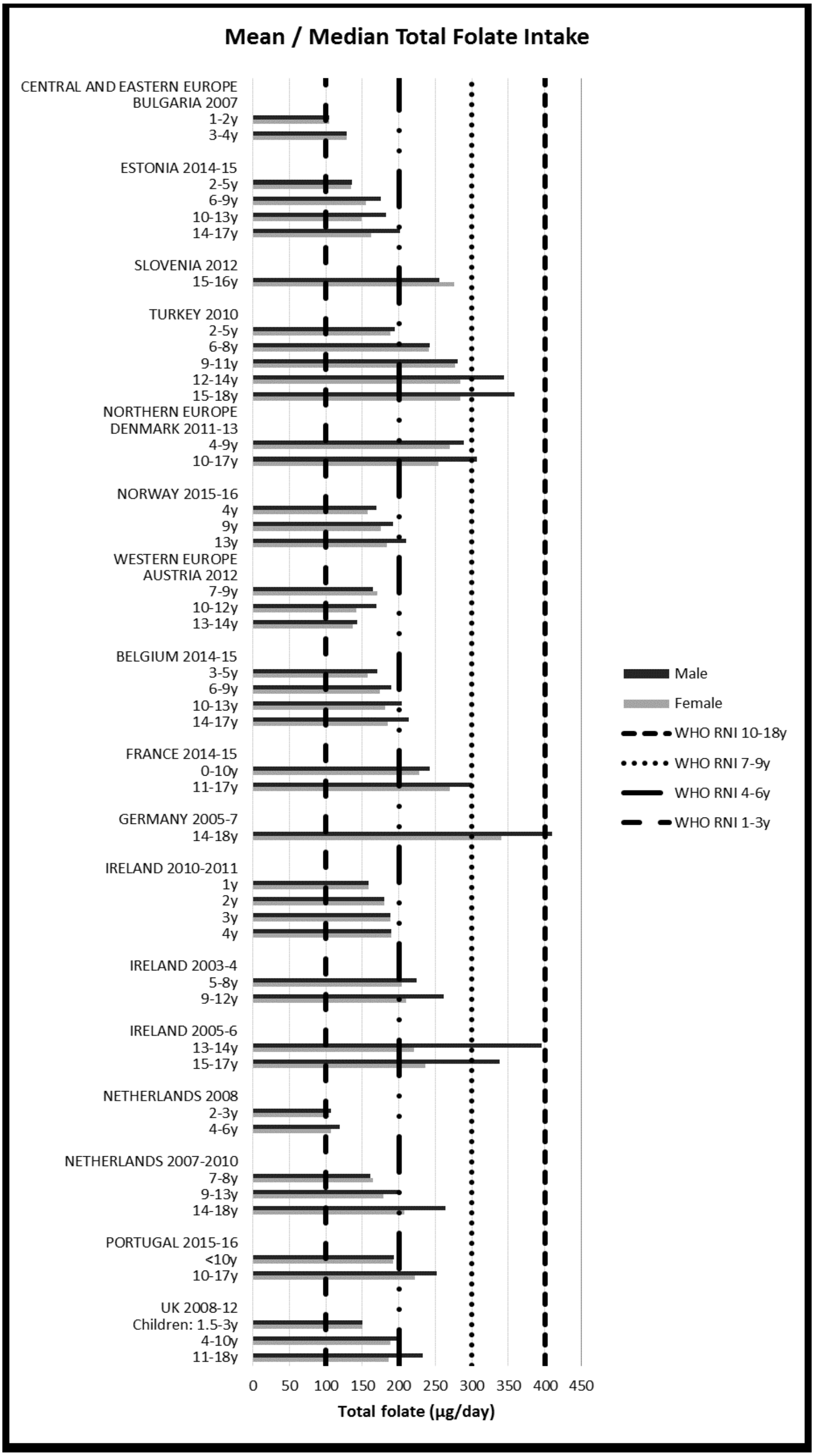

Figure 3.6: Mean/median child vitamin D intake (µg/day) (excluding supplements)

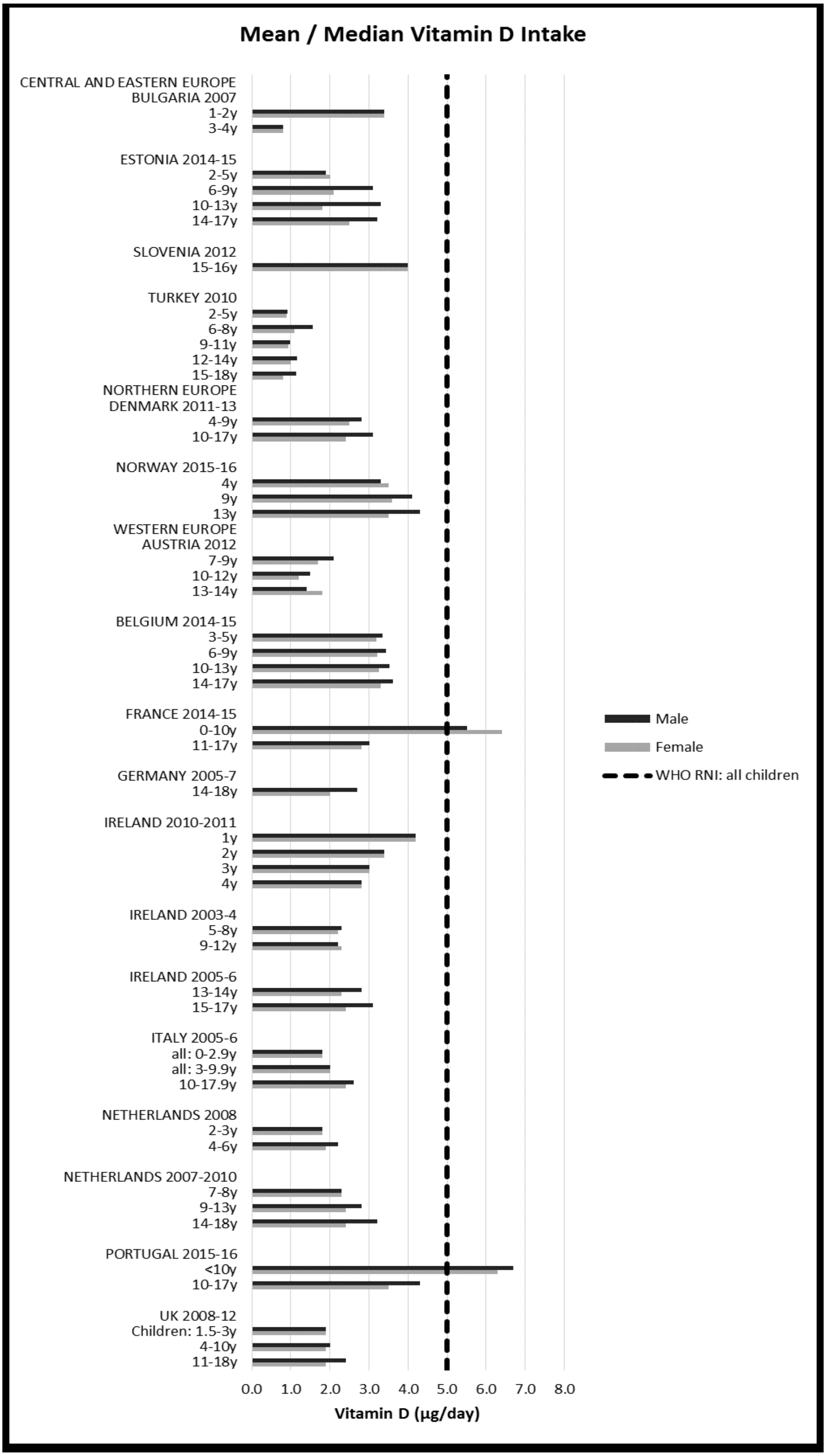

Figure 3.7: Mean/median child sodium intake (mg/day) (excluding supplements)

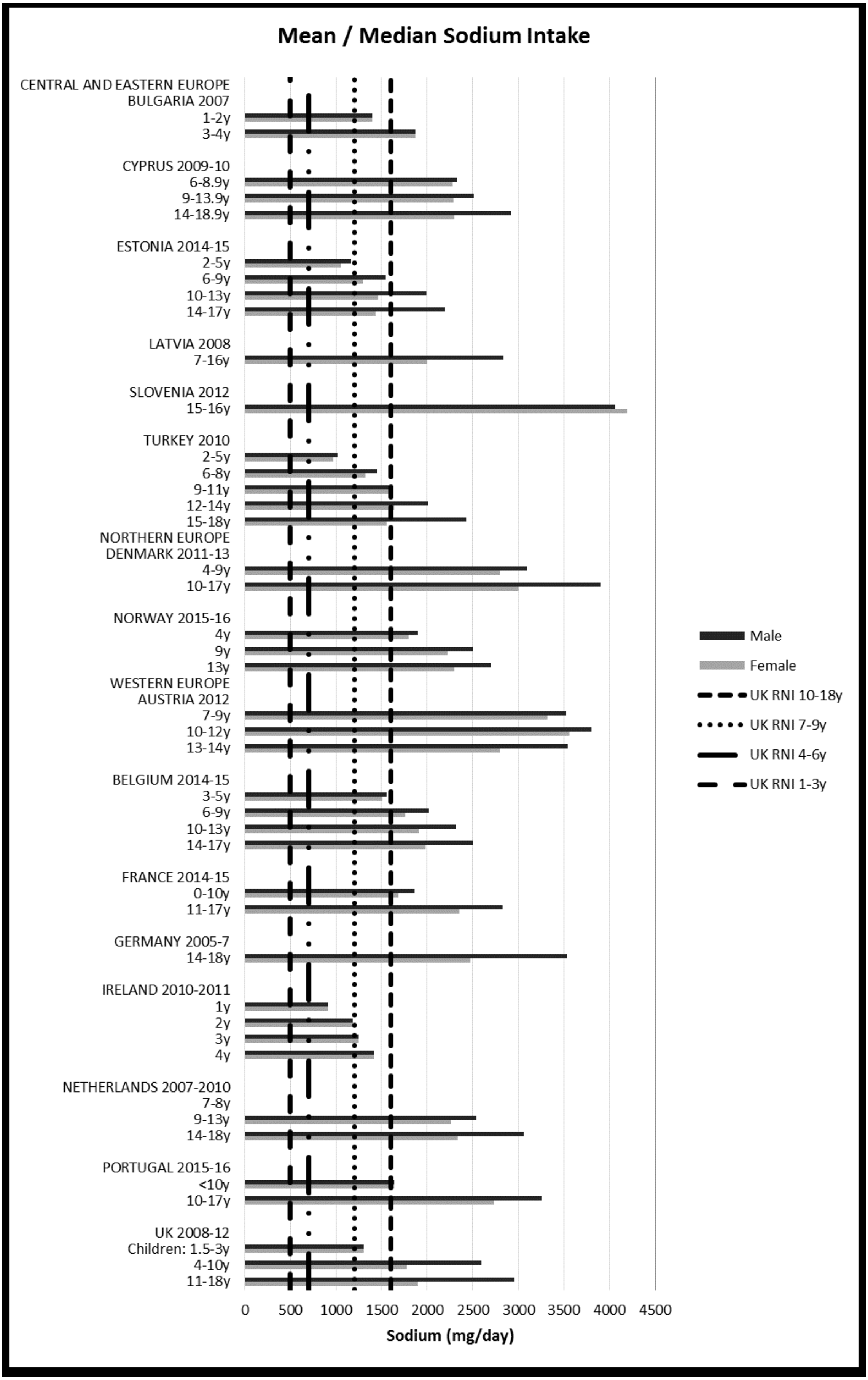

Table 1: Survey inclusion and exclusion criteria

Included	Excluded
Surveys conducted at an individual level	Surveys collected at group i.e. household level
Nationally representative surveys	Non-nationally representative, regional only surveys
Results of surveys reported by published and unpublished reports, academic journals and websites	Surveys with data collected prior to 1990
Surveys that included individuals >2y.	Surveys with samples exclusively <2y
Surveys based on whole diet rather than specific food groups	Surveys with incomplete food group coverage
	Surveys with small sample sizes (n<200)

Table 2: Nutrients of interest in dietary surveys and corresponding WHO RNIs

Macronutrients	WHO RNI format	Lower RNI	Upper RNI	Single Value
Energy (MJ and kcal)	N/A	N/A	N/A	N/A
Carbohydrates (g and %Energy (E))	Target	55%E	75%E	
Sugars (g)	N/A	N/A	N/A	N/A
Sucrose (g)	Maximum	5%E	10%E	
Fibre (g)	Target			25g
Total fat (g)	Maximum	15%E	30%E	
Saturated fats (g)	Maximum			10%E
Monounsaturated fatty acids (MUFA) (g)	N/A	N/A	N/A	N/A
Polyunsaturated fatty acids (PUFA) (g)	Target	6%E	10%E	
Trans Fatty Acids (TFAs) (g)	Maximum			<1%E
Protein (g)	Target	10%E	15%E	
Omega 3 fatty acids (g)	Target	1%E	2%E	
Omega 3 fatty acids (g)	Target	5%E	8%E	

Micronutrients	RNI format	1-3y	4-6y	7-9y	10-18y
Total folate (µg)	Minimum	100µg	200µg	300µg	400µg
Vitamin B12 (µg)	Minimum	0.9µg	1.2µg	1.8µg	2.4µg
Vitamin D (µg)	Target	5µg	5µg	5µg	5µg
Calcium (mg)	Minimum	500mg	600mg	700mg	1300mg

Potassium (mg)*	Minimum/target	800mg	1100mg	2000mg	3100-3500mg
Sodium (mg)*	Maximum	500mg	700mg	1200mg	1600mg
Iron (mg)*	Minimum	6.9mg	6.1mg	8.7mg	11.3-14.8mg
Iodine (µg)	Minimum	90µg	90µg	120µg	150µg
Zinc (mg)	Minimum	4.1mg	4.8mg	5.6mg	7.2-8.6mg

*RNIs are derived from WHO except iron, potassium and sodium, where UK RNIs have been used instead, as WHO iron RNI values are based on different bioavailabilities and potassium and sodium values are downweighted based on energy requirements for children relative to adults.

Table 3: National diet surveys across countries in WHO Europe 2000-2016 with reported nutrient intakes for children and adolescents

Country	Survey Name	Survey Year	Source *	Sample Size	Sample Age	Dietary Methodology	Nutrient Reference Database	Nutrient Intakes by SEG Y/N †	WHO RNIs not met ‡		Reference
Austria	Austrian nutrition report 2012 (OSES)	2010-2012	2	1002	7-14; 18-80	3-day diary (consecutive) (children); 2*24h recall (adults). Face-to-face and phone interview.	Analysis run with software “(nut.s) science” based on Bundeslebensmittelschlüssel 3.01 / Goldberg cut-offs for data cleaning.	N	69%	75/108	(54)
Belgium	Belgium National Food Consumption Survey (BNFCS) 2014	2014-2015	½	3146	3-64	2*24h recall. Face to face electronic interview.	The NIMS Belgian Table of Food Composition (Nubel); Dutch NEVO	N	68%	73/108	(55, 56)
Bulgaria	National survey on nutrition of infants and children under 5 and family child rearing, 2007	2007	2	1723	0-5	2*24h recall via mother (non-consecutive). Face to face interview with the mother,	FCTBL_BG (Food Composition Tables – Bulgaria)	N	60%	30/50	(57-59)
Cyprus	A study of the dietary intake of Cypriot children and adolescents aged 6-18 years	2009-2010	2	1414	6-18	3-day food record (consecutive inc 1 weekend). Self-completed.	USDA Nutrient Database for Standard Reference and Research	N	75%	45/60	(60)
Denmark	Danish National Survey of Diet and Physical Activity (DANSDA) 2011-2013	2011-2013	2	3946	4-75	7-day diary (consecutive). Self-completed (by mother/carer 4-15y).	Danish Food Composition Databank	N	60%	41/68	(61)
Estonia	National Dietary Survey	2014-15	1	4906	4m-74yrs	2*24h recall (age ≥10); 2*24h food diary (age <10); FFQ (age >2). Face to face electronic interview.		Y – income, poverty threshold, education	64%	84/132	Available 2017.
France	Individual National Food Consumption Survey (INCA3)	2014-15	2	5855	0-79	3*24h recalls (15+); 3-day diary (0-14y). Non- consecutive including weekend; phone interview.	Food Composition Database of CIQUAL of ANSES.	Y – education, parent occupational category	82%	56/68	(62)
Germany	German National Nutrition Survey (Nationale Verzehrstudie) II (NVSII)	2005-2007	1/3	15371	14-80	DISHES diet history interview, 24h-recall, diet weighing diary (2*4 days). Face to	Bundeslebensmittelschlüssel (BLS)	N	54%	14/26	(63, 64)

						face electronic interview.					
Ireland	National Pre-school Nutrition Survey	2010-2011	1	500	1-4	4-day weighed food diary (consecutive). Self- completed (by carer).	McCance and Widdowson's The Composition of Foods 5&6 editions	Y – social class and education	57%	110/192	(65, 66)
	National Teens' Food Survey	2005-2006	1	441	13-17	7-day semi-weighed food diary (consecutive). Self- completed.	McCance and Widdowson's The Composition of Foods 5&6 editions	Y – social class and education			(67-69)
	National Children's Food Survey.	2003-2004	1	594	5-12	7-day weighed food diary (consecutive). Self- completed.	McCance and Widdowson's The Composition of Foods 5&6 editions	Y – social class and education			(68-70)
Italy	The third Italian National food consumption survey INRAN-SCAI 2005-2006	2005-2006	2	3323	0.1-97.7	3-day diary (consecutive). Self- completed,	Banca Dati di Composizione degli Alimenti	N	65%	42/72	(71)
Latvia	Latvian National Food Consumption Survey 2007-2009	2008	1	1949	7-64	2*24hr recall, FFQ. Face to face interview.	Latvian National Food Composition Data Base 2009	N	100%	2/2	(72)
Netherlands	Dutch National Food Consumption Survey 2007-2010 (DNFCS 2007-10)	2007-2010	1 / 2	3819	7-69	2*24h recalls. Telephone (adults)/ face to face (children) interview.	Dutch Food Composition Database (NEVO)	Y – education	51%	75/148	(73-75)
	Dutch National Food Consumption Survey – young children (DNFCS 2008)	2005-2006	1	1279	2-6	2-day diary (non-consecutive). Self- completed (by adult).	Dutch Food Composition Database (NEVO)	N			(76)
Norway	UNGKOST 3	2015-2016	1	1721	4-13	4-day online diary plus FFQ (consecutive). Self- completed via web.	The Norwegian Food Composition Tables	Y – parental education	70%	59/84	(77, 78)
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015-2016	4	4221	3m-84y	2*24h recall (non-consecutive) and FPQ (electronic interview) 2-day food diary for children <10y. Face to face electronic interview.	Portuguese Food Composition Table (INSA)	N	61%	39/64	(79, 80)
Slovenia	Dietary Intake of Macro- and Micronutrients in Slovenian Adolescents	2012	2	2224	15-16	FFQ	German Bundeslebensmittelschlüssel (BLS) 3.02	N	44%	15/34	(81)
Spain	ANIBES study	2013	2	2285	9-75	3-day diary + 24h recall (consecutive). Face to face, telephone (interview),	Tablas de Composición de Alimentos, 15ª ed	N	67%	16/24	(82-84)

						tablet and camera (self-report).					
Turkey	Turkey nutrition and health survey 2010 (TNHS)	2010	2	14248	0-100	24hr recall, FFQ. Face to face interview.	BEBS Nutritional Information System Software; Turkish Food Composition Database	N	68%	116/170	(85, 86)
UK	National Diet and Nutrition Survey Rolling Programme (NDNS RP 2008-2012)	2008-2012	2	6,828	1.5 -94	4-day diary (consecutive). Self-completed (by carer 1.5-11y).	McCance and Widdowson's The Composition of Foods integrated dataset	Y – income	74%	80/108	(87)

*1 = email contacts; 2 = general internet searches; 3 = Micha et al. (14); 4) WHO Global Nutrition Policy Review 2017 extracted information.

† Countries that have reported nutrient intakes by socio-economic group (SEG) in addition to age and gender.

‡ The right column provides the number of RNIs not met by each age/gender group out of a total number of RNIs for age/gender group for each nutrient reported by that country. The left column provides this figure as a percentage.

Table 4.1: Estimated means* for <10y and ≥10y by country and region for macronutrients in 21 national dietary surveys in the WHO Europe region

COUNTRY	Energy (MJ)	Protein (g)	CHO (g)	Sugars (g)	Sucrose (g)	Fibre (g)	Total fat (g)	Saturated fats (g)	MUFA (g)	PUFA (g)	TFAs (g)	n-3 (g)	n-6 (g)
Bulgaria (1-4y)	**National survey on nutrition of infants and children under 5 and family child rearing 2007**												
Girls <10y	5.8	47	175	31		13.1	59	15	11	9.4			
Boys <10y	6.1	49	175	31		13.1	59	15	11	9.4			
Girls ≥10y													
Boys ≥10y													
Cyprus (6-8.9y; 9-18.9y)	**A study of the dietary intake of Cypriot children and adolescents aged 6-18 years 2009-10**												
Girls <10y	7.6	73	223			14.6	69	28	30	9.7			
Boys <10y	7.8	75	226			14.8	72	29	31	10.3			
Girls ≥10y	7.5	73	207			14.1	73	28	33	10.6			
Boys ≥10y	8.5	88	225			14.9	85	33	38	12.7			
Estonia (2-9y; 10-17y)	**National Dietary Survey 2014-15**												
Girls <10y					56			27	21	8.7	0.5	1.3	6.7
Boys <10y					61			30	24	9.9	0.6	1.4	7.6
Girls ≥10y	6.6	55	205		52	14.3	62	26	21	9.9	0.4	1.4	7.8
Boys ≥10y	8.8	78	269		63	18.2	83	34	29	13.7	0.6	2.2	10.8
Latvia (7-16y)	**Latvian National Food Consumption Survey 2007-09**												
Girls <10y													
Boys <10y													
Girls ≥10y	6.9												
Boys ≥10y	8.2												
Slovenia (15-16y)	**Dietary Intake of Macro- and Micronutrients in Slovenian Adolescents 2012**												
Girls <10y													
Boys <10y													
Girls ≥10y	9.7	86	379	195	110	31	82	35	29	17.0			
Boys ≥10y	12.7	96	370	170	103	28	82	36	30	16.0			
Turkey (2-8y; 9-18y)	**Turkey nutrition and health survey 2010 (TNHS)**												
Girls <10y	5.3	38	158			12.5	51	17	17	13.4		1.0	12.4
Boys <10y	5.5	41	163			12.9	54	19	18	14.3		1.0	13.3
Girls ≥10y	7.1	50	220			18.7	66	21	22	17.9		1.2	16.6
Boys ≥10y	8.3	61	257			20.6	76	26	25	19.8		1.4	18.3
CEEC MEAN Girls <10y	**5.3**	**39**	**159**	**31**	**56**	**13**	**52**	**17**	**16**	**13**	**0.5**	**1.0**	**12.3**
CEEC MEAN Boys <10y	**5.6**	**42**	**164**	**31**	**61**	**13**	**55**	**19**	**17**	**14**	**0.6**	**1.0**	**13.2**
CEEC MEAN Girls ≥10y	**7.1**	**51**	**222**	**195**	**87**	**19**	**66**	**22**	**22**	**18**	**0.4**	**1.2**	**16.5**
CEEC MEAN Boys ≥10y	**8.4**	**62**	**258**	**170**	**87**	**21**	**76**	**26**	**26**	**20**	**0.6**	**1.4**	**18.2**

Denmark (4-9y, 10-17y)	**Danish National Survey of Diet and Physical Activity (DANSDA) 2011-2013**												
Girls <10y	7.7	64	220		46	19.0	73	29	26	11.0	1.2		
Boys <10y	8.5	71	243		50	21.0	80	32	28	13.0	1.3		
Girls ≥10y	7.8	67	222		53	17.0	73	30	26	11.0	1.1		
Boys ≥10y	9.9	90	277		67	20.0	94	38	34	14.0	1.4		
Norway (4-9y, 13y)	**Ungkost3 2015-16**												
Girls <10y	6.4	59	189		43	14.6	56	24	19	8.6			
Boys <10y	7.1	67	207		44	16.6	62	26	21	9.2			
Girls ≥10y	7.4	68	219		60	15.0	66	27	23	10.0			
Boys ≥10y	8.6	83	247		64	17.0	76	31	27	11.0			
NORTH MEAN Girls <10y	**7.1**	**61**	**205**		**44**	**17**	**65**	**26**	**23**	**10**	**1.2**		
NORTH MEAN Boys <10y	**7.8**	**69**	**225**		**47**	**19**	**71**	**29**	**25**	**11**	**1.3**		
NORTH MEAN Girls ≥10y	**7.6**	**67**	**221**		**56**	**16**	**70**	**29**	**25**	**11**	**1.1**		
NORTH MEAN Boys ≥10y	**9.3**	**87**	**262**		**66**	**19**	**85**	**35**	**31**	**13**	**1.4**		
Austria (7-9y, 10-14y)	**Austrian nutrition report (OSES) 2010-12**												
Girls <10y	8.0	62	248		53	17.0	72	32	23	12.7		1.5	10.0
Boys <10y	8.0	62	245		58	18.0	73	34	22	10.7		1.3	9.6
Girls ≥10y	7.3	62	222		48	16.1	66	30	22	10.3		1.2	9.3
Boys ≥10y	8.2	69	247		49	17.6	75	31	24	13.5		1.4	11.2
Belgium (3-9y, 10-17y)	**The Belgian National Food Consumption Survey (BNFCS) 2014-15**												
Girls <10y	6.2	51	186	99		13.6	57	23	21	9.6	0.7		
Boys <10y	6.8	56	205	111		13.4	62	25	22	9.6	0.7		
Girls ≥10y	7.8	64	221	107		15.5	74	27	27	12.4	0.7		
Boys ≥10y	9.4	79	270	133		16.4	88	32	32	15.0	0.9		
France (0-10y, 11-17y)	**Individual National Food Consumption Survey (INCA3) 2014-15**												
Girls <10y	6.0	53	176	95		12.7	54	24	18	6.4		0.9	4.7
Boys <10y	6.6	58	199	103		13.8	57	26	19	6.6		0.8	5.0
Girls ≥10y	7.6	70	226	98		16.1	66	28	22	8.5		1.0	6.2
Boys ≥10y	8.9	83	262	111		18.1	77	33	26	9.9		1.1	7.3
Germany (14-18y)	**German National Nutrition Survey (Nationale Verzehrstudie) II (NVSII) 2005-07**												
Girls <10y													
Boys <10y													
Girls ≥10y	8.8	66	274			23.2	77						
Boys ≥10y	12.1	94	355			26.0	110						
Ireland (1-8y, 9-17y)	**National pre-school nutrition survey 2010-11; National children's nutrition survey 2003-04; National teens nutrition survey 2005-06**												
Girls <10y	5.4	46	171	76	37	10.5	48	21	16	6.5		0.6	
Boys <10y	5.5	47	177	76	37	10.8	48	22	17	6.5		0.6	
Girls ≥10y	7.1	58	224			9.7	66	27	23	10.5			

Boys ≥10y	8.9	77	281			12.2	82	34	29	12.5			
Italy (0-9.9y, 10-17.9y)	**The third Italian National food consumption survey INRAN-SCAI 2005-06**												
Girls <10y	7.3	67	220	83		13.1	72	24	33	8.7			
Boys <10y	7.3	67	220	83		13.1	72	24	33	8.7			
Girls ≥10y	8.7	82	263	88		16.4	86	27	40	11.1			
Boys ≥10y	10.8	99	327	108		18.1	105	33	49	13.7			
Netherlands (2-8y, 9-18y)	**Dutch National Food Consumption Survey – young children (DNFCS) 2008; Dutch National Food Consumption Survey (DNFCS) 2007-2010**												
Girls <10y	6.3	48	209	127		13.0	53	20		14.0	1.2		
Boys <10y	6.6	50	218	132		14.0	54	21		14.0	1.3		
Girls ≥10y	8.5	67	257	134		16.7	76	29	27	14.2	1.2	1.4	11.6
Boys ≥10y	10.7	81	312	159		19.6	94	35	34	18.1	1.5	1.7	15.0
Portugal (0-9y, 10-17y)	**National Food and Physical Activity Survey (IAN-AF) 2015-16**												
Girls <10y	5.7	58	175	89		12.8	46	21	21	7.2	0.7		5.9
Boys <10y	5.9	56	180	90		13.2	47	21	21	7.4	0.7		6.9
Girls ≥10y	7.9	83	219	88		16.1	67	29	27	11.0	1.2		10.5
Boys ≥10y	9.7	104	273	107		18.2	81	35	32	13.1	1.5		13.1
Spain (9-17y)	**ANIBES 2013**												
Girls <10y													
Boys <10y													
Girls ≥10y	7.8	72	208	88		11.7	80	26	32	13.7			
Boys ≥10y	8.7	83	227	92		11.8	89	30	37	14.8			
UK (1.5-10y, 11-18y)	**National Diet and Nutrition Survey Rolling Programme (NDNS RP) Y1-4 2008-12**												
Girls <10y	5.8	50	187	88		9.9	52	21	18	7.7	1.0	1.2	6.6
Boys <10y	6.0	52	198	92		10.5	54	22	19	8.0	1.0	1.2	6.8
Girls ≥10y	6.6	56	211	90		10.7	60	22	23	10.1	1.1	1.6	8.5
Boys ≥10y	8.3	74	265	116		12.8	74	28	28	11.9	1.4	1.9	10.0
WEST MEAN Girls <10y	**6.3**	**55**	**194**	**92**	**46**	**12**	**57**	**23**	**22**	**8**	**1.0**	**1.0**	**5.9**
WEST MEAN Boys <10y	**6.6**	**57**	**205**	**97**	**49**	**13**	**59**	**24**	**23**	**8**	**1.0**	**1.0**	**6.1**
WEST MEAN Girls ≥10y	**7.9**	**68**	**237**	**95**	**48**	**16**	**72**	**26**	**28**	**11**	**1.1**	**1.3**	**8.0**
WEST MEAN Boys ≥10y	**9.7**	**86**	**289**	**113**	**49**	**18**	**90**	**31**	**33**	**13**	**1.4**	**1.5**	**9.6**
EUROPE MEAN Girls <10y	**6.0**	**50**	**183**	**91**	**46**	**12**	**56**	**21**	**20**	**10**	**1.0**	**1.0**	**8.6**
EUROPE MEAN Boys <10y	**6.3**	**53**	**192**	**95**	**48**	**13**	**58**	**22**	**21**	**10**	**1.0**	**1.0**	**9.2**
EUROPE MEAN Girls ≥10y	**7.7**	**64**	**233**	**95**	**58**	**17**	**71**	**25**	**26**	**13**	**1.1**	**1.3**	**11.4**
EUROPE MEAN Boys ≥10y	**9.4**	**80**	**281**	**113**	**63**	**18**	**86**	**30**	**31**	**15**	**1.4**	**1.5**	**13.1**

* Where mean intakes were reported by a country for more than one age group <10 years, or more than one age group ≥10 years, the number of children/adolescents surveyed in the national diet survey for each age group and gender were used to weight the reported means to produce estimate mean intakes for those aged <10y and those aged ≥10y for each nutrient.
Countries that span the 10y boundary are: Cyprus (9-13.9y); Ireland (9-12y); Latvia (7-16y); the Netherlands (9-13y); Spain (9-12y); Turkey (9-11y) and the UK (4-10y).
For each nutrient regional weighted means for North, West and Central & Eastern Europe and Europe overall were calculated by weighting the <10y and >=10y country means shown in the table by the total child population in that country (22-24).

Table 4.2: Estimated means* for <10y and ≥10y by country and region for micronutrients in 21 national dietary surveys in the WHO Europe region

SURVEY	Total folate (µg)	Vitamin B12 (µg)	Vitamin D (µg)	Calcium (mg)	Potassium (mg)	Sodium (mg)	Iron (mg)	Iodine (µg)	Zinc (mg)
Bulgaria (1-4y)	**National survey on nutrition of infants and children under 5 and family child rearing 2007**								
Girls <10y	117	2.3	2.1	541		1637	5.7		5.9
Boys <10y	117	2.3	2.1	541		1639	5.7		5.9
Girls ≥10y									
Boys ≥10y									
Cyprus (6-8.9y; 9-18.9y)	**A study of the dietary intake of Cypriot children and adolescents aged 6-18 years 2009-10**								
Girls <10y				930	2311	2283	10.9		
Boys <10y				957	2337	2331	11.4		
Girls ≥10y				866	2161	2292	10.5		
Boys ≥10y				974	2432	2699	12.2		
Estonia (2-9y; 10-17y)	**National Dietary Survey 2014-15**								
Girls <10y	142	3.8	2.0	671	2449	1147	8.1	108	6.7
Boys <10y	150	4.7	2.4	738	2689	1314	9.1	122	7.6
Girls ≥10y	156	4.4	2.2	666	2657	1448	9.6	109	7.2
Boys ≥10y	191	5.5	3.3	888	3421	2085	12.4	150	10.2
Latvia (7-16y)	**Latvian National Food Consumption Survey 2007-09**								
Girls <10y									
Boys <10y									
Girls ≥10y						2000			
Boys ≥10y						2840			
Slovenia (15-16y)	**Dietary Intake of Macro- and Micronutrients in Slovenian Adolescents 2012**								
Girls <10y									
Boys <10y									
Girls ≥10y	276	5.9	4.0	1176	3770	4191	16.0	205	12.4
Boys ≥10y	255	6.7	4.0	1094	3494	4059	16.0	181	13.5
Turkey (2-8y; 9-18y)	**Turkey nutrition and health survey 2010 (TNHS)**								
Girls <10y	200	2.1	0.9	520	1665	1048	7.0	45	5.9
Boys <10y	205	2.4	1.1	550	1729	1114	7.4	48	6.4
Girls ≥10y	282	3.6	0.9	553	2065	1591	9.6	53	8.0
Boys ≥10y	327	4.4	1.1	618	2279	2009	10.9	59	9.4
CEEC MEAN Girls <10y	**195**	**2.1**	**1.0**	**526**	**1679**	**1087**	**6.9**	**46**	**5.9**
CEEC MEAN Boys <10y	**200**	**2.4**	**1.1**	**554**	**1744**	**1151**	**7.3**	**49**	**6.4**
CEEC MEAN Girls ≥10y	**280**	**3.6**	**1.0**	**566**	**2097**	**1640**	**9.7**	**56**	**8.0**
CEEC MEAN Boys ≥10y	**324**	**4.4**	**1.2**	**631**	**2310**	**2058**	**11.0**	**62**	**9.5**

Denmark (4-9y, 10-17y)	**Danish National Survey of Diet and Physical Activity (DANSDA) 2011-20132011-2013**								
Girls <10y	270	5.1	2.5	906	2500	2800	8.4	210	8.9
Boys <10y	289	5.6	2.8	1052	2700	3100	9.4	233	9.8
Girls ≥10y	254	4.3	2.4	910	2500	3000	8.3	213	9.1
Boys ≥10y	307	6.0	3.1	1183	3100	3900	10.8	249	12.4
Norway (4-9y, 13y)	**Ungkost3 2015-16**								
Girls <10y	168	4.5	3.6	729	2127	2067	6.6		
Boys <10y	183	5.1	3.8	821	2377	2255	8.2		
Girls ≥10y	183	4.9	3.5	753	2300	2300	8.0		
Boys ≥10y	210	5.9	4.3	918	2700	2700	9.0		
NORTH MEAN Girls <10y	**221**	**4.8**	**3.0**	**820**	**2319**	**2445**	**7.5**	**210**	**8.9**
NORTH MEAN Boys <10y	**237**	**5.3**	**3.3**	**940**	**2544**	**2691**	**8.8**	**233**	**9.8**
NORTH MEAN Girls ≥10y	**220**	**4.6**	**2.9**	**834**	**2403**	**2661**	**8.2**	**213**	**9.1**
NORTH MEAN Boys ≥10y	**260**	**6.0**	**3.7**	**1055**	**2906**	**3319**	**9.9**	**249**	**12.4**
Austria (7-9y, 10-14y)	**Austrian nutrition report (OSES) 2010-12**								
Girls <10y	171	3.5	1.7	739	2259	3320	9.4	102	8.5
Boys <10y	164	3.7	2.1	876	2270	3520	9.7	111	8.8
Girls ≥10y	141	3.7	1.4	683	1939	3339	8.6	88	8.1
Boys ≥10y	164	4.0	1.5	733	2214	3750	10.5	101	9.4
Belgium (3-9y, 10-17y)	**The Belgian National Food Consumption Survey (BNFCS) 2014-15**								
Girls <10y	166	3.5	3.2	670		1645	6.8	115	
Boys <10y	180	4.4	3.4	731		1803	7.7	118	
Girls ≥10y	183	3.6	3.3	681		1940	7.8	117	
Boys ≥10y	209	4.6	3.6	786		2406	9.7	141	
France (0-10y, 11-17y)	**Individual National Food Consumption Survey (INCA3) 2014-15**								
Girls <10y	228	3.5	6.4	801	2020	1691	2.4	110	6.6
Boys <10y	243	3.7	5.5	857	2224	1860	4.6	121	7.0
Girls ≥10y	270	3.9	2.8	681	2538	2352	8.9	122	7.7
Boys ≥10y	300	5.0	3.0	786	2814	2832	10.7	146	9.6
Germany (14-18y)	**German National Nutrition Survey (Nationale Verzehrstudie) II (NVSII) 2005-07**								
Girls <10y									
Boys <10y									
Girls ≥10y	340	4.0	2.0	1023	3011	2471	12.1	171	9.3
Boys ≥10y	410	6.3	2.7	1277	3655	3535	15.6	231	12.7
Ireland (1-8y, 9-17y)	**National pre-school nutrition survey 2010-11; National children’s nutrition survey 2003-04; National teens nutrition survey 2005-06**								
Girls <10y	188	4.1	2.9	789	1750	1193	7.8	156	5.6
Boys <10y	195	4.1	3.0	808	1750	1193	8.1	156	5.8
Girls ≥10y	222	4.1	2.3	764			9.9		6.8

Boys ≥10y	322	5.6	2.7	1028			13.0		9.1
Italy (0-9.9y, 10-17.9y)	**The third Italian National food consumption survey INRAN-SCAI 2005-06**								
Girls <10y		5.0	2.0	731	2235		8.6		9.0
Boys <10y		5.0	2.0	731	2235		8.6		9.0
Girls ≥10y		4.1	2.4	770	3123		10.6		10.9
Boys ≥10y		5.6	2.6	892	2737		12.2		13.3
Netherlands (2-8y, 9-18y)	**Dutch National Food Consumption Survey – young children (DNFCS) 2008; Dutch National Food Consumption Survey (DNFCS) 2007-2010**								
Girls <10y	117	2.7	2.2	756	2357		6.7		5.6
Boys <10y	183	2.8	2.4	832	2362		6.9		5.9
Girls ≥10y	193	3.3	2.4	881	2562	2297	8.5	150	8.5
Boys ≥10y	233	4.1	3.0	1018	3036	2804	9.9	193	10.1
Portugal (0-9y, 10-17y)	**National Food and Physical Activity Survey (IAN-AF) 2015-16**								
Girls <10y	192	2.7	6.3	781	2504	1638	8.5		6.9
Boys <10y	193	2.7	6.7	851	2539	1643	8.9		7.1
Girls ≥10y	222	4.5	3.5	757	2891	2731	16.0		9.7
Boys ≥10y	252	5.1	4.3	922	3409	3255	16.0		12.1
Spain (9-17y)	**ANIBES 2013**								
Girls <10y									
Boys <10y									
Girls ≥10y									
Boys ≥10y									
UK (1.5-10y, 11-18y)	**National Diet and Nutrition Survey Rolling Programme (NDNS RP) Y1-4 2008-12**								
Girls <10y	175	3.8	1.9	780	1989	1625	7.7	134	5.9
Boys <10y	185	4.0	2.0	807	2081	2196	8.2	141	6.2
Girls ≥10y	186	3.6	1.9	670	2065	1902	8.4	109	6.3
Boys ≥10y	233	4.4	2.4	889	2536	2960	10.7	141	8.3
WEST MEAN Girls <10y	**190**	**3.8**	**3.5**	**768**	**2106**	**1715**	**6.3**	**122**	**6.9**
WEST MEAN Boys <10y	**206**	**4.0**	**3.3**	**808**	**2198**	**2026**	**7.2**	**130**	**7.2**
WEST MEAN Girls ≥10y	**251**	**4.3**	**2.3**	**824**	**2640**	**2286**	**9.9**	**133**	**8.4**
WEST MEAN Boys ≥10y	**298**	**5.2**	**2.8**	**1002**	**2948**	**3078**	**12.1**	**170**	**10.8**
EUROPE MEAN Girls <10y	**193**	**3.3**	**2.7**	**691**	**1974**	**1492**	**6.6**	**93**	**6.6**
EUROPE MEAN Boys <10y	**205**	**3.5**	**2.6**	**729**	**2062**	**1702**	**7.3**	**99**	**6.9**
EUROPE MEAN Girls ≥10y	**259**	**4.1**	**2.0**	**755**	**2481**	**2095**	**9.8**	**109**	**8.3**
EUROPE MEAN Boys ≥10y	**304**	**5.0**	**2.4**	**903**	**2768**	**2765**	**11.8**	**137**	**10.4**

* Where mean intakes were reported by a country for more than one age group <10 years, or more than one age group ≥10 years, the number of children/adolescents surveyed in the national diet survey for each age group and gender were used to weight the reported means to produce estimate mean intakes for those aged <10y and those aged ≥10y for each nutrient.
Countries that span the 10y boundary are: Cyprus (9-13.9y); Ireland (9-12y); Latvia (7-16y); the Netherlands (9-13y); Spain (9-12y); Turkey (9-11y) and the UK (4-10y).
For each nutrient regional weighted means for North, West and Central & Eastern Europe and Europe overall were calculated by weighting the <10y and >=10y country means shown in the table by the total child population in that country (22-24).

Appendix 1 – Reported mean macronutrient intakes for children and adolescents in European national dietary surveys

COUNTRY	SURVEY	YEAR	Energy (MJ)	Energy (Kcal)	Protein (g)	CHO (g)	Sugars (g)	Sucrose (g)	Fibre (g)	Total fat (g)	Saturated fats (g)	MUFA (g)	PUFA (g)	TFAs (g)	n-3 (g)	n-6 (g)
Austria	**Austrian nutrition report**	2010-2012														
	female: 7-9y		8.0	1910	62	248		53	17.0	72	31.8	23.3	12.7		1.5	10.0
	female: 10-12y		7.2	1731	61	225		48	17.0	63	28.9	21.2	9.6		1.1	8.8
	female: 13-14y		7.5	1783	67	214		49	14.0	73	31.7	23.8	11.9		1.3	10.3
	male: 7-9y		8.0	1920	62	245		58	18.0	73	34.1	23.5	10.7		1.3	9.6
	male: 10-12y		8.1	1940	68	247		49	18.0	73	30.2	23.7	12.9		1.3	10.8
	male: 13-14y		8.6	2058	72	247		51	16.0	82	34.3	27.4	16.0		1.9	12.8
Belgium	**The Belgian food consumption survey 2014-15**	2014-2015														
	female: 3-5y		5.6	1329	46	166	92		12.9	50	20.0	18.0	8.0	0.6		
	female: 6-9y		6.8	1633	56	204	105		14.2	64	25.0	23.0	11.0	0.7		
	female: 10-13y		7.6	1812	63	219	107		15.2	72	27.0	26.0	12.0	0.7		
	female: 14-17y		8.0	1904	66	223	106		15.8	76	28.0	28.0	13.0	0.8		
	male: 3-5y		5.9	1406	48	179	100		12.3	52	21.0	18.0	8.0	0.6		
	male: 6-9y		7.6	1824	63	227	120		14.3	70	28.0	26.0	11.0	0.8		
	male: 10-13y		9.0	2149	75	260	131		15.9	85	32.0	31.0	14.0	0.9		
	male: 14-17y		9.9	2369	83	280	135		17.0	92	33.0	34.0	16.0	0.9		
Bulgaria	**National survey on nutrition of infants and children under 5 and family child rearing, 2007**	2007														
	female: 1y		5.0	1185	43	159	27		11.5	50	14	10.4	8.4			
	female: 2y		5.7	1370	43	159	27		11.5	50	14	10.4	8.4			
	female: 3y		6.3	1496	51	191	35		14.6	68	15	11.7	10.3			
	female: 4y		6.6	1579	51	191	35		14.6	68	15	11.7	10.3			
	male: 1y		5.0	1206	43	159	27		11.5	50	14	10.4	8.4			
	male: 2y		5.9	1409	43	159	27		11.5	50	14	10.4	8.4			
	male: 3y		6.7	1592	55	191	35		14.6	68	15	11.7	10.3			
	male: 4y		7.2	1718	55	191	35		14.6	68	15	11.7	10.3			
Cyprus	**A study of the dietary intake of Cypriot children and**															

	adolescents aged 6-18 years															
	female: 6-8.9y		7.6	1811	73	223			14.6	69	27.6	30.4	9.7			
	female: 9-13.9y		7.5	1793	74	209			14.0	73	28.7	32.9	10.6			
	female: 14-18.9y		7.5	1781	73	205			14.1	74	28.3	33.6	10.7			
	male: 6-8.9y		7.8	1856	75	226			14.8	72	28.9	31.3	10.3			
	male: 9-13.9y		7.9	1898	82	221			14.7	76	29.5	34.0	11.4			
	male: 14-18.9y	2009-2010	9.1	2180	96	231			15.2	96	37.1	43.8	14.3			
Denmark	**Danish Dietary habits 2011-2013**															
	female: 4-9y		7.7	1840	64	220		46	19.0	73	29.0	26.0	11.0	1.2		
	female: 10-17y		7.8	1864	67	222		53	17.0	73	30.0	26.0	11.0	1.1		
	male: 4-9y	2011-	8.5	2032	71	243		50	21.0	80	32.0	28.0	13.0	1.3		
	male: 10-17y	2013	9.9	2366	90	277		67	20.0	94	38.0	34.0	14.0	1.4		
Estonia	**National Dietary Survey**															
	female: 2-5y				48											
	female: 6-9y				56			56			26.7	20.9	8.7	0.5	1.3	6.7
	female: 10-13y		6.7	1602	54	214		55	14.2	61	26.6	20.4	8.9	0.5	1.2	7
	female: 14-17y		6.6	1568	56	199		51	14.4	63	25.3	22.3	10.6	0.4	1.6	8.4
	male: 2-5y				51											
	male: 6-9y				67			61			30.4	23.7	9.9	0.6	1.4	7.6
	male: 10-13y	2014-	8.3	1993	73	252		59	16.3	79	32.8	27.9	12.9	0.6	2	10.2
	male: 14-17y	2015	9.4	2242	85	288		66	20.4	87	35.7	30.8	14.7	0.6	2.5	11.6
France	**INCA3**	2014-														
	female: 0-10y	2015	6.0	1433	53	176	95		12.7	54	24.3	17.8	6.4		0.9	4.7
	female: 11-17y		7.6	1818	70	226	98		16.1	66	27.9	22.4	8.5		1.0	6.2
	male: 0-10y		6.6	1574	58	199	103		13.8	57	25.7	18.9	6.6		0.8	5.0
	male: 11-17y		8.9	2123	83	262	111		18.1	77	33.0	26.1	9.9		1.1	7.3
Germany	**German National Nutrition Survey II**															
	female: 14-18y	2005-	8.8	2108	66	274			23.2	77						
	male: 14-18y	2007	12.1	2883	94	355			26.0	110						
Ireland	**National Pre-school Nutrition Survey**	2010-2011														

	1y		4.2	1005	39	126	70	25	10.5	38	17.7	13.6	4.2		0.6	
	2y		4.7	1122	43	146	74	33	11.6	42	18.8	14.0	5.4		0.7	
	3y		4.8	1148	43	154	76	41	12.0	41	18.9	13.8	5.5		0.6	
	4y		5.3	1264	47	171	84	49	12.8	45	20.0	15.2	6.3		0.7	
Ireland	**National children's Food Survey**															
	female: 5-12y		6.7	1601	54	217			8.8	61	26.2	20.8	9.0			
	female: 5-8y		6.4	1517	52	208			8.5	58	25.6	19.6	8.3			
	female: 9-12y		7.0	1654	56	227			9.2	63	26.9	21.9	9.6			
	male: 5-12y		7.4	1759	60	246			10.0	66	28.4	22.5	9.4			
	male: 5-8y	2003-	6.8	1625	55	226			9.2	61	26.5	20.6	8.6			
	male: 9-12y	2004	8.0	1890	64	264			10.8	70	30.3	24.3	10.2			
Ireland	**National Teens' Food Survey**															
	female: 13-17y		7.1	1696	60	222			10.1	68	27.2	24.4	11.1			
	female: 13-14y		7.0	1674	59	220			9.7	67	27.0	24.2	10.7			
	female: 15-17y		7.2	1712	61	223			10.3	69	27.3	24.5	11.5			
	male: 13-17y		9.5	2256	86	293			13.1	89	36.7	31.6	14.0			
	male: 13-14y	2005-	9.0	2137	82	277			12.3	85	35.3	29.7	13.2			
	male: 15-17y	2006	9.9	2344	88	304			13.7	92	37.7	33.0	14.7			
Italy	**The third Italian National food consumption survey INRAN-SCAI**															
	all: 0-2.9		4.7	1113	42	147	71		8.2	44	16.6	19.1	4.7			
	all: 3-9.9		8.0	1914	74	240	86		14.4	80	25.4	37.0	9.8			
	female: 10-17.9	2005-	8.7	2091	82	263	88		16.4	86	26.8	40.3	11.1			
	male: 10-17.9	2006	10.8	2576	99	327	108		18.1	105	33.1	49.0	13.7			
Latvia	**Latvian National Food Consumption Survey 2007-2009**															
	female: 7-16y	2007-	6.9	1660												
	male: 7-16y	2009	8.2	1948												
Netherlands	**Dutch National Food Consumption Survey – young children (DNFCS) 2008**															
	female: 2-3y	2008	5.5	1308	43	187	119		12.0	43	16.0			1.1		

	female: 4-6y		6.2	1479	46	209	129		13.0	51	20.0			1.4		
	male: 2-3y		5.8	1375	44	196	124		13.0	46	18.0			1.2		
	male: 4-6y		6.7	1587	51	222	135		14.0	55	21.0			1.4		
Netherlands	**Dutch National Food Consumption Survey (DNFCS) 2007-2010**															
	female: 7-8y		8.4	2011	51	255	140		15.0	76	29.0	17.0	8.0			
	female: 9-13y		8.6	2042	63	262	141		15.9	78	29.4	20.0	9.0		1.4	11.7
	female: 14-18y		8.5	2028	68	253	127		17.5	75	28.7	23.0	10.0		1.5	11.6
	male: 7-8y		8.1	1929	56	258	141		16.0	71	27.0	18.0	8.0			
	male: 9-13y	2007-	10.0	2275	74	292	154		17.8	86	32.3	23.0	10.0		1.6	13.3
	male: 14-18y	2010	11.3	2690	83	332	164		21.4	102	37.3	27.0	11.0		1.9	16.7
Norway	**Ungkost3**															
	female: 4y		5.5	1315	51	158		28	14.0	50	21.0	17.0	8.0			
	female: 9y		6.9	1649	63	207		51	15.0	60	25.0	20.0	9.0			
	female: 13y		7.4	1769	68	219		60	15.0	66	27.0	23.0	10.0			
	male: 4y		6.1	1458	56	176		30	16.0	54	23.0	18.0	8.0			
	male: 9y	2015-	7.8	1864	74	228		53	17.0	68	28.0	23.0	10.0			
	male: 13y	2016	8.6	2055	83	247		64	17.0	76	31.0	27.0	11.0			
Portugal	**National Food and Physical Activity Survey (IAN-AF)**															
	female: <10y		5.7	1361	57.9	175	89		12.8	46	21.0	20.5	7.2	0.7		5.9
	female: 10-17y		7.9	1872	82.8	219	88		16.1	67	28.7	27.0	11.0	1.2		10.5
	male: <10y	2015-	5.9	1392	56.2	180	90		13.2	47	21.0	20.9	7.4	0.7		6.9
	male: 10-17y	2016	9.7	2303	103.5	273	107		18.2	81	34.9	31.8	13.1	1.5		13.1
Slovenia	**Dietary Intake of Macro- and Micronutrients in Slovenian Adolescents**															
	female: 15-16y		9.7	2312	86	379	195	110	31.0	82	35.0	29.0	17.0			
	male: 15-16y	2012	12.7	3043	96	370	170	103	28.0	82	36.0	30.0	16.0			
Spain	**ANIBES**															
	female: 9-12y		7.9	1893	73	209	88		12.2	82	27.5	33.6	14.0			
	female: 13-17y		7.6	1823	71	206	87		11.2	77	25.2	31.2	13.4			
	male: 9-12y		8.4	2006	81	218	94		11.5	87	29.6	35.8	14.2			
	male: 13-17y	2013	8.9	2124	85	235	91		12.1	91	30.0	37.3	15.4			
Turkey	**Turkey nutrition and**	2010														

	health survey 2010 (TNHS)															
	female: 2-5y		5.0	1190	37	148			11.5	49	16.9	15.8	12.5		0.9	11.5
	female: 6-8y		6.3	1510	45	193			15.8	60	19.6	19.0	16.9		1.2	15.6
	female: 9-11y		7.0	1679	51	218			18.3	64	21.5	21.8	16.5		1.2	15.1
	female: 12-14y		7.2	1723	51	221			18.8	68	22.1	22.6	18.5		1.3	17.2
	female: 15-18y		7.1	1701	49	221			18.9	65	20.5	21.6	18.6		1.2	17.3
	male: 2-5y		5.2	1253	39	152			12.0	52	17.9	16.9	13.6		1.0	12.6
	male: 6-8y		6.6	1587	49	202			16.1	62	21.1	20.1	16.8		1.1	15.6
	male: 9-11y		7.0	1677	52	211			17.5	66	22.4	21.8	17.6		1.2	16.3
	male: 12-14y		8.4	2017	62	261			21.1	77	25.5	25.4	20.5		1.4	18.9
	male: 15-18y		9.6	2288	68	300			23.2	85	28.7	29.2	21.4		1.6	19.7
UK	**National Diet and Nutrition Survey (NDNS) Years 1-4**															
	Children: 1.5-3y		4.8	1126	43	151	76		8.2	43	18.5	14.4	5.8	0.8	0.9	4.9
	females: 4-10y		6.3	1489	53	205	95		10.7	56	22.3	20.0	8.7	1.1	1.3	7.4
	females: 11-18y		6.6	1569	56	211	90		10.7	60	21.7	22.7	10.1	1.1	1.6	8.5
	males: 4-10y	2008-2012	6.6	1573	57	219	100		11.5	58	23.0	21.0	9.0	1.1	1.4	7.6
	males: 11-18y		8.3	1972	74	265	116		12.8	74	27.8	27.6	11.9	1.4	1.9	10.0

Appendix 2 – Reported mean micronutrient intakes for children and adolescents in European national dietary surveys

COUNTRY	SURVEY	YEAR	Total folate (µg)	Vitamin B12 (µg)	Vitamin D (µg)	Calcium (mg)	Potassium (mg)	Sodium (mg)	Iron (mg)	Iodine (µg)	Zinc (mg)
Austria	**Austrian nutrition report**	2010-2012									
	female: 7-9y		171	3.5	1.7	739	2259	3320	9.4	102	8.5
	female: 10-12y		142	3.6	1.2	675	1969	3560	8.7	89	8.0
	female: 13-14y		137	4.1	1.8	704	1867	2800	8.5	87	8.5
	male: 7-9y		164	3.7	2.1	876	2270	3520	9.7	111	8.8
	male: 10-12y		169	4.0	1.5	753	2215	3800	10.5	103	9.4
	male: 13-14y		143	3.9	1.4	649	2211	3540	10.3	94	9.4
Belgium	**The Belgian food consumption survey 2014-15**	2014-2015									
	female: 3-5y		157	3.5	3.2	667		1511	6.4	114	
	female: 6-9y		174	3.6	3.2	672		1765	7.2	115	
	female: 10-13y		181	3.6	3.3	678		1905	7.7	116	
	female: 14-17y		185	3.6	3.3	684		1983	8.0	118	
	male: 3-5y		170	4.3	3.4	715		1555	7.2	111	
	male: 6-9y		189	4.4	3.4	744		2018	8.1	124	
	male: 10-13y		204	4.5	3.5	774		2318	9.4	136	
	male: 14-17y		214	4.6	3.6	799		2499	10.1	146	
Bulgaria	**National survey on nutrition of infants and children under 5 and family child rearing, 2007**	2007									
	female: 1y		104	2.1	3.4	536		1400	5.0		5.2
	female: 2y		104	2.1	3.4	536		1400	5.0		5.2
	female: 3y		129	2.5	0.8	547		1873	6.3		6.5
	female: 4y		129	2.5	0.8	547		1873	6.3		6.5
	male: 1y		104	2.1	3.4	536		1400	5.0		5.2
	male: 2y		104	2.1	3.4	536		1400	5.0		5.2
	male: 3y		129	2.5	0.8	547		1873	6.3		6.5
	male: 4y		129	2.5	0.8	547		1873	6.3		6.5
Cyprus	**A study of the dietary intake of Cypriot children and adolescents aged 6-18 years**										
	female: 6-8.9y					930	2311	2283	10.9		
	female: 9-13.9y					876	2166	2289	10.7		
	female: 14-18.9y					859	2158	2294	10.4		

	male: 6-8.9y					957	2337	2331	11.4		
	male: 9-13.9y					929	2364	2515	11.5		
	male: 14-18.9y	2009-2010				1028	2515	2924	13.0		
Denmark	**Danish Dietary habits 2011-2013**										
	female: 4-9y		270	5.1	2.5	966	2500	2800	8.4	210	8.9
	female: 10-17y		254	4.3	2.4	910	2500	3000	8.3	213	9.1
	male: 4-9y		289	5.6	2.8	1052	2700	3100	9.4	233	9.8
	male: 10-17y	2011-2013	307	6.0	3.1	1183	3100	3900	10.8	249	12.4
Estonia	**National Dietary Survey**										
	female: 2-5y		134	3.7	2.0	640	2300	1056	7.6	103	6.3
	female: 6-9y		155	3.9	2.1	724	2700	1299	9.0	116	7.3
	female: 10-13y		149	4.2	1.8	715	2600	1467	9.5	116	7.0
	female: 14-17y		162	4.5	2.5	630	2700	1434	9.6	104	7.4
	male: 2-5y		135	3.6	1.9	664	2500	1171	8.0	107	6.8
	male: 6-9y		175	6.4	3.1	861	3000	1549	11.0	148	8.9
	male: 10-13y		182	5.5	3.3	871	3100	1990	11.8	144	9.5
	male: 14-17y	2014-2015	201	5.4	3.2	907	3800	2196	13.2	157	11.0
France	**INCA3**	2014-2015									
	female: 0-10y		228	3.5	6.4	801	2020	1691	7.7	110	6.6
	female: 11-17y		270	3.9	2.8	859	2538	2352	8.9	122	7.7
	male: 0-10y		243	3.7	5.5	857	2224	1860	8.7	121	7.0
	male: 11-17y		300	5.0	3.0	996	2814	2832	10.7	146	9.6
Germany	**German National Nutrition Survey II**										
	female: 14-18y		340	4.0	2.0	1023	3011	2471	12.1	171	9.3
	male: 14-18y	2005-2007	410	6.3	2.7	1277	3655	3535	15.6	231	12.7
Ireland	**National Pre-school Nutrition Survey**										
	1y		159	4.1	4.2	840	1716	918	7.0	182	5.4
	2y		180	4.2	3.4	786	1724	1186	7.6	162	5.4
	3y		188	3.8	3.0	718	1732	1250	7.2	139	5.2
	4y	2010-2011	189	4.0	2.8	748	1830	1421	7.8	142	5.5
Ireland	**National children's Food Survey**										
	female: 5-12y		207	4.2	2.3	808			8.5		6.2
	female: 5-8y		204	4.3	2.2	815			8.4		6.0
	female: 9-12y	2003-2004	210	4.1	2.3	801			8.7		6.4

	male: 5-12y		243	4.7	2.2	918			10.3		7.1
	male: 5-8y		224	4.3	2.3	869			9.3		6.4
	male: 9-12y		261	5.0	2.2	965			11.2		7.6
Ireland	**National Teens' Food Survey**										
	female: 13-17y		230	4.2	2.3	738			10.7		7.2
	female: 13-14y		221	4.1	2.3	725			12.4		7.0
	female: 15-17y		236	4.2	2.4	748			9.4		7.2
	male: 13-17y		320	6.0	3.0	1070			14.1		10.2
	male: 13-14y		396	6.0	2.8	1004			12.3		10.0
	male: 15-17y	2005-2006	338	6.1	3.1	1118			15.5		10.3
Italy	**The third Italian National food consumption survey INRAN-SCAI**										
	all: 0-2.9			2.6	1.8	664	1471		5.4		5.6
	all: 3-9.9			5.7	2.0	749	2441		9.4		9.9
	female: 10-17.9			6.5	2.4	770	2737		10.6		10.9
	male: 10-17.9	2005-2006		6.9	2.6	892	3123		12.2		13.3
Latvia	**Latvian National Food Consumption Survey 2007-2009**										
	female: 7-16y							2000			
	male: 7-16y	2007-2009						2840			
Netherlands	**Dutch National Food Consumption Survey – young children (DNFCS) 2008**										
	female: 2-3y		104	2.6	1.8	734			6.1		5.0
	female: 4-6y		107	2.5	1.9	748			6.7		5.2
	male: 2-3y		107	2.6	1.8	788			6.1		5.2
	male: 4-6y	2008	119	2.9	2.2	854			7.1		5.9
Netherlands	**Dutch National Food Consumption Survey (DNFCS) 2007-2010**										
	female: 7-8y		164	3.3	2.3	817	2357		7.8		7.7
	female: 9-13y		179	3.3	2.4	892	2502	2257	8.2	141	8.2
	female: 14-18y		207	3.3	2.4	870	2622	2336	8.7	150	8.7
	male: 7-8y		161	3.0	2.3	878	2362		8.1		7.5
	male: 9-13y		202	3.7	2.8	943	2757	2544	9.2	164	9.1
	male: 14-18y	2007-2010	264	4.5	3.2	1093	3314	3064	10.6	193	11.1
Norway	**Ungkost3**										
	female: 4y	2015-	157	4.5	3.5	682	2000	1800	6.0		
	female: 9y	2016	175	4.5	3.6	756	2200	2220	7.0		

	female: 13y		183	4.9	3.5	753	2300	2300	8.0		
	male: 4y		169	4.7	3.3	757	2200	1900	7.0		
	male: 9y		192	5.3	4.1	866	2500	2500	9.0		
	male: 13y		210	5.9	4.3	918	2700	2700	9.0		
	National Food and Physical Activity Survey (IAN-AF)										
	female: <10y		191.5	2.7	6.3	781	2504	1638	8.5		6.9
	female: 10-17y		222.4	4.5	3.5	757	2891	2731	10.7		9.7
	male: <10y	2015-	192.9	2.7	6.7	851	2539	1643	8.9		7.1
Portugal	male: 10-17y	2016	251.8	5.1	4.3	922	3409	3255	12.1		12.1
Slovenia	**Dietary Intake of Macro- and Micronutrients in Slovenian Adolescents**										
	female: 15-16y		276	5.9	4.0	1167	3770	4191	16.0	205	12.4
	male: 15-16y	2012	255	6.7	4.0	1094	3494	4059	16.0	181	13.5
	ANIBES										
	female: 9-12y										
Spain	female: 13-17y										
	male: 9-12y										
	male: 13-17y	2013									
	Turkey nutrition and health survey 2010 (TNHS)										
	female: 2-5y		188	2.0	0.9	515	1593	971	6.6	44	5.6
	female: 6-8y		241	2.2	1.1	540	1925	1324	8.3	50	7.1
	female: 9-11y		277	2.3	0.9	549	2087	1587	9.6	52	7.9
Turkey	female: 12-14y		284	2.1	1.0	545	2049	1636	9.6	52	8.0
	female: 15-18y		284	2.3	0.8	562	2059	1560	9.7	54	8.0
	male: 2-5y		195	2.3	0.9	549	1675	1019	7.0	47	6.1
	male: 6-8y		243	2.9	1.6	553	1924	1453	8.7	51	7.5
	male: 9-11y		281	2.9	1.0	554	2039	1599	9.3	53	8.1
	male: 12-14y		344	3.4	1.2	603	2388	2009	11.5	56	9.5
	male: 15-18y	2010	359	3.1	1.1	697	2430	2428	12.1	68	10.5
	National Diet and Nutrition Survey (NDNS) Years 1-4										
	Children: 1.5-3y		150	3.9	1.9	773	1796	1307	6.3	142	5.2
UK	females: 4-10y		188	3.7	1.9	783	2084	1782	8.4	130	6.2
	females: 11-18y		186	3.5	1.9	670	2065	2600	8.4	109	6.3
	males: 4-10y	2008-	201	4.0	2.0	823	2211	1902	9.0	141	6.6
	males: 11-18y	2012	233	4.7	2.4	889	2536	2960	10.7	141	8.3

Chapter 6 Inequalities in education and national income are associated with poorer diet: pooled analysis of individual participant data across 12 European countries

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6.1 Abstract

Background:

Malnutrition linked to noncommunicable diseases (NCDs) presents major health problems across Europe. The World Health Organisation (WHO) encourages countries to conduct national dietary surveys to obtain data to inform public health policies designed to prevent NCDs.

Methods:

Data on 27334 participants aged 19-64y were harmonised and pooled across national dietary survey datasets from 12 countries across the WHO European Region. Weighted mean nutrient intakes were age-standardised to the Eurostat 2013 European Standard Population (ESP). Associations between country-level Gross Domestic Product (GDP) and key nutrients and nutrient densities were investigated using linear regression. The potential mitigating influence of participant-level educational status was explored, allowing for survey sampling methods used.

Findings:

Higher GDP was positively associated with total sugar intake (5·0% energy, 95% CI 0·6, 9·3). Scandinavian countries had the highest vitamin D intakes. Participants with higher educational status had better nutritional status, particularly within lower

GDP countries. A 10% higher GDP was associated with lower total fat intakes (-0·2% energy, 95% CI -0·3, -0·1) and higher daily total folate intakes (14µg, 95% CI 12, 16) in higher educated individuals.

Interpretation:

Lower income countries and lower education groups had poorer diet, particularly for micronutrients. We demonstrate for the first time that higher educational status appeared to have a mitigating effect on poorer diet in lower income countries. It illustrates the feasibility and value of harmonising national dietary survey data to inform European policy regarding access to healthy diets, particularly in disadvantaged groups. It specifically highlights the need for strong policies supporting nutritional status, prioritising lower education groups and lower income countries.

6.2 Introduction

Malnutrition in the form of both nutrient deficiencies and over-nutrition related non-communicable diseases (NCDs) like overweight, obesity and cardiovascular disease (CVD) has been documented as reaching epidemic proportions on an international scale. Global obesity tripled between 1975-2016 (1). In Europe 45% of deaths are attributable to CVD, with diet being the primary behavioural risk factor (2). There is evidence that iron, calcium, vitamin D, folate and iodine are inadequately consumed in European children (3) and adults (4). The World Health Organisation (WHO) has developed nutrient intake guidelines underpinned by the e-library of Evidence for Nutrition Actions (eLENA), which can form the basis of monitoring programmes, and assist governments in formulating policy to improve diet quality.

The WHO European Food and Nutrition Action Plan aims to reduce the impact of malnutrition in the WHO European region, starting with more effective monitoring through national dietary surveys (5). Monitoring enables the identification of trends, dietary inadequacies and inequalities, which can help inform and evaluate more targeted policies to improve population health across the WHO European Region. Current monitoring within the region is incomplete, with particularly sparse coverage of Central and Eastern Europe (6). This is concerning, as nutrition policies in these countries may therefore lack an appropriate evidence base.

WHO recommended nutrient intakes (RNIs) of both macro and micronutrients are not widely achieved (4). Despite evidence that higher socioeconomic status is associated with better diet quality globally (7, 8), few WHO European Member States report intakes by socioeconomic group (4); this information would facilitate monitoring of potential health inequalities (5).

This research therefore aims to harmonise national individual level dietary survey data from across the WHO European Region, exploring geographical variations in key nutrient intakes, standardised to the European Standard Population (ESP). It also aims to investigate both between and within-country socioeconomic inequalities through measures of country-level Gross Domestic Product (GDP) and individual-level education.

6.3 Methods

6.3.1 Harmonisation and Pooling of National Surveys

National dietary surveys were identified from published summary reports, as previously reported in detail (6). For countries where surveys were available, individual-level nutrient intake and demographic data were requested between October 2016 and April 2018. Survey data was obtained from 12 datasets across 12 countries (Austria; Denmark; Estonia; Finland; France; Germany; Hungary; Kazakhstan; Macedonia; the Netherlands; Sweden; the UK). See appendix 1 for details of surveys obtained.

Macronutrients were expressed as % energy (%E), to reduce variation caused by differences in methodology or reporting (9). Micronutrient intakes are from food only, excluding supplements. As differing numbers of dietary assessment days were collected, a mean value per individual was calculated. Children and the elderly were not included in all surveys sampled, and were therefore excluded to focus on adults aged 19-64y. Countries were grouped into three European regions: Central and Eastern, Northern, and Western.

Education level was harmonised across surveys, grouping into lower, intermediate and higher educational levels. Lower education comprised any education below secondary school level, intermediate included secondary school, college and vocational equivalents, and higher education incorporated any education beyond secondary school or college level. In the Finnish data, education was categorised by the total number of education years into sex and birth year-specific tertiles, to adjust for the number of years in education rather than educational attainment.

All analyses used sampling weights based on the inverse of the probability that the participant was sampled. Nine countries included a weighting variable within the dataset. Weightings were created for the three remaining countries (Kazakhstan, Macedonia, Sweden) using national population figures by age group for the latest year in which data collection took place (10). Age-standardised mean nutrient intakes were produced using the Eurostat 2013 European Standard Population (ESP) to facilitate comparisons between countries with different population structures (11). ESP proportions for the relevant age groups covering ages 19-64y were multiplied by the national population figures for those age groups. Population figures were taken from the latest year of data collection for the national dietary survey in question (10).

6.3.2 Statistical Analyses

Mean age-standardised daily intakes were estimated for the whole country and also by individual-level educational group and sex for each country for nutrients of concern identified *a priori*: energy (kcal/day); total fat (%E); trans fatty acid (TFA) (%E); total sugar (%E); iron (mg/day); total folate (µg/day); vitamin D (µg/day). Where total sugar intake was not reported as such (Germany, the Netherlands, Sweden), it was derived from monosaccharides plus disaccharides. To minimise risk of selection bias, no individuals were excluded for presumed under-reporting (12). Two-sided p-values were used throughout and statistical significance was set at $p<0{\cdot}05$.

Country-level age-standardised mean nutrient intakes were plotted against *per capita* GDP ($) in 2016(13, 14), with associations estimated using linear regression. Age-standardised analyses were repeated by educational group, in men and women separately, for each country. All individual-level regression models were weighted by the inverse probability of sampling and stratified by country. The extent to which the associations between nutrient intakes and GDP differed by the participants' educational level was estimated using linear regression, adjusted for age and sex. Similarly, the extent to which the associations between individuals' nutrient intakes and education differed between men and women was also assessed, adjusting for age and GDP. GDP was log-transformed in all analyses, with estimates presented for a 10% increase in GDP.

6.4 Results

6.4.1 Harmonisation and Pooling of National Surveys

Datasets were obtained for 27334 participants from 12 countries within the WHO European Region: three Northern European countries (Denmark, Finland, Sweden); five Western European countries (Austria, France, Germany, Netherlands, UK) and four Central and Eastern European countries (Estonia, Hungary, Kazakhstan, Macedonia). The survey collection years spanned 2005-2016. Either 24hr recall, diet history interview or diary methods were used; see appendix 1 for survey details. All 12 national surveys provided data on the nutrients selected for analysis, except for TFAs (not reported by Austria, France, Germany, Hungary, Sweden) and vitamin D (not reported by Austria). There were 2027 (7%) participants in the lower, 16980 (62%) in the intermediate and 8327 (30%) in the higher education groups.

6.4.2 Total Energy and Macronutrient Intakes

6.4.2.1 Country-level Analysis

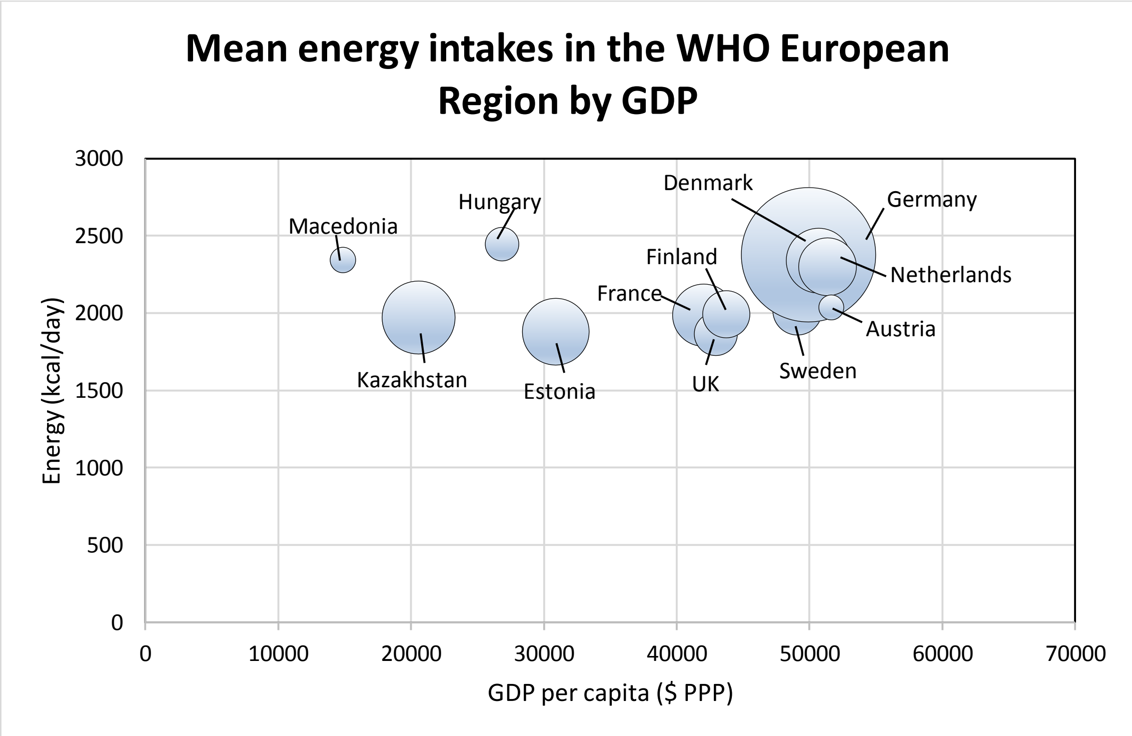
Age-standardised mean daily energy and macronutrient intakes are presented in figures 1a-1d and appendix 2. Between-country comparisons found that mean country energy and macronutrient intakes did not vary by national income other than in total sugar (figures 1a-1d, appendix 3). With each 10% increase in GDP mean country total sugar intakes increased by 5% energy (5%E, 95% CI 0·6, 9·3). Geographical variations in energy and macronutrient intakes across Europe are shown in figures 2a-2d.

Hungarian men had the highest age-standardised mean daily energy intake (2800kcal, 95% CI 2676, 2923) and % of energy from fat (39%E, 95%CI 38, 39), and UK men the lowest (2103kcal, 95% CI 2030, 2176); (33%E, 95%CI 32, 33). Geographic variation in energy intake was similar for women, although intakes were lower and differences between countries less pronounced (appendix 2). In women, fat intakes were highest in France (39%E, 95%CI 38, 39) and lowest in Macedonia (32%E, 95%CI 31, 33). All countries that reported TFAs (Denmark, Estonia, Finland, Kazakhstan, Macedonia, the Netherlands, UK) had mean daily intakes below the WHO recommended <1%E. Kazakhstan had the highest intakes, with 0·63%E (95% CI 0·58, 0·68) and 0·61%E (0·56, 0·65) for men and women respectively. Estonia had the lowest intakes in both men and women, with 0·25%E (95% CI 0·24, 0·27) and 0·27%E (95% CI 0·26, 0·28) respectively (appendix 2). Germany had the highest male (22%E 95%CI 22, 22) and female (26%E 95% CI 26, 26) daily % of energy from total sugar. Macedonia had the lowest male and female intakes at 9%E (95% CI 7, 10) and 11%E (95% CI 10, 12) respectively (appendix 2). There were no apparent geographic patterns in macronutrient intakes on a European regional level.

6.4.2.2 Participant-level Analysis

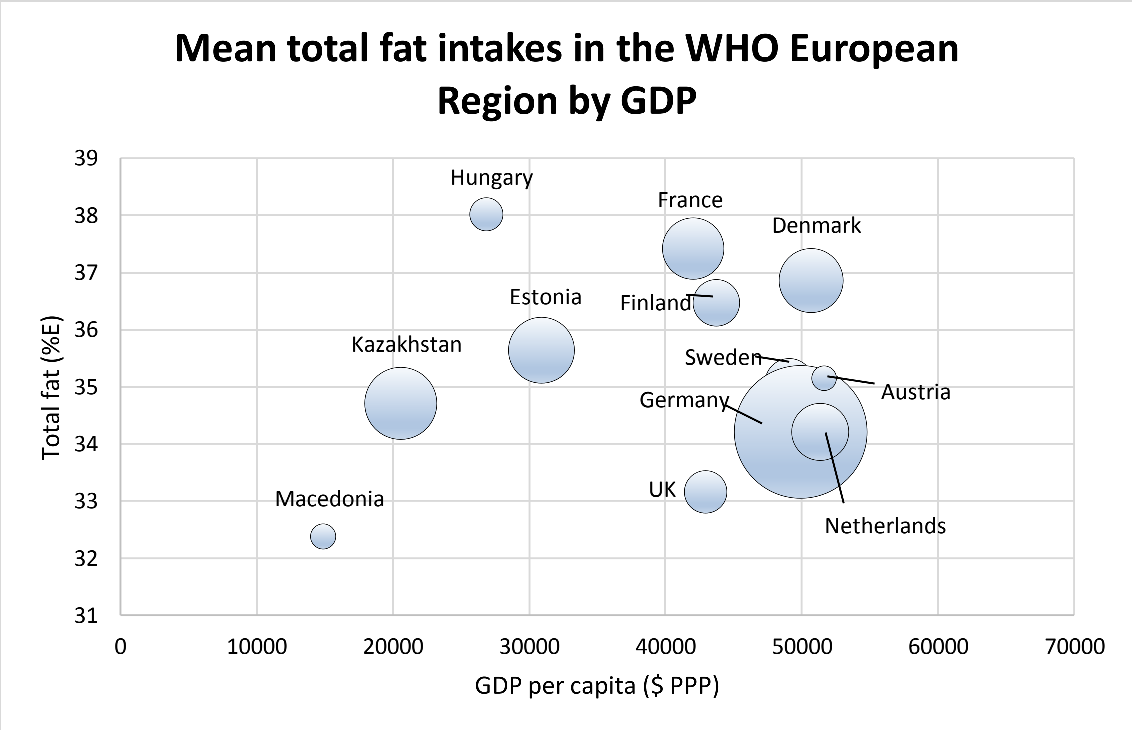
Lower educational levels were associated with a lower mean energy intake in both men and women. However, this was more pronounced in lower GDP countries (figure 3a, appendices 4-5). In lower GDP countries having a higher education level was associated with having a higher mean total fat and TFA intake, but in higher GDP countries higher educational levels were associated with lower mean fat intake. This pattern was most prominent in women (figures 3b and 3c, appendix 5). The direction of associations between education and total sugar intakes varied more than in energy and fats (figure 3d, appendices 4-5).

Figure 1a – Age-standardised mean energy intakes for WHO European Member States, by GDP



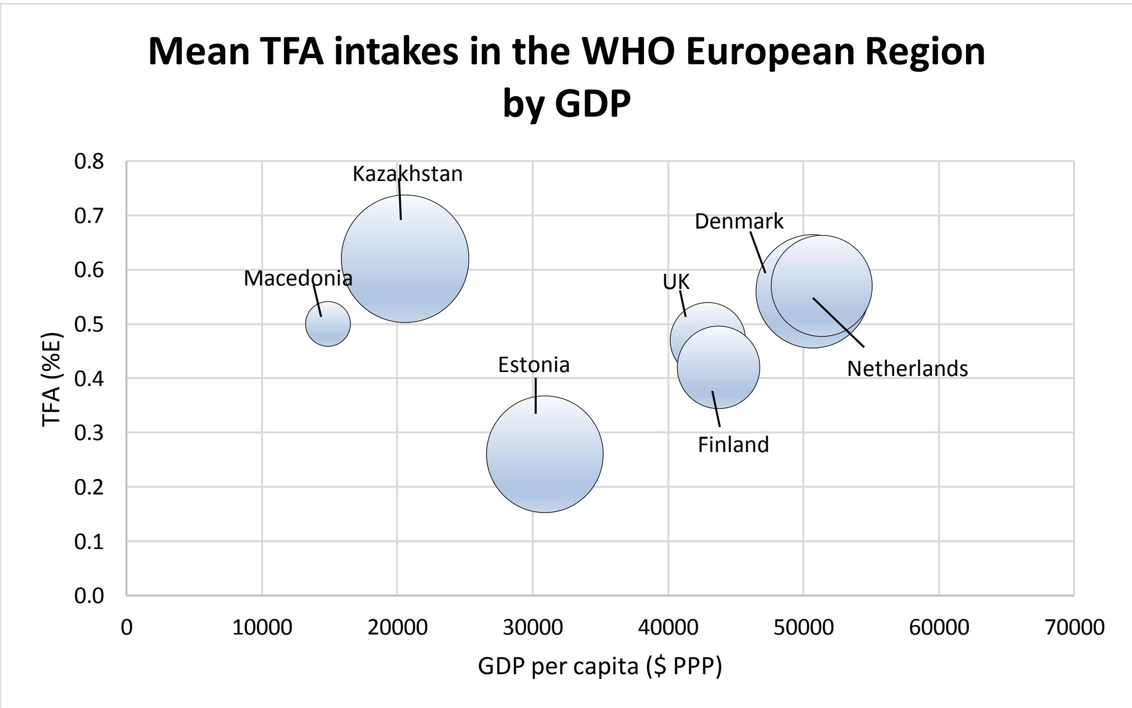
NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 1b – Age-standardised mean % of energy from fat for WHO European Member States, by GDP



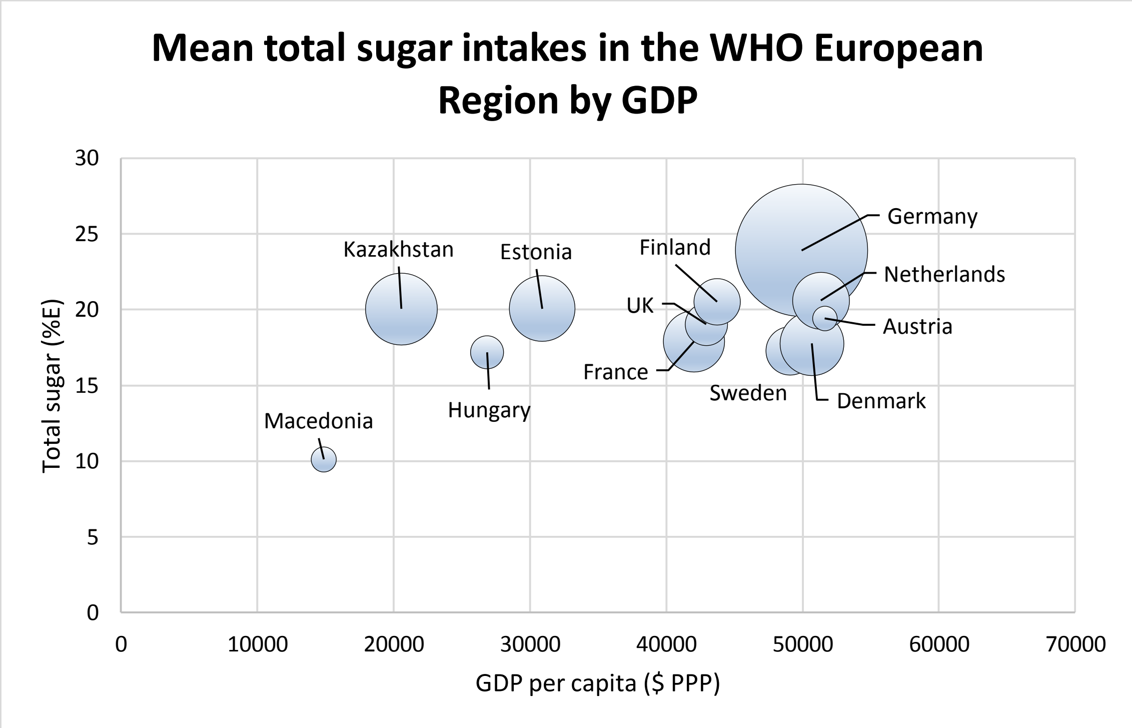
NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 1c – Age-standardised mean % of energy from TFAs for WHO European Member States, by GDP



NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 1d – Age-standardised mean % of energy from total sugar for WHO European Member States, by GDP



NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 2a – Age-standardised mean energy intakes for WHO European Member States

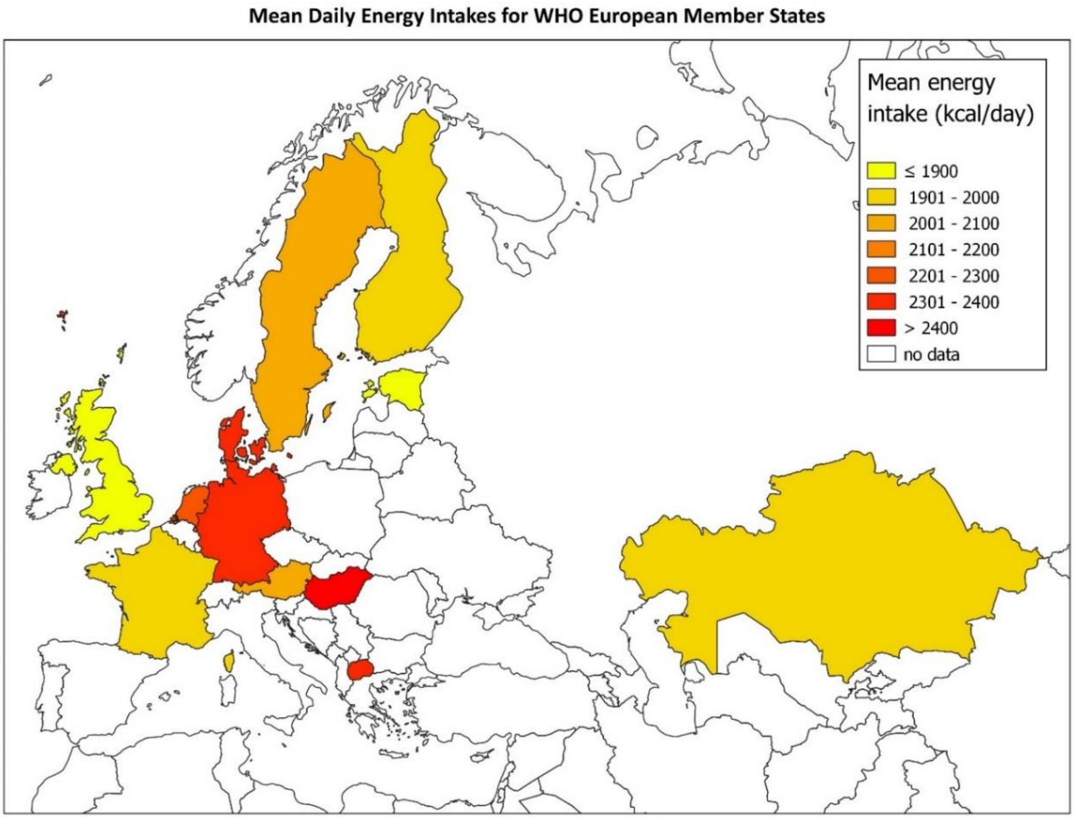


Figure 2b – Age-standardised mean % of energy from total fat for WHO European Member States

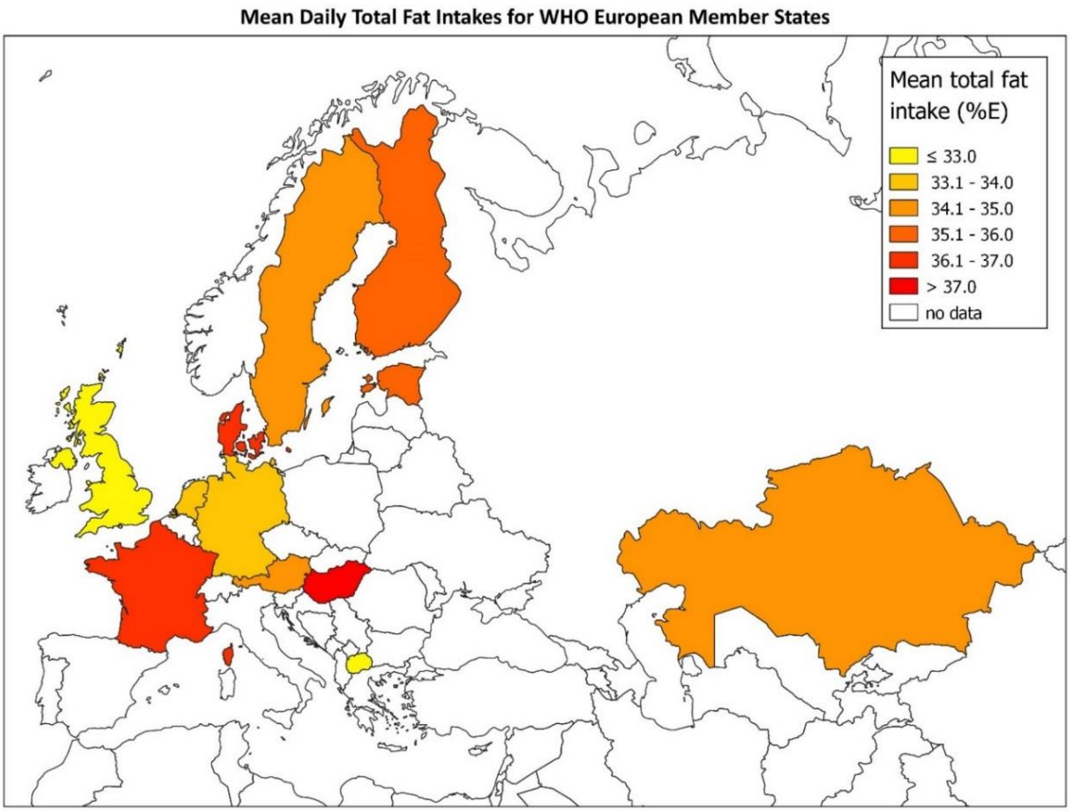


Figure 2c – Age-standardised mean % of energy from TFAs for WHO European Member States

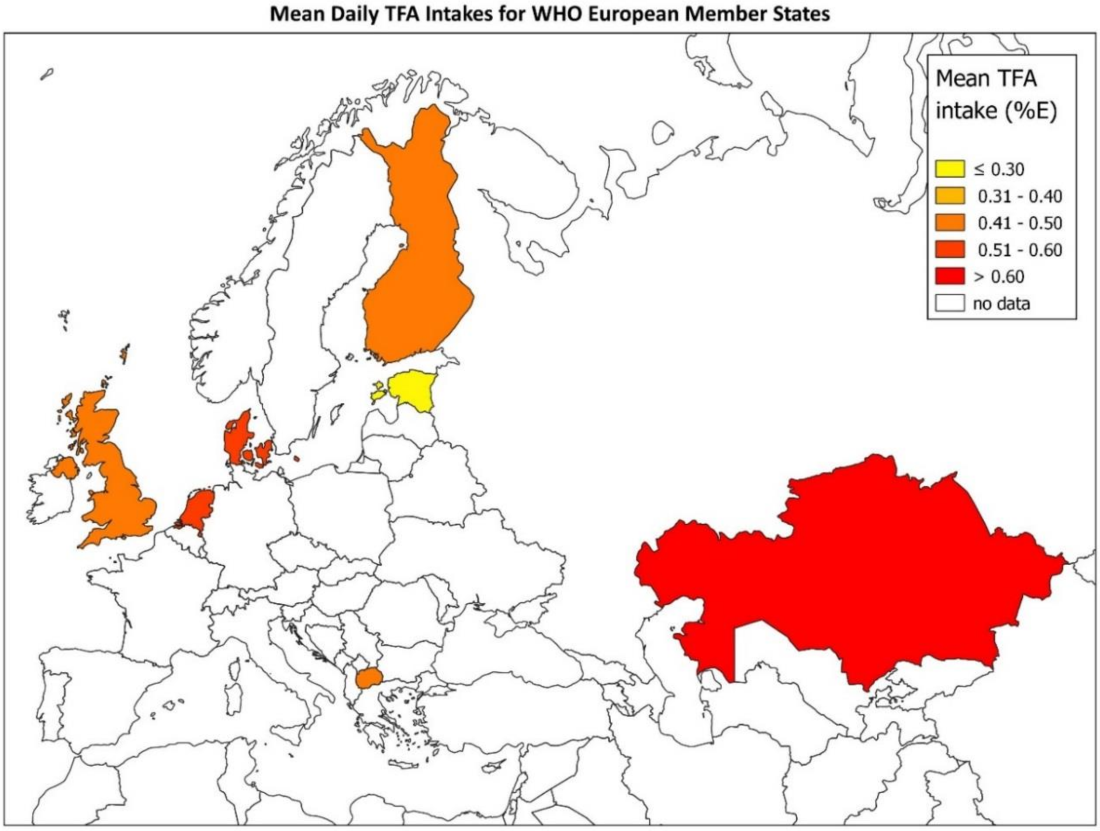


Figure 2d – Age-standardised mean % of energy from total sugar for WHO European Member States

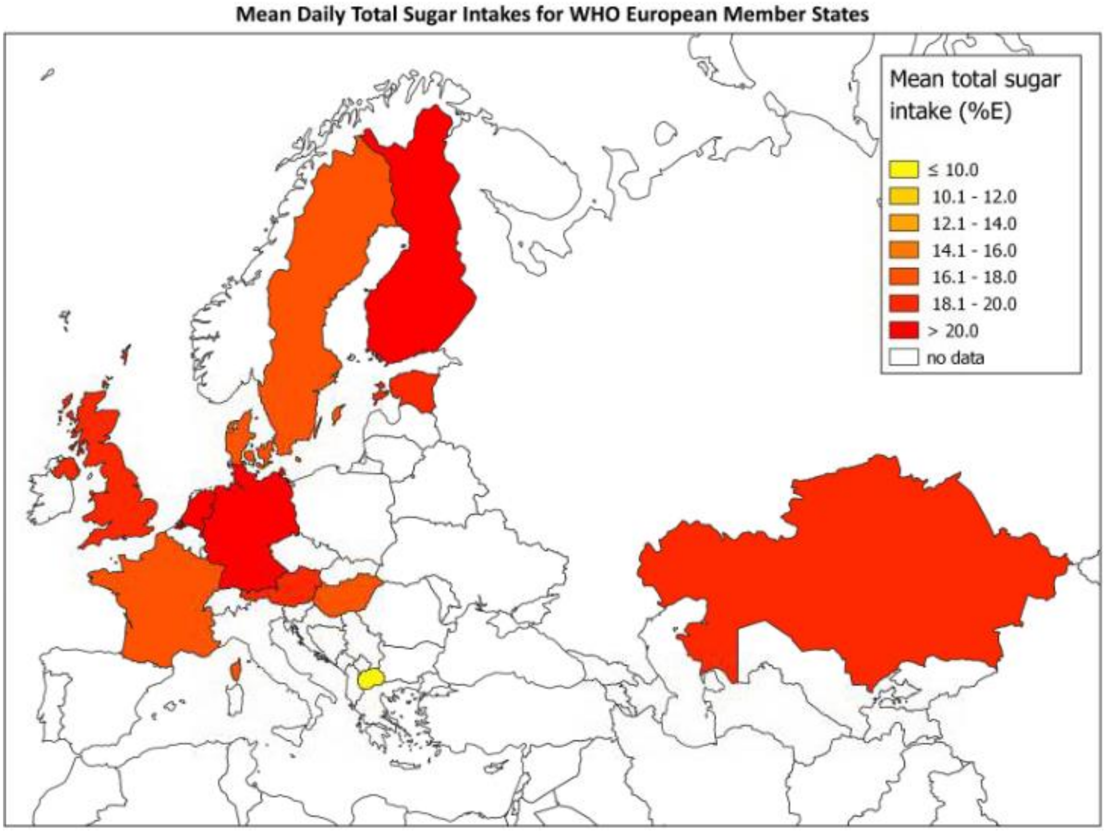
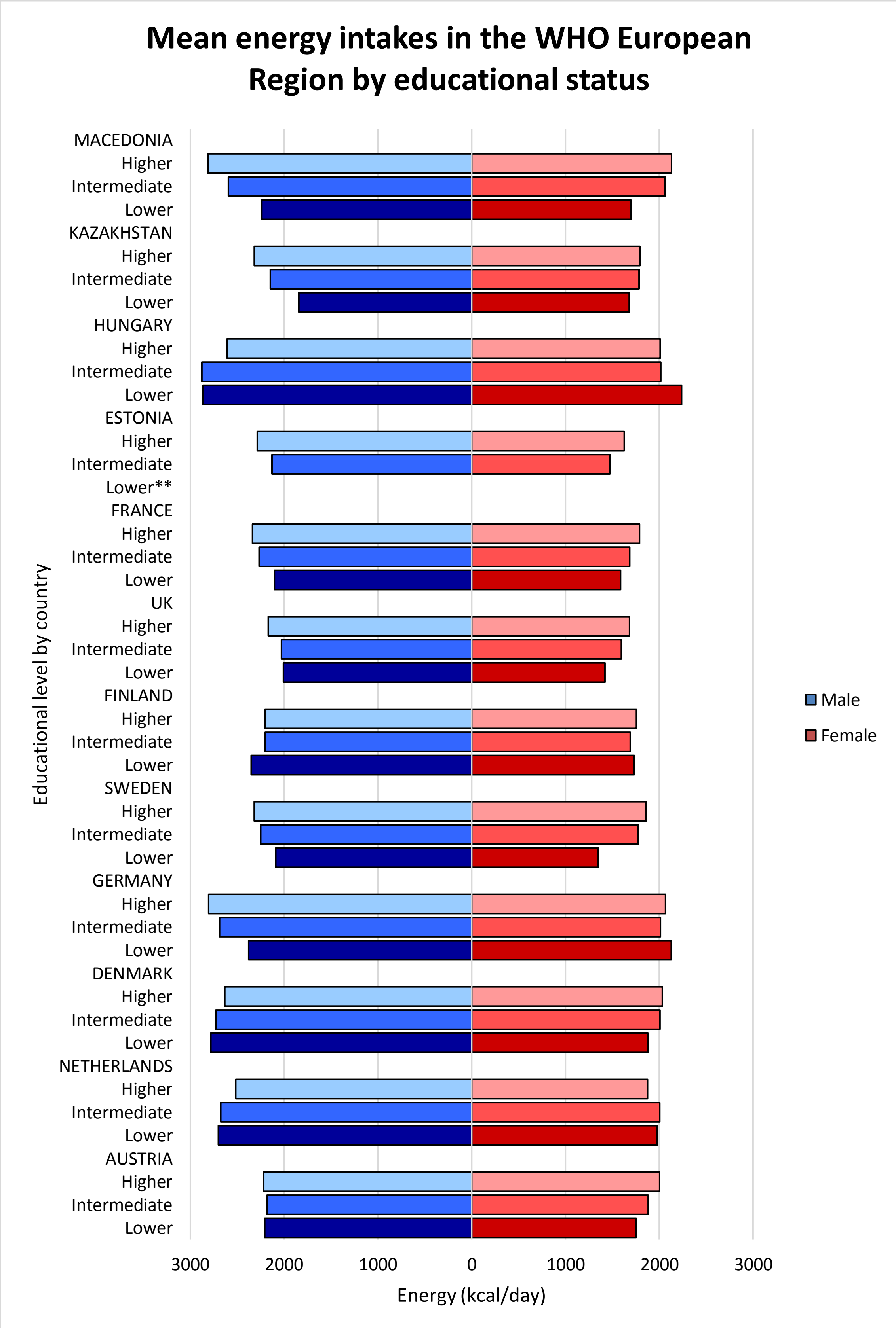


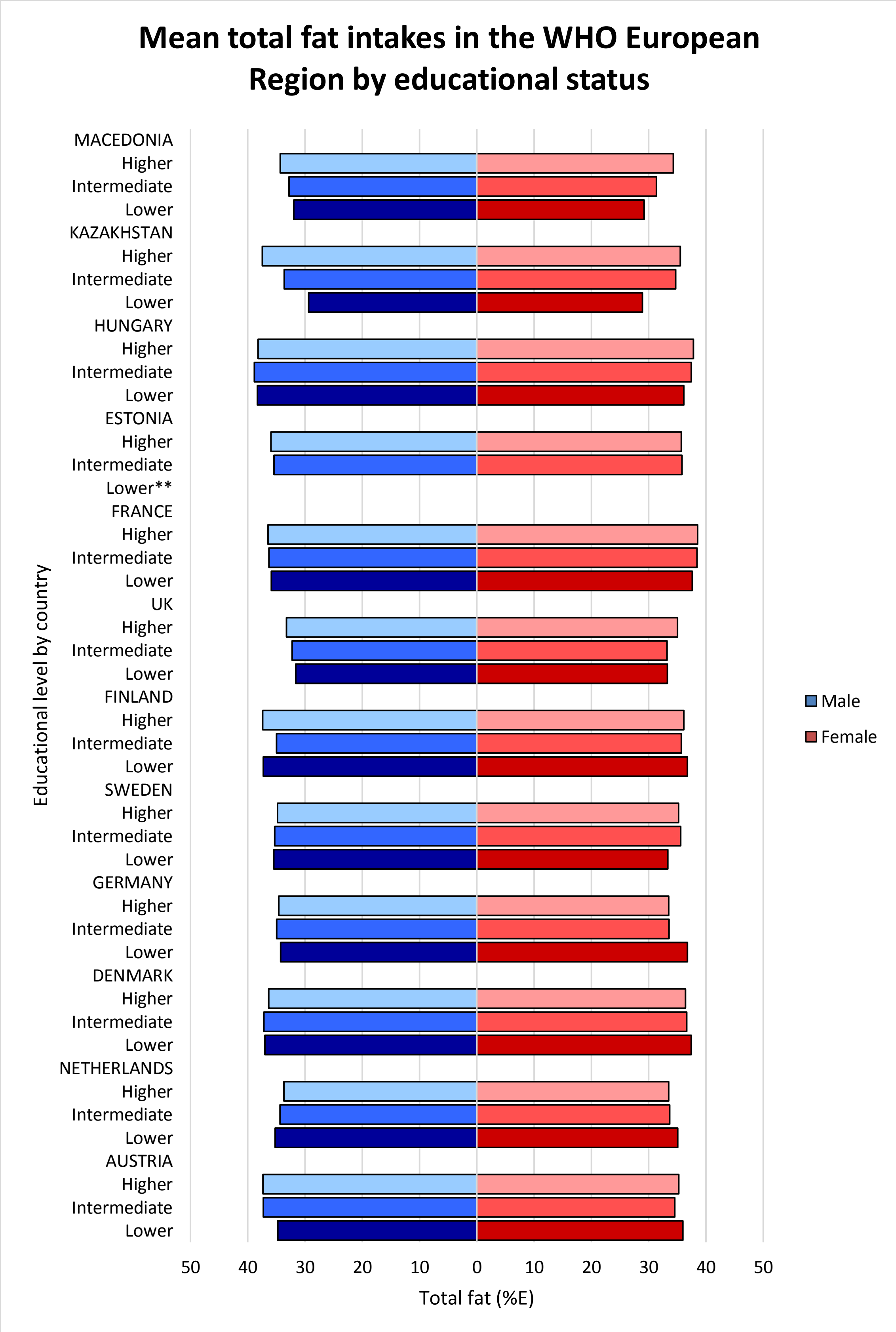
Figure 3a – Age-standardised mean energy intakes for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

**Lower educated Estonian intakes not included due to n<3 individuals.

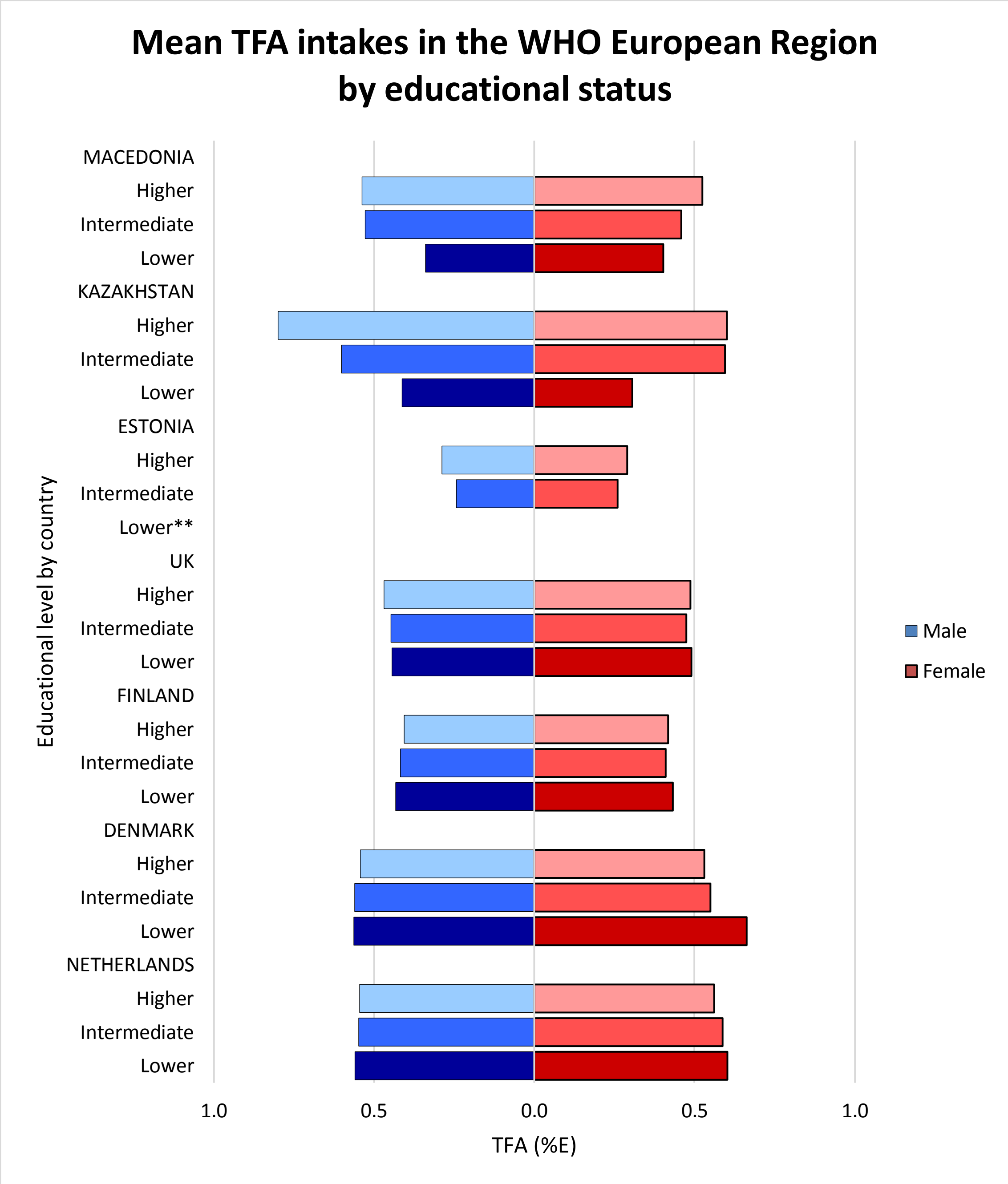
Figure 3b – Age-standardised mean % of energy from total fat for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

**Lower educated Estonian intakes not included due to n<3 individuals.

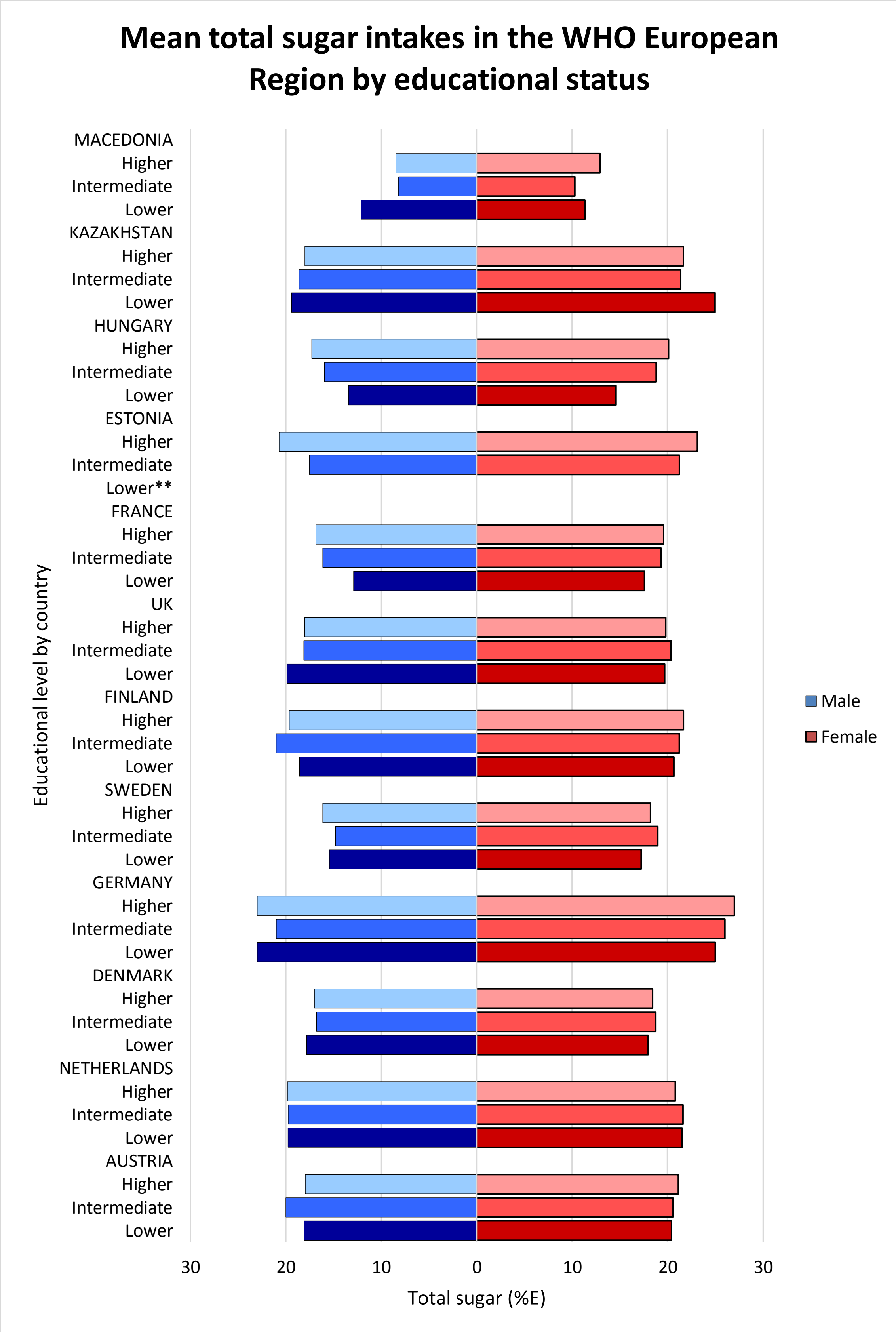
Figure 3c – Age-standardised mean % of energy from total fat for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

** Lower educated Estonian intakes not included due to n<3 individuals.

Figure 3d – Age-standardised mean % of energy from total sugar for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

** Lower educated Estonian intakes not included due to n<3 individuals.

6.4.3 Macronutrient Intakes

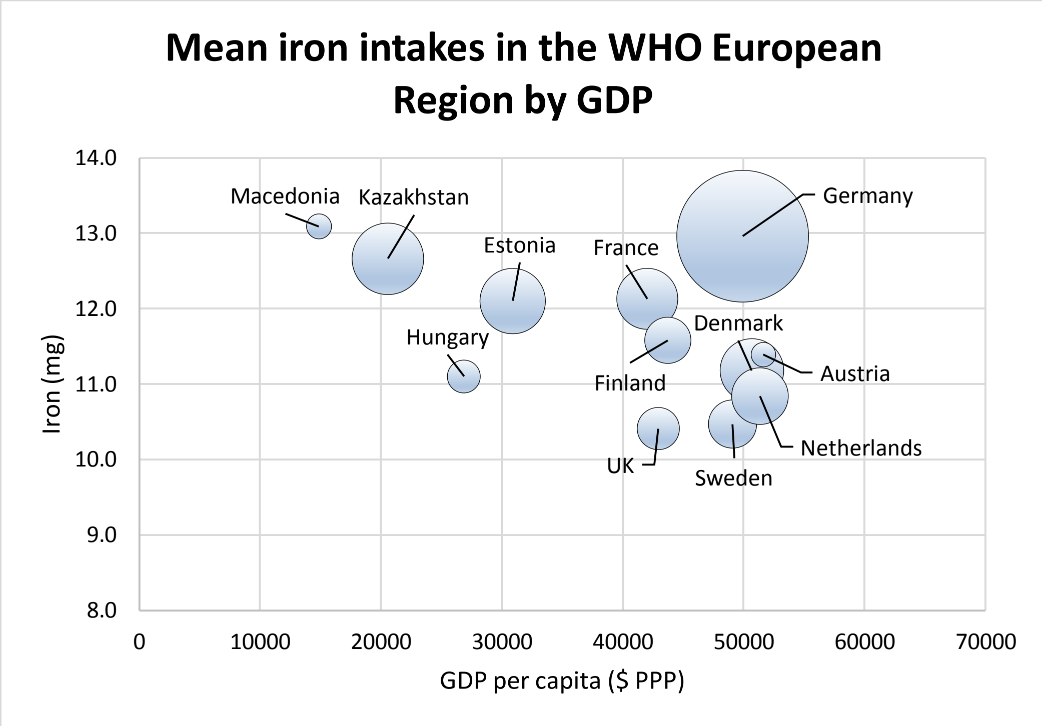
6.4.3.1 Country-level Analysis

Age-standardised mean micronutrient intakes are presented in figures 4a-4c and appendix 2. Geographical variations in micronutrient intakes across Europe are shown in figures 5a-5c. Mean daily iron intakes were highest in Macedonia for men and women, at 14·8mg/day (95% CI 13·8, 15·9) and 11·7mg/day (95% CI 10·9, 12·5) respectively. Sweden had the lowest male intakes (11·5mg/day, 95% CI 11·2, 11·9) and the UK had the lowest female intakes (9·2mg/day, 95% CI 8·9, 9·6). Mean daily total folate intakes were highest in Macedonian men (462µg/day, 95% CI 394, 530) and women (364µg/day, 95% CI 306, 422) and lowest in Kazakh men (124µg/day, 95% CI 121, 128) and women (107µg/day, 95% CI 104, 110). Finland had the highest mean daily vitamin D intakes in men (10·7µg/day, 95% CI 9·9, 11·4) and women (8·2µg/day, 95% CI 7·8, 8·7); Kazakhstan had the lowest, at 1·1µg/day (95% CI 1·0, 1·2) and 0·8µg/day (95% CI 0·8, 0·9) for men and women respectively (appendix 2). There was no evidence of associations between GDP and intakes of the included micronutrients (figures 4a-4c, appendix 3). At a European regional level, the vitamin D intake range was lowest in Northern European countries, which also had the two highest intakes (figure 5c).

6.4.3.2 Participant-level Analysis

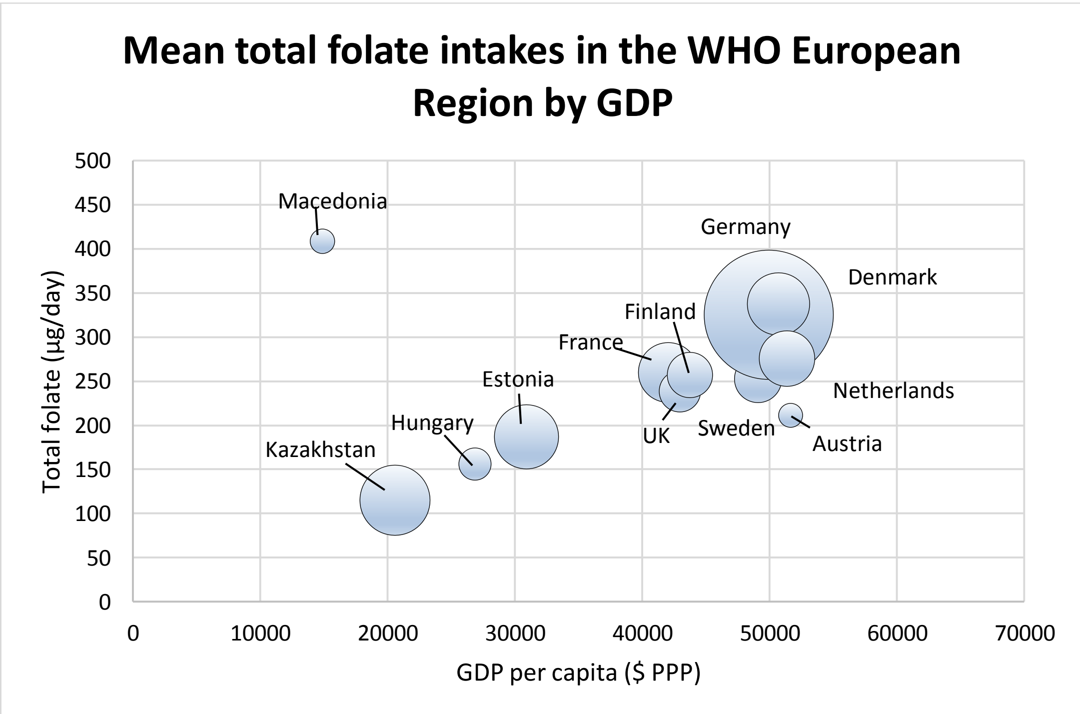
Within-country comparisons found that, with few exceptions, less education was significantly associated with lower iron, total folate and vitamin D intakes in both sexes (figures 6a-6c, appendices 4-5).

Figure 4a – Age-standardised mean iron intakes for WHO European Member States, by GDP



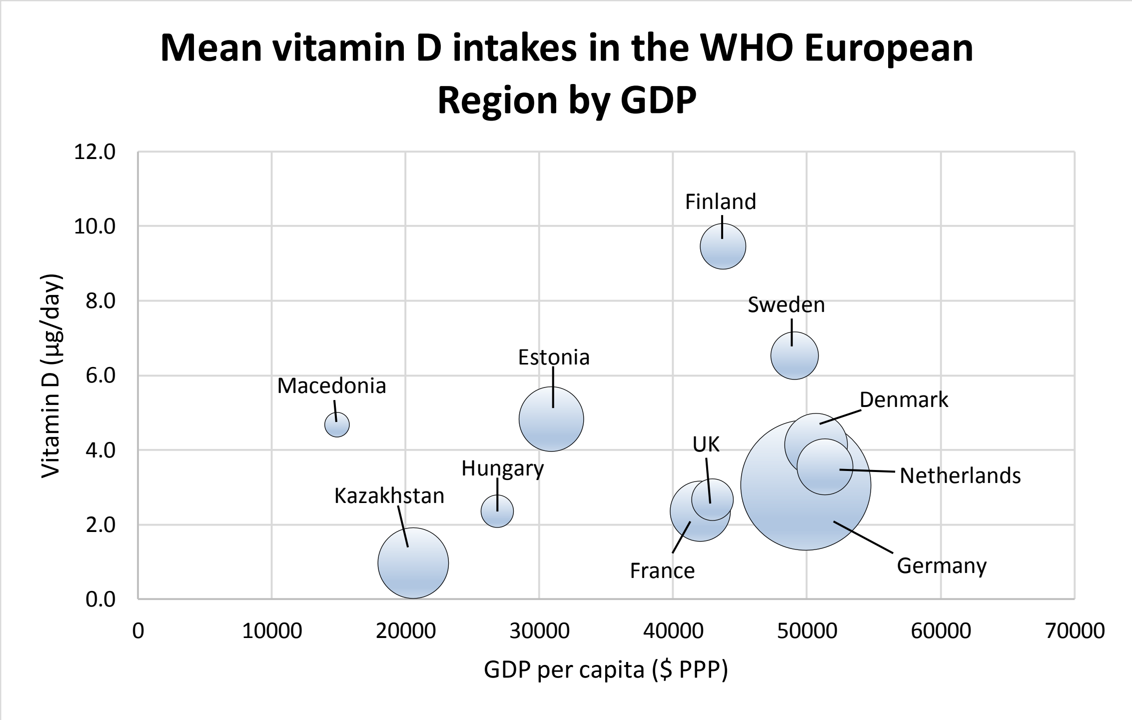
NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 4b – Age-standardised mean total folate intakes for WHO European Member States, by GDP



NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 4c – Age-standardised mean vitamin D intakes for WHO European Member States, by GDP



NB – The bubble size is proportionate to the sample size for of the survey used for each country.

Figure 5a – Age-standardised mean iron intakes for WHO European Member States

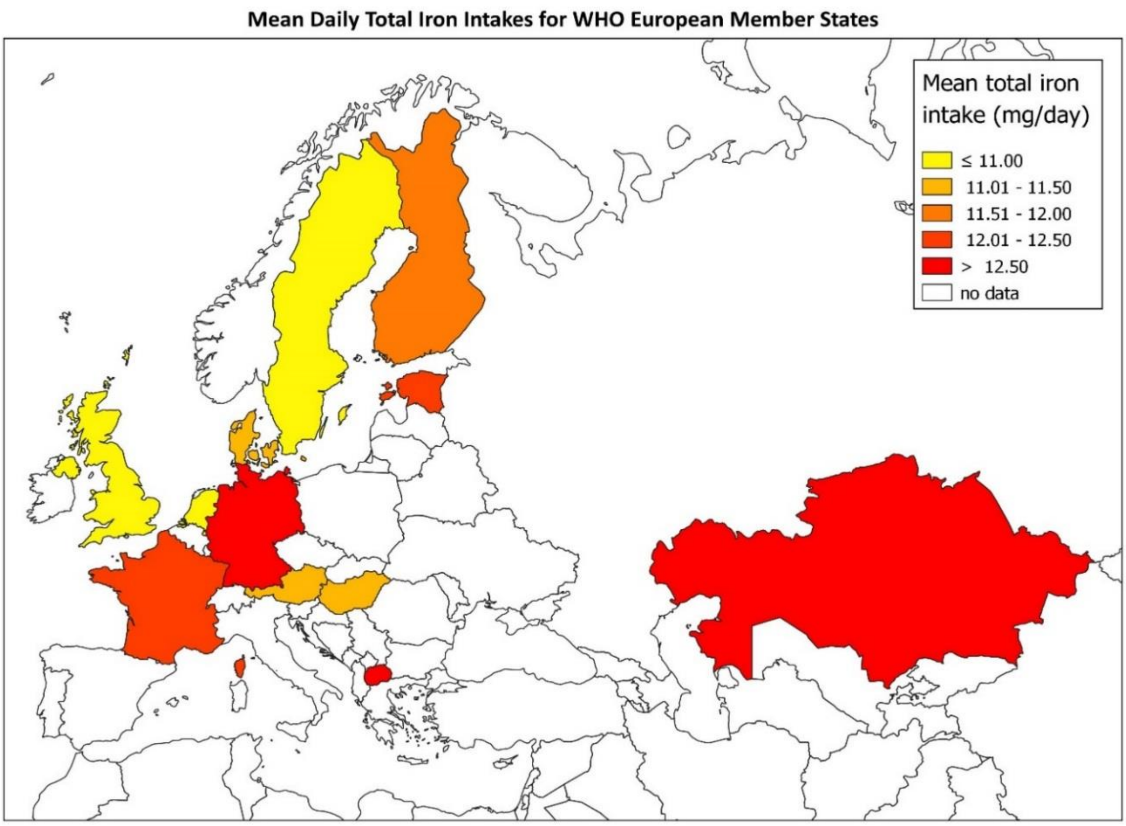


Figure 5b – Age-standardised mean total folate intakes for WHO European Member States

Mean Daily Total Folate Intakes for WHO European Member States

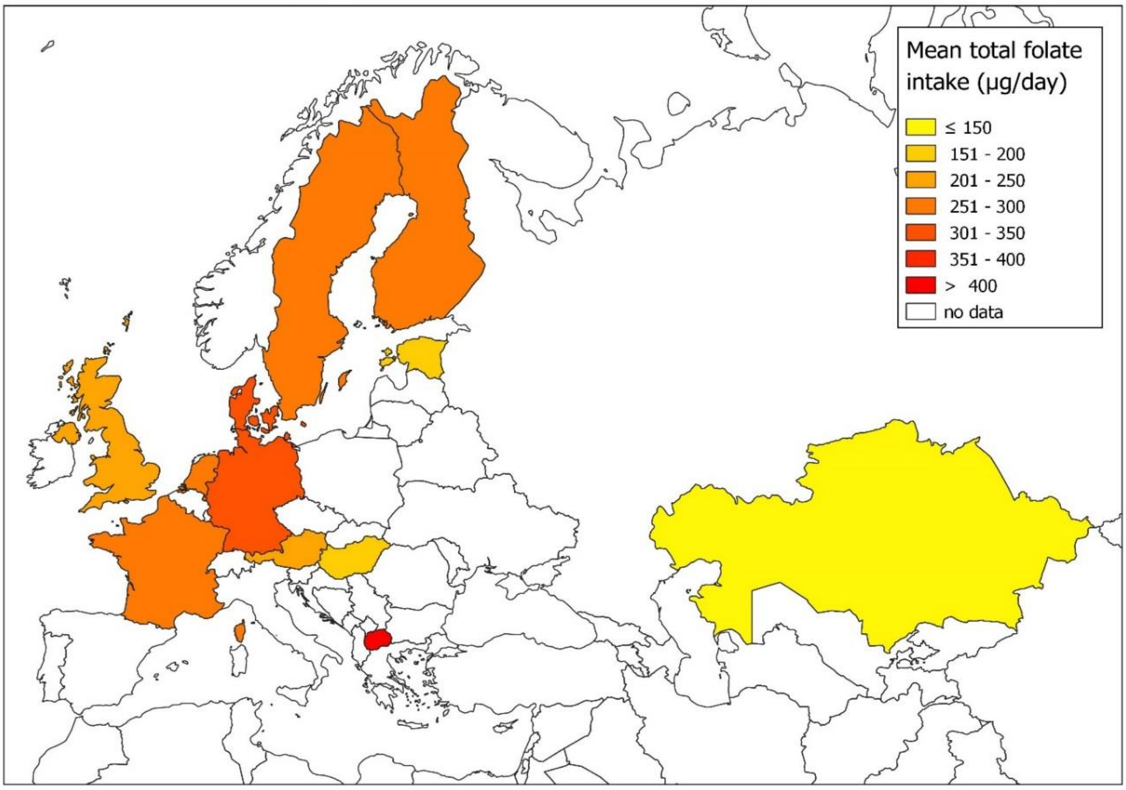


Figure 5c – Age-standardised mean vitamin D intakes for WHO European Member States

Mean Daily Total Vitamin D Intakes for WHO European Member States

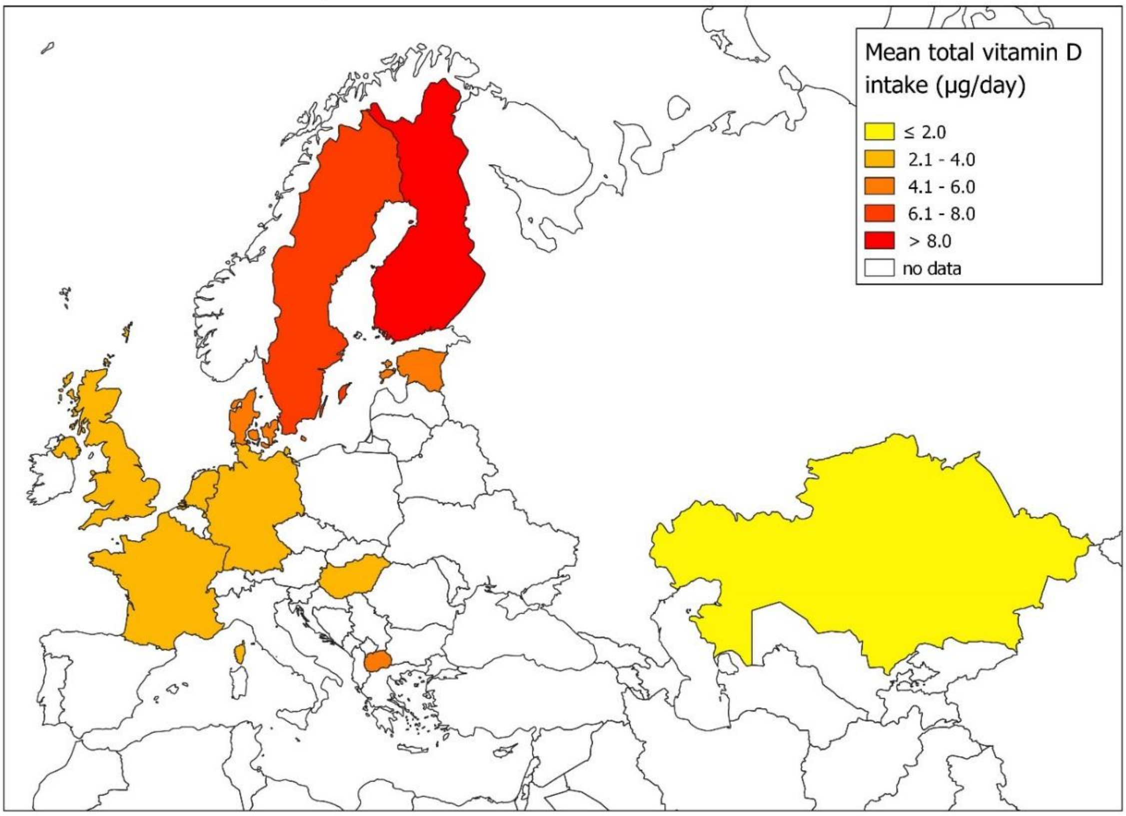
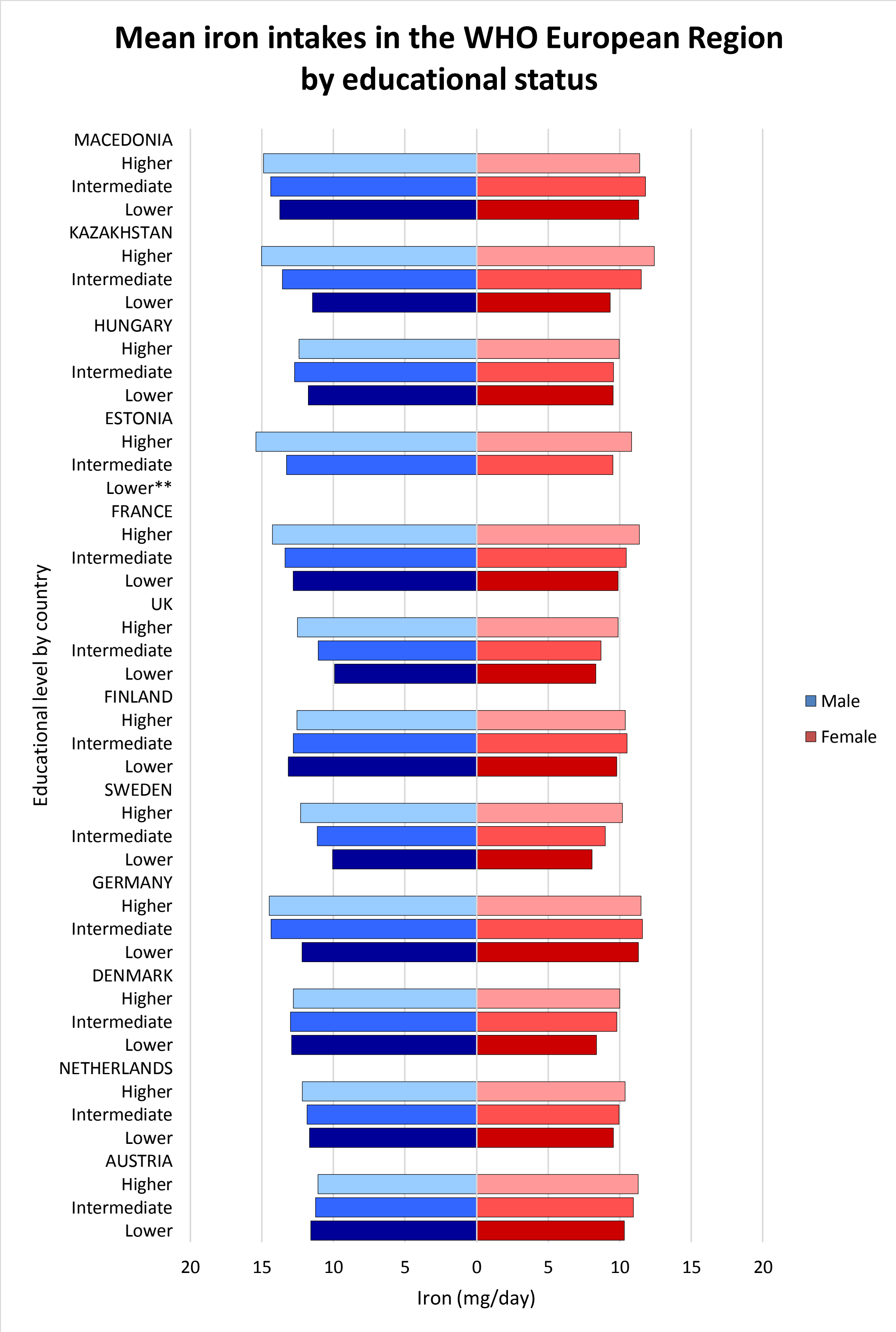


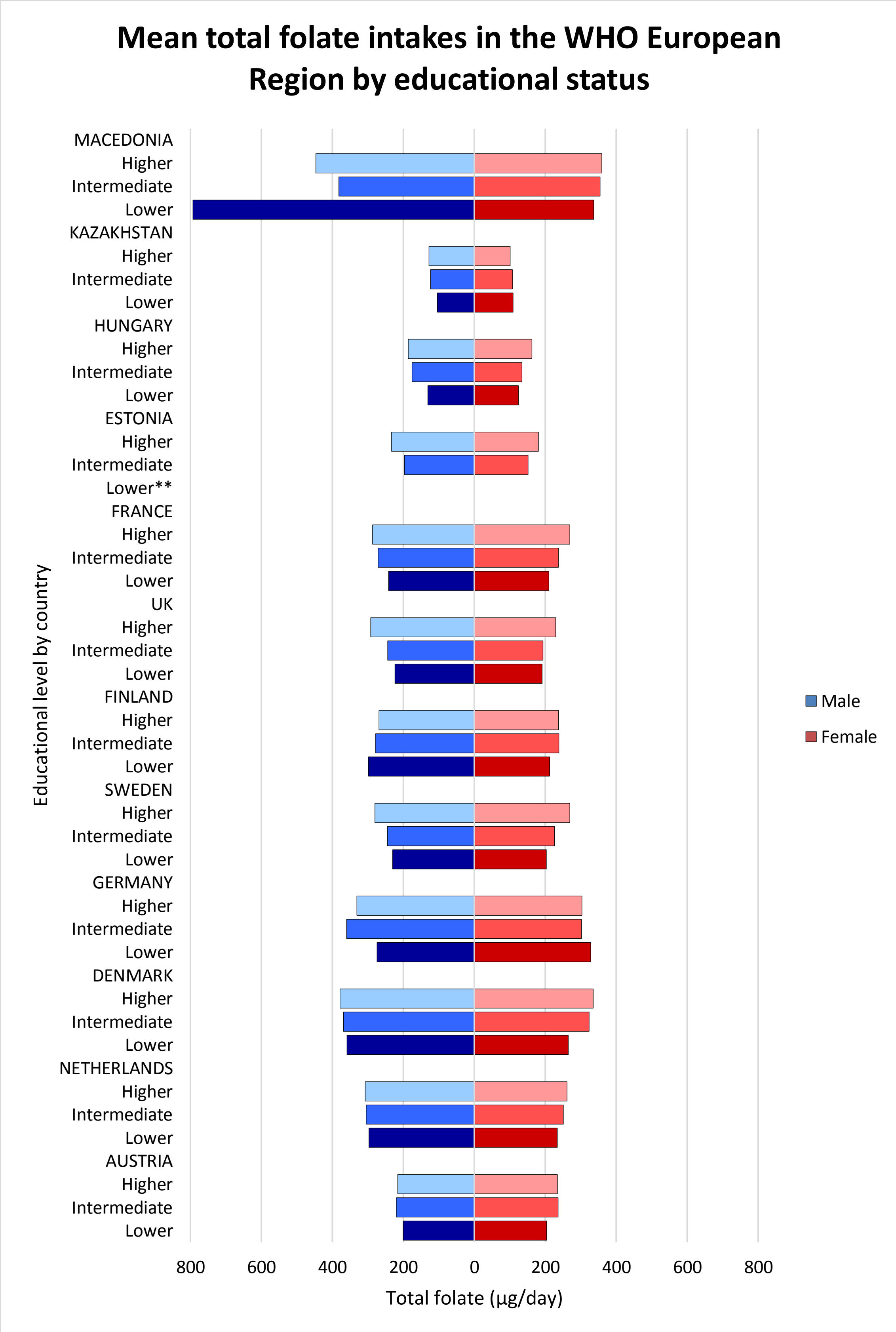
Figure 6a – Age-standardised mean iron intakes for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

** Lower educated Estonian intakes not included due to n<3 individuals.

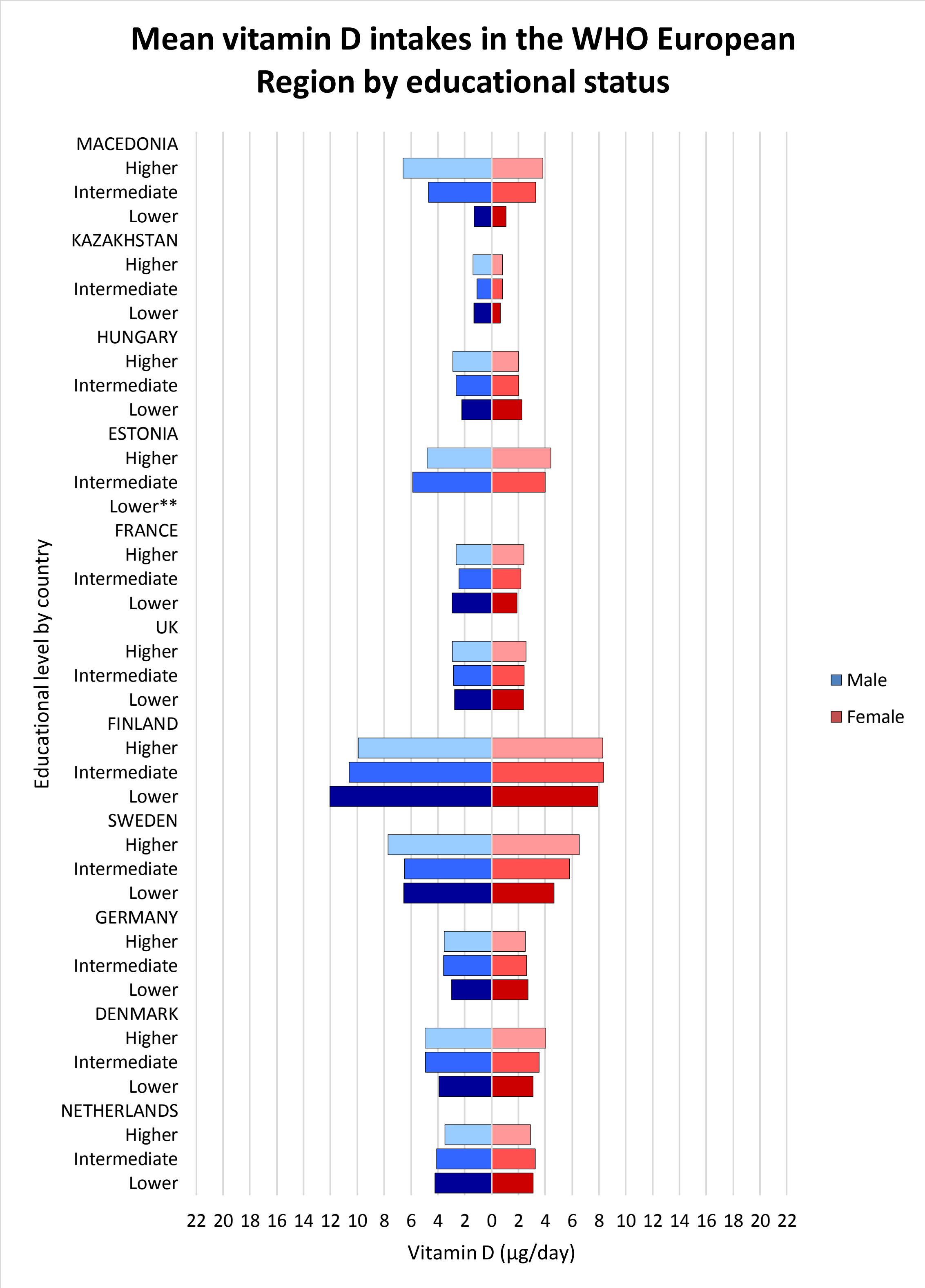
Figure 6b – Age-standardised mean total folate intakes for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

** Lower educated Estonian intakes not included due to n<3 individuals.

Figure 6c – Age-standardised mean vitamin D intakes for WHO European Member States, split by sex and education*



*Countries ordered by GDP from lowest to highest.

** Lower educated Estonian intakes not included due to n<3 individuals.

6.4.4 Multiple Regression Analyses

Associations between lower GDP and excess macronutrient and poorer micronutrient intakes were attenuated or reversed in individuals with higher educational levels. A 10% higher GDP was associated with lower total fat (-0·2%E, 95% CI -0·3, -0·1) and TFA (-0·01%E, 95% CI -0·01, -0·01) in higher education groups, but lower education groups had higher intakes as GDP increased (table 1). A higher GDP was associated with higher daily total folate intake and vitamin D intakes for all education levels, but was most pronounced in the intermediate education group (18µg, 95% CI 18, 19 for total folate; 0·17µg, 95% CI 0·15, 0·19 for vitamin D). For iron, higher GDP was associated with lower intakes in all education groups, but particularly in the higher educational group (-0·1mg, 95% CI -0·16, -0·05) (table 1). There was no evidence that men and women had different associations between education and nutrient intake, other than total sugar ($p<0.001$) and vitamin D ($p=0·004$).

Lower education was more strongly associated with higher vitamin D intakes in men (1.4µg, 95% CI 1.0, 1.9) than in women (0.8µg, 95% CI 0.6, 1.1). Lower education was associated with lower daily total sugar intakes, but more so in women (-3·0%E, 95% CI -3·5, -2·4) than in men (-1·1%E, 95% CI -1·8, -0·5) (see appendix 6).

Table 1 – Association between nutrient intake and GDP, by educational status, adjusted for age and sex.

	Lower education			Intermediate education			Higher education			
	Slope*	**95% CI**		**Slope***	**95% CI**		**Slope***	**95% CI**		**p-value****
Energy (kcal)	24	5	42	34	30	37	28	21	35	0·2
Total fat (%E)	0·2	-0·02	0·4	0·05	0·004	0·09	-0·2	-0·3	-0·1	<0·001
TFA (%E)	0·02	0·01	0·04	-0·004	-0·01	0·00001	-0·01	-0·01	-0·001	<0·001
Total sugar (%E)	0·4	0·2	0·6	0·4	0·3	0·4	0·4	0·3	0·5	0·9
Iron (mg)	-0·03	-0·16	0·09	-0·004	-0·03	0·02	-0·10	-0·16	-0·05	0·004
Total folate (µg)	2	-11	15	18	18	19	14	12	16	<0·001
Vitamin D (µg)	0·10	0·03	0·17	0·17	0·15	0·19	0·10	0·03	0·16	0·04

*Slope represents the change in nutrient intake (per unit specified) for each 10% increase in GDP.

** P-value represents the difference between subgroups defined by educational status in estimated association between GDP and nutrient intake.

6.5 Discussion

This paper presents key nutrient intakes of particular concern (5) within harmonised individual-level national survey data, pooled across 12 WHO European Member States. Each survey is sampled and weighted to provide representative data from that country, with the pooled data contributing substantial insight into dietary sufficiency across the region. Potential socioeconomic inequalities were assessed using country-level GDP and individual-level educational attainment.

Higher GDP countries had higher mean total sugar intakes. However, most countries had high energy and macronutrient intakes above recommended levels; lower GDP countries may therefore face future elevated levels of obesity-related NCDs, as currently observed in higher income countries. This is already occurring (7), making government-level policy interventions imperative to prevent the situation worsening. The importance of policy is demonstrated by TFA intakes; although below the WHO <1%E recommendation, Kazakhstan had the highest mean % energy from TFAs, and until 2018, had no TFA-reduction strategy (15).

Central and Eastern European countries had lower total folate intakes, except for Macedonia. This could be explained by high national production of fruit and vegetables in Macedonia, which in turn may translate to individual diets. Northern European countries had higher vitamin D intakes, though less so in Denmark. Potential explanations include Scandinavian dietary customs such as greater oily fish consumption, which is a source of vitamin D (16). Finland and Sweden also have extensive fortification programmes, which could explain the slightly lower Danish intakes, as Denmark does not have as strong a fortification programme (17).

Socioeconomic inequalities across WHO Europe were evident on an individual level, as men and women with less education generally had lower intakes of nutrients encouraged as part of a healthy diet, particularly iron and total folate. In some countries, lower education groups had higher intakes of energy and macronutrients, particularly total sugar. This extends into Europe evidence of a positive association between socioeconomic status and diet quality seen in the US (18, 19). The underlying mechanism may involve diet costs; lower educated individuals may have lower paid occupations (20), resulting in less income for the range of foods needed for a balanced, healthy diet. This is compounded by lower health literacy and reduced ability to apply nutrition knowledge within budgetary constraints (21).

Greater educational attainment at individual level appeared to have a mitigating impact against the effects of low GDP for most nutrients. Although the overall effect size for individual nutrients was small, with a combined total population of almost 300 million across the 12 countries studied (10), small shifts could have an important impact on public health. National income and diet quality appear to be linked, and education could protect against some of the negative effects of poor nutrition on population health and productivity. Lower education may result in poor quality diets, and the accompanying adverse health consequences could negatively affect GDP, as less healthy individuals are less economically productive (22). However for iron, lower intakes with higher GDP was most pronounced in the higher education groups. This may be because higher education groups in the higher income countries adopt a more plant-based, and therefore lower iron, diet (23).

These findings illustrate the importance of policy development to address the public health implications of the effect of GDP and education on nutritional status. The early recognition of nutrition as an essential socio-political consideration was contributed to by an understanding that soldiers fighting the Boer War were malnourished and that good nutrition was lacking in the working classes (24). Modern European society faces issues of a similar magnitude. Without a strong policy focus to support good diet quality, prioritising lower income countries and lower education groups, large sections of European populations may have suboptimal intakes, with significant health and economic impacts.

6.5.1 Strengths and Limitations

This work is the first to harmonise and pool the individual-level survey data from national dietary surveys across WHO Member States, spanning all regions of Europe. This provides the largest representative dietary survey review of diet across WHO Europe, and evidence on which to base policy. The individual-level data harmonisation, with statistical analyses stratified by sex, and using European age standardisation based on the most recent ESP (11), facilitates between-country comparisons of nationally representative nutrient intakes to a degree not previously achieved.

The exploration of GDP and educational level in relation to nutrient intakes, is a previously under-studied area. In particular, this is the first time that individual participant data has been analysed in this way to explore the interactions between socioeconomic status, education and diet. Our analyses highlight the need for future research to further explore nutrient intakes in disadvantaged groups across Europe.

It is not possible to adequately evaluate these associations using summary reports alone, because not all surveys report on socioeconomic status or education (4). We use education in part as a proxy for socioeconomic status. This has previously been used in relevant literature and official reports, including the Global Burden of Disease socio-demographic index (25) and the Euro-Peristat report (26). However, although efforts at harmonising national dietary surveys, such as the EU MENU project, are progressing, this is limited to the EU (27). In terms of harmonising educational level, although education was the best available indicator for individual socioeconomic status and broadly compatible education groups were created, it is possible that different countries expect different standards at each level.

The analyses have limitations. Socioeconomic inequalities were harder to assess at national level; with only 12 countries on which to test associations between nutrient intakes and GDP, the simple national level regression analysis lacked sufficient power to adequately test for significance or estimate associations with great precision. However, utilising the harmonised and pooled individual-level data improved our ability to detect associations. Nevertheless, there were few participants in the survey from Macedonia, resulting in wide confidence intervals in the lower education groups for total folate. In the Estonian survey, the lower education group contained fewer than three individuals, so associations for this group were not included to avoid statistical disclosure.

A further limitation is the nutrient composition databases from which nutrient intake values are derived. Not all countries' databases are necessarily equally comprehensive or up-to-date; some mean nutrient intake values may therefore be less accurate. Differential treatment of fortification in national food composition databases may also make associations less reliable. Nutrient values may be calculated differently across countries, and some countries may not routinely analyse for certain nutrients. For example, TFA coverage in the Estonian database is poor quality and Sweden no longer report TFAs because the average population intake is below 1%E and therefore no longer a public health concern (28). Nutrient values are based on a composite sample of a limited selection of foods. These may not include foods typically consumed by population subgroups, such as ethnic or street food. These subgroups may therefore have higher or lower intakes than the population average, hiding further potential health inequalities.

Despite harmonisation of data, the biggest limitation remains the heterogeneity in methods between the national dietary surveys. The surveys used different dietary assessment tools, so comparisons between countries must still be treated with caution. However, to reduce selection bias, we followed EFSA recommendations to include under-reporters of energy intake (12). This removes another source of variation found in survey summary reports (3, 4). Differential under-reporting means that true intakes are not necessarily reflected by the data. Under-reporting may be particularly affected by educational attainment (29), justifying our focus on macronutrient densities.

6.6 Conclusion

This paper draws together individual datasets from national dietary surveys across 12 WHO European Member States. Potential socioeconomic inequalities were investigated by assessing selected nutrient intakes by GDP and education.

These analyses can inform future research and policy development. National dietary survey data can enable exploration of variation between countries, as well as investigating nutrient intakes by demographic parameters and assessment of inequalities in disadvantaged groups. To aid this and facilitate valid data pooling, national dietary survey harmonisation should be encouraged and data made publicly accessible.

Inequalities between and within countries were shown; higher GDP countries had higher total sugar intakes. Within-country associations between lower education and higher intakes were particularly pronounced for macronutrient intakes, suggesting overall poorer diet quality. In countries with lower GDP having less education was associated with having a lower mean energy intake and higher education with having higher fat intakes. In contrast, higher education in higher GDP countries was associated with lower fat intakes. Lower education groups generally had lower micronutrient intakes. Education mitigated against the influence of GDP on nutrient intakes, suggesting that socioeconomic factors operate on national and individual levels. Having a higher education may mitigate against the increased fats intakes seen with increased GDP, and having lower education may weaken beneficial increases in total folate.

It is critical for countries to understand that increasing the educational level of their population will lead to better nourished populations, and the ability to improve GDP. Policies should therefore be put in place to achieve this.

Funding

This project was funded by the WHO Regional Office for Europe.

Appendix 1 – National Dietary Survey Datasets Obtained

Country	Survey	Data Collection	Dietary Methodology	Total n*	Male			Female		
					Lower education	Intermediate education	Higher education	Lower education	Intermediate education	Higher education
Macedonia	First Macedonian Food Consumption Survey	2015	2*24h recall	387	6	123	40	16	136	66
Kazakhstan	Nutritional and health status survey of the population in Kazakhstan	2008	2*24h recall	3071	17	1116	268	25	1270	375
Hungary	Hungarian Diet & Nutritional Status Survey (OTÁP 2014)	2014	3-day non-consecutive diary	663	30	181	86	34	209	123
Estonia	National Dietary Survey	2014-2015	2*24h recall	2573	2	518	215	2	988	848
France	Individual National Food Consumption Survey (INCA2)	2006-2007	7-day consecutive diary	2235	25	589	302	47	839	433
UK	National Diet and Nutrition Survey Rolling Programme Y7-8 (NDNS RP 2014-2016)	2014-2016	4-day consecutive diary	988	67	164	180	85	229	263
Finland	The National FINDIET 2012 survey (FINRISK)	2012	2*24h consecutive recall	1283	187	191	200	235	218	252

Sweden	Riksmaten 2010-2011 Swedish Adults Dietary Survey	2010-2011	4-day consecutive web-based diary	1405	72	267	272	53	334	407
Germany	German National Nutrition Survey II (NVSII)	2005-2007	Diet history interview (DISHES).	10090	46	3129	1371	49	4106	1389
Denmark	Danish National Survey of Diet and Physical Activity (DANSDA)	2011-2013	7-day consecutive pre-coded diary	2355	138	723	267	139	646	442
Netherlands	Dutch National Food Consumption Survey 2007-2010 (DNFCS 2007-10)	2007-2010	2*24h recall	1933	282	460	222	338	432	199
Austria	Austrian nutrition report 2012 (OSES)	2010-2012	2*24h recall, non-consecutive diary	351	56	42	47	76	70	60

* Unweighted numbers of adults aged 19-64y used in analyses.

Appendix 2 – Mean adult energy and nutrient intakes in the WHO European Region by sex

	Male				Female			
Energy (kcal)	N	Mean	95% CI		N	Mean	95% CI	
Macedonia	169	2705	2544	2866	218	2051	1930	2172
Kazakhstan	1401	2178	2138	2217	1670	1788	1756	1820
Hungary	297	2800	2676	2923	366	2099	1999	2198
Estonia	735	2157	2091	2224	1839	1535	1503	1566
France	919	2275	2227	2324	1321	1711	1679	1743
UK	450	2103	2030	2176	632	1628	1580	1675
Finland	585	2250	2175	2325	710	1730	1683	1777
Sweden	612	2269	2202	2335	794	1788	1746	1830
Germany	4665	2719	2681	2757	5666	2023	1995	2051
Denmark	1172	2690	2624	2755	1259	2000	1951	2048
Netherlands	964	2645	2594	2696	969	1960	1922	1997
Austria	147	2225	2125	2324	225	1868	1794	1942
Total Fat (%E)	N	Mean	95% CI		N	Mean	95% CI	
Macedonia	169	33	31	35	218	32	31	33
Kazakhstan	1401	34	34	35	1670	35	35	36
Hungary	297	39	38	39	366	37	37	38
Estonia	735	36	35	36	1839	36	35	36
France	919	36	36	37	1321	39	38	39
UK	450	33	32	33	632	34	33	34
Finland	585	37	36	38	710	36	36	37
Sweden	612	35	34	35	794	35	35	36
Germany	4665	35	35	35	5666	34	33	34
Denmark	1172	37	36	37	1259	37	36	37
Netherlands	964	34	34	35	969	34	33	35
Austria	147	36	35	37	225	35	34	36
TFA (%E)	N	Mean	95% CI		N	Mean	95% CI	
Denmark	1172	0·56	0·54	0·57	1259	0·57	0·55	0·58
Macedonia	169	0·50	0·41	0·59	218	0·49	0·42	0·56
Kazakhstan	1401	0·63	0·58	0·68	1670	0·61	0·56	0·65
Estonia	735	0·25	0·24	0·27	1839	0·27	0·26	0·28
UK	450	0·46	0·43	0·48	632	0·48	0·46	0·50
Finland	585	0·42	0·40	0·44	710	0·42	0·40	0·44
Netherlands	964	0·55	0·53	0·57	969	0·59	0·57	0·62
Total Sugar (%E)	N	Mean	95% CI		N	Mean	95% CI	
Macedonia	169	9	7	10	218	11	10	12
Kazakhstan	1401	19	18	19	1670	21	21	22
Hungary	297	16	15	17	366	19	18	20
Estonia	735	18	18	19	1839	22	22	23
France	919	16	16	17	1321	19	19	20
UK	450	18	17	19	632	20	19	21
Finland	585	20	19	21	710	21	21	22
Sweden	612	16	15	16	794	19	18	19
Germany	4665	22	22	22	5666	26	26	26
Denmark	1172	17	17	18	1259	18	18	19
Netherlands	964	20	19	20	969	21	21	22
Austria	147	18	17	19	225	20	19	21
Iron (mg)	N	Mean	95% CI		N	Mean	95% CI	

Macedonia	169	14·8	13·8	15·9	218	11·7	10·9	12·5
Kazakhstan	1401	13·8	13·5	14·1	1670	11·6	11·3	12·0
Hungary	297	12·4	11·8	12·9	366	9·9	9·4	10·3
Estonia	735	13·8	13·1	14·5	1839	10·0	9·7	10·3
France	919	13·6	13·1	14·1	1321	10·7	10·4	11·0
UK	450	11·6	11·1	12·2	632	9·2	8·9	9·6
Finland	585	12·9	12·3	13·4	710	10·3	9·9	10·6
Sweden	612	11·5	11·2	11·9	794	9·5	9·2	9·8
Germany	4665	14·3	14·2	14·5	5666	11·5	11·4	11·6
Denmark	1172	12·8	12·5	13·1	1259	9·6	9·4	9·9
Netherlands	964	11·9	11·6	12·1	969	9·8	9·6	10·0
Austria	147	12·0	11·4	12·5	225	10·9	10·4	11·4
Total Folate (µg)	N	Mean	95% CI		N	Mean	95% CI	
Macedonia	169	462	394	530	218	364	306	422
Kazakhstan	1401	124	121	128	1670	107	104	110
Hungary	297	170	158	181	366	143	133	152
Estonia	735	206	199	213	1839	162	157	166
France	919	274	266	282	1321	246	239	252
UK	450	264	251	277	632	214	204	224
Finland	585	283	262	305	710	230	222	237
Sweden	612	260	252	268	794	245	238	253
Germany	4665	349	337	361	5666	300	293	307
Denmark	1172	361	351	372	1259	314	304	323
Netherlands	964	303	295	312	969	248	240	255
Austria	147	211	198	224	225	211	199	223
Vitamin D (µg)	N	Mean	95% CI		N	Mean	95% CI	
Macedonia	169	6·3	3·6	9·0	218	3·3	1·9	4·7
Kazakhstan	1401	1·1	1·0	1·2	1670	0·8	0·8	0·9
Hungary	297	2·7	2·4	2·9	366	2·1	1·9	2·2
Estonia	735	5·6	4·9	6·2	1839	4·1	3·7	4·4
France	919	2·5	2·4	2·6	1321	2·3	2·1	2·4
UK	450	2·8	2·6	3·1	632	2·5	2·3	2·7
Finland	585	10·7	9·9	11·4	710	8·2	7·8	8·7
Sweden	612	7·1	6·6	7·5	794	6·0	5·7	6·3
Germany	4665	3·5	3·4	3·6	5666	2·6	2·5	2·7
Denmark	1172	4·6	4·3	4·8	1259	3·7	3·5	4·0
Netherlands	964	4·0	3·9	4·2	969	3·1	2·9	3·3

* Where total sugar was not defined as a single variable of that name, it was defined as monosaccharides plus disaccharides and a variable created to denote this value.

NB – countries are ordered by GDP from lowest to highest.

Appendix 3 – Association between mean nutrient intakes and GDP in 12 countries of the WHO European Region

	Slope*	95% CI		p-value
Energy (kcal)	-57	-419	305	0·7
Total fat (%E)	1·0	-1·8	3·8	0·4
TFA (%E)	-0·006	-0·291	0·279	1·0
Total sugar (%E)	5·0	0·6	9·3	0·03
Iron (mg)	-1·28	-2·58	0·02	0·05
Total folate (µg)	12	-126	150	0·2
Vitamin D (µg)	1·4	-2·7	5·5	0·5

*Slope represents the change in nutrient intake (per unit specified) for each 10% increase in GDP.

Appendix 4 – Age standardised mean energy and nutrient intakes for adult men in the WHO European Region by educational status

	Lower Education				Intermediate Education				Higher Education			
Energy (kcal)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	6	2242	2168	2315	123	2593	2374	2813	40	2812	2492	3132
Kazakhstan	17	1843	1641	2045	1116	2147	2105	2188	268	2317	2213	2422
Hungary	30	2864	2634	3094	181	2877	2737	3016	86	2607	2464	2751
Estonia*	2	N/A	N/A	N/A	518	2129	2049	2208	215	2286	2188	2383
France	25	2103	1971	2235	589	2266	2207	2325	302	2337	2257	2417
UK	67	2007	1875	2139	164	2028	1939	2118	180	2168	2072	2265
Finland	187	2350	2193	2507	191	2202	2070	2333	200	2204	2104	2304
Sweden	72	2089	1945	2232	267	2249	2073	2426	272	2318	2245	2391
Germany	46	2378	2104	2653	3129	2687	2646	2729	1371	2805	2722	2888
Denmark	138	2781	2633	2929	723	2728	2644	2812	267	2632	2525	2740

Netherlands	282	2701	2605	2796	460	2675	2607	2744	222	2516	2430	2601
Austria	56	2206	2098	2315	42	2182	2028	2335	47	2217	2089	2346
Total Fat (%E)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	6	32	30	34	123	33	31	35	40	34	31	38
Kazakhstan	17	29	26	33	1116	34	33	34	268	37	36	39
Hungary	30	38	37	40	181	39	38	40	86	38	37	39
Estonia*	2	N/A	N/A	N/A	518	35	35	36	215	36	35	37
France	25	36	34	38	589	36	36	37	302	36	36	37
UK	67	32	30	33	164	32	31	33	180	33	32	34
Finland	187	37	36	39	191	35	33	37	200	37	36	39
Sweden	72	35	34	37	267	35	34	36	272	35	34	36
Germany	46	34	33	36	3129	35	35	35	1371	35	34	35
Denmark	138	37	36	38	723	37	37	38	267	36	35	37
Netherlands	282	35	34	36	460	34	34	35	222	34	33	34
Austria	56	35	34	36	42	37	36	39	47	37	36	39
TFA (%E)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Denmark	138	0·56	0·53	0·60	723	0·56	0·54	0·58	267	0·54	0·51	0·57
Macedonia	6	0·34	0·20	0·48	123	0·53	0·43	0·63	40	0·54	0·36	0·72
Kazakhstan	17	0·41	0·24	0·58	1116	0·60	0·54	0·66	268	0·80	0·67	0·93
Estonia*	2	N/A	N/A	N/A	518	0·24	0·23	0·26	215	0·29	0·27	0·31
UK	67	0·44	0·41	0·48	164	0·45	0·41	0·48	180	0·47	0·44	0·50
Finland	187	0·43	0·41	0·46	191	0·42	0·38	0·45	200	0·41	0·38	0·43
Netherlands	282	0·56	0·52	0·60	460	0·55	0·52	0·58	222	0·55	0·51	0·58
Total Sugar (%E)**	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	6	12	10	14	123	8	7	10	40	8	7	10
Kazakhstan	17	19	16	23	1116	19	18	19	268	18	17	19
Hungary	30	13	11	16	181	16	15	17	86	17	16	18
Estonia*	2	N/A	N/A	N/A	518	18	17	18	215	21	20	22
France	25	13	11	14	589	16	16	17	302	17	16	18
UK	67	20	19	21	164	18	17	19	180	18	17	19
Finland	187	19	17	20	191	21	19	23	200	20	18	21

Sweden	72	15	14	17	267	15	14	16	272	16	15	17
Germany	46	23	21	25	3129	21	21	22	1371	23	22	24
Denmark	138	18	16	19	723	17	16	17	267	17	16	18
Netherlands	282	20	19	21	460	20	19	21	222	20	19	21
Austria	56	18	17	19	42	20	18	22	47	18	17	19
Iron (mg)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	6	13·7	12·3	15·2	123	14·4	13·1	15·7	40	14·9	13·1	16·7
Kazakhstan	17	11·5	10·1	12·9	1116	13·6	13·2	13·9	268	15·0	14·2	15·9
Hungary	30	11·8	10·5	13·0	181	12·7	12·0	13·4	86	12·4	11·7	13·1
Estonia*	2	N/A	N/A	N/A	518	13·3	12·6	13·9	215	15·4	13·7	17·1
France	25	12·8	11·0	14·6	589	13·4	12·8	13·9	302	14·3	13·6	14·9
UK	67	9·9	8·9	10·9	164	11·1	10·5	11·6	180	12·5	11·7	13·3
Finland	187	13·2	12·0	14·3	191	12·8	11·8	13·8	200	12·5	11·8	13·3
Sweden	72	10·1	9·2	10·9	267	11·1	10·3	11·9	272	12·3	11·8	12·8
Germany	46	12·2	11·0	13·4	3129	14·4	14·1	14·6	1371	14·5	14·1	14·9
Denmark	138	12·9	12·3	13·5	723	13·0	12·6	13·4	267	12·8	12·1	13·5
Netherlands	282	11·7	11·2	12·1	460	11·8	11·5	12·2	222	12·2	11·7	12·6
Austria	56	11·6	11·0	12·2	42	11·2	10·3	12·2	47	11·1	10·4	11·8
Total Folate (µg)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	6	793	656	930	123	382	348	415	40	447	365	529
Kazakhstan	17	104	91	117	1116	123	120	127	268	128	121	135
Hungary	30	131	116	146	181	176	160	191	86	186	171	202
Estonia*	2	N/A	N/A	N/A	518	197	189	205	215	233	223	244
France	25	242	204	279	589	271	262	280	302	287	274	299
UK	67	224	198	249	164	244	231	257	180	292	269	315
Finland	187	299	244	353	191	278	247	309	200	269	251	287
Sweden	72	230	214	246	267	245	229	261	272	280	268	293
Germany	46	274	240	308	3129	360	343	377	1371	331	313	349
Denmark	138	359	335	382	723	369	355	383	267	379	349	408
Netherlands	282	297	281	313	460	305	292	318	222	308	292	323
Austria	56	200	188	213	42	220	197	242	47	216	199	233

Vitamin D (µg)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	6	1·3	0·8	1·8	123	4·7	2·6	6·8	40	6·6	3·0	10·2
Kazakhstan	17	1·3	0·5	2·1	1116	1·1	1·0	1·2	268	1·4	1·1	1·7
Hungary	30	2·2	1·8	2·6	181	2·6	2·4	2·9	86	2·9	2·4	3·4
Estonia*	2	N/A	N/A	N/A	518	5·9	5·0	6·8	215	4·8	4·1	5·5
France	25	2·9	1·8	4·1	589	2·4	2·3	2·6	302	2·6	2·4	2·8
UK	67	2·8	2·3	3·2	164	2·8	2·5	3·1	180	2·9	2·5	3·4
Finland	187	12·0	10·6	13·5	191	10·6	9·2	12·1	200	9·9	9·0	10·9
Sweden	72	6·5	5·5	7·6	267	6·5	5·8	7·1	272	7·7	7·0	8·4
Germany	46	3·0	2·4	3·6	3129	3·6	3·5	3·7	1371	3·5	3·3	3·7
Denmark	138	3·9	3·4	4·4	723	4·9	4·6	5·3	267	5·0	4·3	5·6
Netherlands	282	4·2	3·9	4·5	460	4·1	3·8	4·3	222	3·5	3·2	3·7

* Lower educated Estonian intakes not included due to n<3 individuals.
** Where total sugar was not defined as a single variable of that name, it was defined as monosaccharides plus disaccharides and a variable created to denote this value.

NB – countries are ordered by GDP from lowest to highest.

Appendix 5 – Age standardised mean energy and nutrient intakes for adult women in the WHO European Region by educational status

	Lower Education				Intermediate Education				Higher Education			
Energy (kcal)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	16	1697	1451	1944	136	2059	1908	2211	66	2129	1961	2297
Kazakhstan	25	1678	1427	1930	1270	1783	1748	1819	375	1793	1686	1900
Hungary	34	2237	2017	2457	209	2015	1917	2113	123	2008	1913	2104
Estonia*	2	N/A	N/A	N/A	988	1473	1429	1516	848	1626	1585	1666
France	47	1586	1470	1703	839	1684	1643	1724	433	1788	1741	1835
UK	85	1420	1302	1538	229	1595	1514	1675	263	1682	1609	1754
Finland	235	1732	1640	1824	218	1690	1622	1758	252	1755	1679	1831

Sweden	53	1349	1242	1456	334	1775	1699	1850	407	1858	1809	1906
Germany	49	2127	1970	2284	4106	2011	1986	2037	1389	2065	1983	2147
Denmark	139	1877	1779	1974	646	2006	1945	2067	442	2032	1956	2107
Netherlands	338	1977	1911	2043	432	2004	1944	2064	199	1874	1806	1943
Austria	76	1753	1651	1855	70	1881	1760	2001	60	2002	1866	2139
Total Fat (%E)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	16	29	27	32	136	31	30	33	66	34	32	37
Kazakhstan	25	29	27	31	1270	35	34	35	375	36	34	37
Hungary	34	36	35	37	209	37	37	38	123	38	37	39
Estonia*	2	N/A	N/A	N/A	988	36	35	36	848	36	35	36
France	47	38	36	39	839	38	38	39	433	39	38	39
UK	85	33	32	35	229	33	32	34	263	35	34	36
Finland	235	37	35	38	218	36	34	37	252	36	35	37
Sweden	53	33	32	35	334	36	35	36	407	35	35	36
Germany	49	37	35	39	4106	34	33	34	1389	34	33	34
Denmark	139	37	36	39	646	37	36	37	442	36	36	37
Netherlands	338	35	34	36	432	34	33	34	199	34	33	34
Austria	76	36	35	37	70	35	33	36	60	35	34	37
TFA (%E)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Denmark	139	0·66	0·61	0·71	646	0·55	0·53	0·57	442	0·53	0·51	0·55
Macedonia	16	0·40	0·21	0·60	136	0·46	0·38	0·54	66	0·52	0·39	0·65
Kazakhstan	25	0·31	0·14	0·47	1270	0·60	0·54	0·65	375	0·60	0·52	0·69
Estonia*	2	N/A	N/A	N/A	988	0·26	0·25	0·27	848	0·29	0·27	0·31
UK	85	0·49	0·45	0·53	229	0·47	0·44	0·51	263	0·49	0·46	0·52
Finland	235	0·43	0·40	0·46	218	0·41	0·38	0·44	252	0·42	0·39	0·45
Netherlands	338	0·60	0·56	0·64	432	0·59	0·55	0·62	199	0·56	0·52	0·61
Total Sugar (%E)**	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	16	11	9	13	136	10	9	11	66	13	11	15
Kazakhstan	25	25	22	28	1270	21	21	22	375	22	20	23
Hungary	34	15	13	16	209	19	18	20	123	20	19	21
Estonia*	2	N/A	N/A	N/A	988	21	21	22	848	23	22	24

France	47	18	15	20	839	19	19	20	433	20	19	20
UK	85	20	18	21	229	20	19	22	263	20	19	21
Finland	235	21	20	22	218	21	20	22	252	22	21	23
Sweden	53	17	16	19	334	19	18	20	407	18	18	19
Germany	49	25	23	27	4106	26	25	26	1389	27	26	27
Denmark	139	18	17	19	646	19	18	19	442	18	18	19
Netherlands	338	22	21	22	432	22	21	22	199	21	20	22
Austria	76	20	19	22	70	21	19	23	60	21	20	22
Iron (mg)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	16	11·3	9·9	12·8	136	11·8	10·9	12·7	66	11·4	10·2	12·6
Kazakhstan	25	9·3	7·7	10·9	1270	11·5	11·1	11·9	375	12·4	11·7	13·2
Hungary	34	9·5	8·7	10·4	209	9·6	9·1	10·1	123	10·0	9·4	10·6
Estonia*	2	N/A	N/A	N/A	988	9·5	9·2	9·9	848	10·8	10·4	11·3
France	47	9·9	9·2	10·6	839	10·5	10·1	10·8	433	11·4	10·9	11·9
UK	85	8·3	7·3	9·3	229	8·7	8·3	9·1	263	9·9	9·4	10·3
Finland	235	9·8	9·2	10·4	218	10·5	9·9	11·1	252	10·4	9·9	10·9
Sweden	53	8·1	7·5	8·7	334	9·0	8·5	9·5	407	10·2	9·8	10·5
Germany	49	11·3	10·5	12·1	4106	11·6	11·4	11·7	1389	11·5	11·1	11·9
Denmark	139	8·4	7·9	8·8	646	9·8	9·5	10·1	442	10·0	9·6	10·4
Netherlands	338	9·6	9·2	10·0	432	10·0	9·6	10·3	199	10·4	10·0	10·8
Austria	76	10·3	9·6	11·0	70	11·0	10·0	11·9	60	11·3	10·5	12·1
Total Folate (μg)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	16	337	267	406	136	354	281	428	66	359	318	400
Kazakhstan	25	109	88	130	1270	107	104	110	375	101	96	106
Hungary	34	124	112	136	209	134	123	145	123	162	146	178
Estonia*	2	N/A	N/A	N/A	988	152	146	157	848	181	174	187
France	47	210	196	224	839	237	229	245	433	269	258	280
UK	85	191	164	218	229	194	183	204	263	229	217	242
Finland	235	212	199	225	218	238	224	253	252	237	225	249
Sweden	53	203	182	224	334	226	216	236	407	269	258	280
Germany	49	328	292	364	4106	302	294	310	1389	303	276	331

Denmark	139	265	246	283	646	324	308	339	442	335	320	351
Netherlands	338	234	220	247	432	251	240	262	199	261	247	276
Austria	76	204	188	220	70	236	197	275	60	234	218	251
Vitamin D (µg)	N	Mean	95% CI		N	Mean	95% CI		N	Mean	95% CI	
Macedonia	16	1·1	0·8	1·4	136	3·3	1·8	4·8	66	3·8	1·8	5·9
Kazakhstan	25	0·7	0·4	0·9	1270	0·8	0·7	0·9	375	0·8	0·7	0·9
Hungary	34	2·3	1·9	2·6	209	2·0	1·9	2·2	123	2·0	1·8	2·2
Estonia*	2	N/A	N/A	N/A	988	4·0	3·6	4·4	848	4·4	3·8	5·0
France	47	1·9	1·6	2·2	839	2·2	2·0	2·3	433	2·4	2·2	2·6
UK	85	2·4	2·1	2·7	229	2·4	2·2	2·7	263	2·6	2·3	2·8
Finland	235	7·9	7·1	8·7	218	8·3	7·6	9·1	252	8·3	7·5	9·0
Sweden	53	4·7	3·8	5·5	334	5·8	5·3	6·3	407	6·5	6·1	7·0
Germany	49	2·7	1·9	3·5	4106	2·6	2·5	2·7	1389	2·5	2·4	2·7
Netherlands	338	3·1	2·9	3·3	432	3·3	3·0	3·5	199	2·9	2·5	3·3
Denmark	139	3·1	2·7	3·5	646	3·5	3·3	3·8	442	4·0	3·6	4·5

* Lower educated Estonian intakes not included due to n<3 individuals.
** Where total sugar was not defined as a single variable of that name, it was defined as monosaccharides plus disaccharides and a variable created to denote this value.

NB – countries are ordered by GDP from lowest to highest.

Appendix 6 – Association between nutrient intake and educational status, by sex, adjusted for age and GDP

	MEN – Lower vs. Intermediate			**MEN – Higher vs. Intermediate**			**WOMEN – Lower vs. Intermediate**			**WOMEN – Higher vs. Intermediate**			
	Slope*	95% CI		Slope*	95% CI		Slope*	95% CI		Slope*	95% CI		**P-value****
Energy (kcal)	-6	-81	69	43	-1	87	-67	-115	-20	-12	-37	12	0·06
Total fat (%E)	0·9	0·3	1·5	0·2	-0·2	0·5	0·9	0·3	1·4	0·4	0·1	0·7	0·7
TFA (%E)	0·07	0·04	0·10	0·01	-0·02	0·04	0·07	0·04	0·11	-0·01	-0·04	0·02	0·5
Total sugar (%E)	-1·1	-1·8	-0·5	0·9	0·5	1·2	-3·0	-3·5	-2·4	-0·2	-0·6	0·1	<0·001
Iron (mg)	-1·4	-1·7	-1·0	0·4	0·1	0·7	-1·3	-1·6	-1·0	0·1	-0·1	0·2	0·1
Total folate (µg)	-15	-35	5	-2	-11	8	-31	-39	-22	2	-4	9	0·2
Vitamin D (µg)	1·4	1·0	1·9	0·2	-0·01	0·4	0·8	0·6	1·1	0·5	0·4	0·7	0·004

* Slope represents the change in nutrient intake (per unit specified) for each 10% increase in GDP.

** P-value represents the difference between subgroups defined by educational status in estimated association between GDP and nutrient intake.

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Chapter 7 An exploration of socio-economic and food characteristics of high trans fatty acid consumers in the Dutch and UK national surveys after voluntary product reformulation

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7.1 Abstract

Background: Trans fatty acids (TFA) increase the risk of mortality and chronic diseases. TFA intakes have fallen since reformulation, but may still be high in certain, vulnerable, groups.

Objective: To investigate socio-economic and food consumption characteristics of high TFA consumers after voluntary reformulation in the Netherlands and UK.

Methods: Post-reformulation data of adults aged 19-64 was analysed in two national surveys: the Dutch National Food Consumption Survey (DNFCS) collected 2007-2010 using 2*24hr recalls (N=1933) and the UK National Diet and Nutrition Survey (NDNS) years 3&4 collected 2010/11 and 2011/12 using 4-day food diaries (N=848). The socio-economic and food consumption characteristics of the top 10% and remaining 90% TFA consumers were compared. Means of continuous data were compared using t-tests and categorical data means using chi-squared tests. Multivariate logistic regression models indicated which socio-demographic variables were associated with high TFA consumption.

Results: In the Dutch analyses, women and those born outside the Netherlands were more likely to be top 10% TFA consumers than men and Dutch-born. In the UK unadjusted analyses there was no significant trend in socio-economic characteristics between high and lower TFA consumers, but there were regional differences in the multivariate logistic regression analyses. In the Netherlands, high TFA consumers were more likely to be consumers of cakes, buns & pastries; cream; and fried potato than the remaining 90%. Whereas in the UK, high TFA consumers were more likely to be consumers of lamb; cheese; and dairy desserts and lower crisps and savoury snack consumers.

Conclusion: Some socio-demographic differences between high and lower TFA consumers were evident post-reformulation. High TFA consumers in the Dutch 2007-10 survey appeared more likely to obtain TFA from artificial sources than those in the UK survey. Further analyses using more up-to-date food composition databases may be needed.

Key words:
Nutritional Epidemiology Group
World Health Organisation
Trans fatty acids (TFA)
Industry product reformulation
Voluntary TFA reduction
WHO TFA recommendations
Socio-economic disadvantage
Consumer characteristics
National dietary surveys

7.2 Introduction

Trans fatty acids (TFAs) are linked to all-cause mortality and various chronic diseases, most notably coronary heart disease (CHD) (1). CHD causes around 10,200 deaths in the Netherlands (2) and approximately 73,000 deaths in the UK annually, making it the largest cause of mortality (3). In addition, for every 2% total energy gained from TFAs there is a corresponding 23% increase in CHD incidence (4). Industrial trans fatty acids (iTFA) are artificially produced in processed foods by hydrogenating vegetable or fish oils (5) and are associated with CHD mortality and total CHD (1). Bakery products, spreads, packaged snack foods and deep-fried fast foods have been identified as major sources of iTFA (6). The UK Low Income Diet and Nutrition Survey found unequal consumption of TFA by socio-economic status, with the most deprived groups having higher intakes of processed foods and takeaways (7). Pearson-Stuttard et al. (8) suggest that reducing iTFA intake could substantially reduce health inequalities in CHD mortality. They estimated that a 1% reduction in TFA of daily energy intake would result in five times fewer deaths and six times more life years in the most deprived quintile than the most affluent.

The World Health Organisation (WHO) advises consuming <1% of total energy from TFAs (9). To achieve this the WHO European food and nutrition action plan calls for a 'virtual elimination' of iTFAs (10). Denmark was the first country to ban iTFA use by setting a maximum limit of 2g TFA per 100g total fat (11). This has been effective in reducing iTFA content in foods and a decline in cardiovascular mortality has been directly attributed to the policy (11). The ban was replicated in a number of European countries, including Austria, Iceland, Norway, Hungary and Switzerland (12). Latvia plan to implement an iTFA ban by 2018, while Turkey and Georgia have introduced legal measures relating to labelling. Conversely, the UK and Netherlands have largely pursued voluntary iTFA reduction through product reformulation and advanced production techniques. However, voluntary approaches may have significant limitations; since they may not apply to the entire food supply chain, reformulation efforts may be uneven across product categories, and population subgroups could continue to consume high amounts even if the average population intake is at or below recommended levels (13). The UK and Netherlands thus provide sound case studies for exploring potential advantages and drawbacks of voluntary approaches (14).

As part of public health iTFA reduction policies, the Dutch Task Force for the Improvement of the Fatty Acid Composition (Task Force verantwoorde vetzuursamenstelling: TFIFAC) launched in 2003. This initiative prompted manufacturers to reformulate and lower iTFA content in products, but was self-regulatory, so not monitored by government or an independent body (15). In the UK, the Public Health Responsibility Deal (PHRD) iTFA reduction pledge (16) was introduced later, in 2011 in response to consumer health concerns. In this scheme businesses were permitted to reference actions undertaken prior to 2011, so new measures were not guaranteed across all PHRD signatories. However, their broadly common approach means that the impact of voluntary iTFA reduction in these countries can be explored and compared, with a view to advising other European countries. Further parallels are that both UK and Dutch TFA intake had been moderate compared to many other European nations; mean TFA intake in men was 1.3% total energy in the UK (1996) and 1.5% in the Netherlands (1992), compared to extremes of 2.1% in Iceland (1990) and 0.5% in Greece (1995) and Italy (1980-84). In addition, Sweden also employs a self-regulatory approach and had a moderate TFA intake (17).

Although the latest Dutch National Food Consumption Survey (DNFCS) (18) and UK National Diet and Nutrition Survey (NDNS) (19) reported that on average Dutch and UK adults meet the WHO and Dutch national limits of <1% total energy intake (9), these averages could still mask inequalities within certain groups, like those on low incomes (20). For instance in Portugal, biscuits and pastry products typically imported and available in budget outlets have higher TFA levels than the majority of products in the country, which meet WHO guidelines (21).

The aim of this research is to analyse the Dutch and UK national nutrition surveys, which incorporate data gathered after voluntary product reformulation, to determine the characteristics of high compared to lower TFA consumers, and to determine whether similarities in Dutch and UK consumers exist, with particular reference to socially disadvantaged groups and consumption of food groups. The Dutch and UK examples could therefore advance understanding of the merits and limitations of voluntary TFA reduction in the context of minimising health inequalities.

7.3 Methods

Two government-funded national surveys collected post-product reformulation were obtained and analysed for TFA content in relation to socio-economic and dietary characteristics (22, 23).

7.3.1 Dutch data

Data analysed from the Dutch National Food Consumption Survey (DNFCS) was collected March 2007-April 2010 (18) after industry product reformulation. The samples were drawn from consumer panels from Market Research GfK Panel Services, representative on age, gender, region, education and urbanisation. The DNFCS 2007-10 collected food data from individuals aged 7-69 using two 24-hour dietary recalls on two non-consecutive days by trained dietitians during home visits using the computer-based interview program EPIC–Soft, now called GloboDiet (©IARC) (18). Portion sizes were given either by weight/volume or estimated using standard or household measures, or pictorial representations (18). Demographic information was collected using age-specific general questionnaires (18).

TFA values in the DNFCS 2007-10 survey were based on values in the Dutch Food Composition Database, NEVO 2011 (24). Nutrient data in NEVO 2011 originate from several sources in addition to the Dutch National Institute for Public Health and the Environment's (RIVM) preferred chemical analyses from accredited laboratories. TFA values from the food industry collated by the Dutch task force (TFIFAC) informed the NEVO TFA values for potato products, bread, pastry, cakes and biscuits (excluding foods made with butter), (meat) snacks and salads, fats and margarines (15). Other TFA sources include scientific publications, foreign food composition tables and derived nutrients from comparable foods (24).

7.3.2 UK Data

UK Data incorporating the reduced TFA content of reformulated products was analysed from years 3&4 (2010/2011 & 2011/2012) of the 2008-12 NDNS Rolling Programme (RP) (19). Years 1&2 of the NDNS RP data were not included in the analyses because NDNS RP year 1 did not incorporate post-reformulation TFA compositions and year 2 data only incorporated some changes.

The UK NDNS 2008-12 RP collected data from individuals aged over 1.5 using a consecutive four-day food diary; portion sizes were estimated using household measures and food packaging labels (Bates et al., 2014). The samples were drawn from UK Postcode Address Files, selected using multi-stage random probability sampling with postal sectors as the primary sampling units. Laboratory-analysed TFA levels in processed foods high in iTFAs and targeted for reformulation (25, 26) were incorporated into the nutrient composition tables supporting years 3&4 (2010/2011 & 2011/2012) of the NDNS RP. These mostly popular and widely purchased products were gathered between 2008 and 2010 in the UK (25, 26). Sub-samples of the food products had been combined in equal weights to form a composite sample for analysis, with 5-16 sub-samples for each food sample category (26). The UK Department of Health (DH) adopted the new

TFA values where they were lower than in the existing composition tables; where they were equal or higher, existing values were retained.

7.3.3 Statistical Methods

The percentage of individuals who consumed more than the current WHO recommended limits on TFAs (9) i.e. more than or equal to 1% of their total energy from TFAs, was determined for Dutch and UK adults aged 19-64 using the intake averaged over 2 and 4 days, respectively. Due to low numbers in the UK post-reformulation surveys consuming above WHO recommended TFA limits (n=22) and the potential distortion of total energy intake by high alcohol consumers, further analyses were conducted on the top 10% of TFA consumers as a percentage of food (rather than total) energy intake, defined as non-alcohol energy. These were then compared to the remaining 90% for adults aged 19-64, for both the Netherlands and the UK.

Characteristics of the top 10% TFA consumers were compared to lower TFA consumers using socio- demographic variables, which were the same or similar in the UK and Dutch surveys. These variables were: age, continuous and grouped (19-34y, 35-49y, 50-64y); gender; education (Dutch: High (University or higher vocational), medium (higher general secondary or Intermediate vocational), Lower (primary or lower vocational). UK: High (Degree), Medium (Qualifications below degree), Lower (No qualifications or in FT education); in employment (Yes/No); monthly income split into 5 groups (Dutch: net. UK: gross); region split into 4 groups (Dutch: 1) three largest cities in West Netherlands, 2) Rest of the West, 3) North, 4) East, South. UK: 1) London, East & South England, 2) North England, 3) Midlands, 4) Scotland, Wales & Northern Ireland); household size (number of people in household); Origin/Ethnicity (Dutch: native or non-Dutch native (born outside of the Netherlands). UK: (white or non-white)); smoking status (current, ex-regular, never regular); whether drinks alcohol (Yes/No). The means of continuous data were compared using t-tests and categorical data were compared using chi squared tests within country.

Food and nutrient intakes were also compared between the high and lower TFA groups. Where data was reasonably normally distributed, selected macro and micronutrient intake comparisons were undertaken by t-tests. Additionally, the percentage of consumers of selected food groups known to be high in TFA content were compared between the high and lower TFA intake groups using chi squared tests.

Multivariate logistic regression models for the Dutch and UK datasets were undertaken separately to determine which socio-demographic characteristics were independently associated with high TFA consumption. This incorporated age as a continuous variable; gender, qualifications as three categories (high, medium and low); income and region categorised as above; total number in the household and a binary ethnic origin variable.

Sensitivity analysis was conducted whereby all analyses were rerun after the identification and exclusion of under-reporters. Following the Oxford equations derived from Henry (27), survey height and weight data were used to generate Basal Metabolic Rate (BMR) and BMR:energy intake ratio variables. A general Physical Activity Level (PAL) of 1.55 was set to generate a low cut off via the Goldberg method (28). For continuity, analyses were rerun after excluding under-reporters from the original top 10% group rather than generating a new top 10%.

All analyses were weighted using the survey weights provided to produce estimated results representative of the Dutch (29) and UK populations (30). Statistical significance was set at $p<0.05$. All analyses used Stata version 13 (31).

7.4 Results

There were 1933 adults aged 19-64 in the Dutch and 848 in the UK analyses. In the DNFCS 2007-10, on average men and women aged 19-64 consumed 0.6% total energy (0.5% for men; 0.6% for women) and 0.6% food energy (0.6% for men and women) from TFAs. In the UK NDNS RP (Y3&4), adults consumed 0.5% total energy (0.5% for men and women) and 0.5% food energy from TFAs (0.5% for men and women). On average over the two survey days, 7.4% of Dutch adults consumed more TFAs than the current WHO recommended limits and Dutch national guidelines (5.7% males; 9.0% females, p=0.01). In the UK NDNS RP 2.5% of adults consumed more than the current WHO recommended limits on TFAs (1.9% males; 3.0% females) over the four survey days. Consumers above the WHO recommended limits in the Netherlands had 1.3% (95%CI: 1.3, 1.4) of total energy intake from TFAs. This was similar to the UK, where 1.2% (95%CI: 1.1, 1.4) of total energy intake came from TFAs. Thus, in both surveys, TFA intake as a % total energy was more than twice as high in those not meeting WHO recommendations than those who did, who consumed 0.5% TFA from total energy (p<0.001). Mean TFA intake in the Dutch survey was 3.5g (95%CI: 3.2, 3.7) in those not meeting the WHO recommendations – significantly higher (p<0.001) than those meeting the recommendations (1.3g (95%CI: 1.3, 1.3)). In the UK this was 2.2g (95%CI: 1.9, 2.4) compared to 1.0g (95%CI: 1.0, 1.1) (p<0.001).

For the top 10% TFA consumers in the Dutch survey, mean TFA intake was significantly higher than for the remaining 90% at 3.3g compared to 1.3g (**table 1**). This is higher than the top 10% TFA consumers in the UK NDNS RP years 3&4 (1.9g compared to 0.9g).

7.4.1 Socio-demographic characteristics of the top 10% TFA consumers

In the Dutch analysis, there were significant differences relating to gender and ethnicity between the top 10% Dutch TFA consumers and remaining consumers (table 1). Females were more likely to be top 10% consumers than males (table 1). Non-Dutch natives were more likely to be in the top 10% TFA consumers and although not significant, in the UK analyses a higher proportion of non-white respondents were also in the top 10% TFA consumers (table 1). In the unadjusted analyses there were no significant differences in other socio-demographic or socio-economic variables in either country, including age, education, employment status, income, geographic region or number of people in household. There were also no significant differences relating to smoking status or alcohol intake.

In the multivariate logistic regression analyses (**table 2**) of the Dutch data, women were more likely than men to be top 10% consumers of TFAs (OR, 95%CI =1.39, 0.99, 1.94; p=0.05). Non-native individuals were nearly two and half times more likely to be top 10% consumers than Dutch native individuals (OR, 95%CI =2.42, 1.16, 5.04). These non-natives were from Germany, France, Hungary, Poland, Romania, Brazil, Dutch Caribbean, Indonesia, Korea and Suriname. Aside from the second lowest income category in the UK data, which was more likely to feature in the top 10% TFA consumers, there were no significant differences related to income in either country. However, in the UK multivariate analysis, top 10% consumers were more likely to reside in the Midlands than in London, East and South England (OR, 95%CI =2.30, 1.11, 4.78).

7.4.2 Food and nutrition intake of the top 10% TFA consumers

In relation to foods and other nutrients consumed, the top 10% of TFA consumers in the UK NDNS (2010/11 to 2011/12) had higher fat and saturated fat and lower sugars and vitamin E intakes as %FE (**table 3**). They were also more likely to be consumers of lamb, butter and cheese, and less likely to be consumers of crisps and savoury snacks and dairy desserts than the remaining 90%. In comparison, the Dutch top 10% TFA consumers also had significantly higher fat and saturated fat intake as %FE, and although the same pattern for these nutrients was observed, intake was higher than in the UK (table 3). As in the UK, the top 10% Dutch TFA consumers consumed more butter than the remaining 90%, but there were no significant differences in lamb, cheese or crisps and savoury snack consumption. The top 10% Dutch TFA consumers did consume significantly more cream and buns, cakes and pastries (table 3). The top 10% UK, but not Dutch TFA consumers also consumed less vitamin C and E than the remaining 90%.

7.4.3 Sensitivity Analysis

Sensitivity analysis to exclude under-reporters reduced the top 10% UK TFA consumer group by 50% (n=44) compared to 12% for the Dutch (n=165). The analysis showed a slight increase in the percentage consuming above the WHO and Dutch guidelines (7.7% Dutch and 2.6%UK adults) and also in the TFA intake of these over-consumers (3.6g for Dutch and 2.3g for UK adults). Intakes of total and food energy from TFAs either remained the same or showed marginal changes. Where changes occurred in socio-demographic and diet association, most became non-significant, including gender in the DNFCS and region, sugar and vitamin E intake and dairy dessert consumption in the NDNS. Exceptions included cream consumption becoming significant in the NDNS, age in the DNFCS and a strengthened association between non-Dutch natives and being in the top TFA consumer groups. The association remained between iTFA-containing buns, cakes and pastries in high Dutch TFA consumers and food groups characterised by ruminant TFAs (lamb, butter, cheese, cream) in high UK TFA consumers.

7.5 Discussion

On average, the TFA consumed in the Dutch and UK nationally representative surveys was well below the WHO recommendations of <1% total energy, being 0.6% and 0.5% respectively. However, we found 7% of Dutch adults in the DNFCS 2007-10 consumed more than the WHO recommended limits; this group consumed 1.3% (3.5g) of their total energy from TFAs. Only 2.5% of UK adults in the NDNS RP (2010/11 to 2011/12) consumed over the WHO recommended limits; this group obtained 1.2% (2.2g) total energy from TFAs. Dutch women were more likely than men to feature in the top 10% consumers, possibly due to differences in dietary patterns. Those born outside the Netherlands were significantly more likely to be top 10% TFA consumers. There were no significant socio-economic associations, but in the UK multivariate analysis, top 10% consumers were more likely to reside in the Midlands, where incomes are generally lower than in London, East and South England (32). The food consumption profile of the top 10% UK TFA consumers was predominantly ruminant-based (lamb, butter, cheese), but the Dutch higher TFA intake still featured both industrial and ruminant TFAs (butter and also cream, buns, cakes and pastries). Although the UK survey is more recent than the Dutch, voluntary measures to reduce TFA started much earlier in the Netherlands (2003), (15) than in the UK (2011) (16). In addition to differences in the number of collection days used in the surveys, some of the differences in results between the countries may reflect differences in how recently and thoroughly the food composition tables underpinning the survey data have been updated, particularly regarding TFA.

We reported that a considerably larger proportion of adults (7%) consumed TFAs over the Dutch national and WHO recommended limits, than that in the Dutch DNFCS 2007-10 report, where recommended limits were exceeded by only 1-5% of the population depending on age group and gender (18). Whilst we used the observed individual mean TFA intake over two collection days in our analyses of Dutch data, and over four collection days for the UK, habitual (usual) intake was estimated for the DNFCS 2007-10 report (18). Collection of a limited number of days food intake can lead to considerable within-individual variation, which tends to widen intake distributions produced from observed individual mean intakes, resulting in overestimation of the more extreme percentiles (33). The habitual intake distribution by age and gender used in the DNFCS 2007-10 report was estimated from the observed daily intake by correcting for the intra-individual (day-to-day) variation using SPADE (Statistical Program to Assess Dietary Exposure) (34). In addition, the use of consumption data of two rather than four days for defining food consumer and high TFA intake groups may result in more misclassification for the Dutch data, than the UK.

It is difficult to establish how up-to-date were the food composition tables underpinning the TFA content of post-reformulated foods available during the survey periods. The UK uses industry updates (25, 26) to inform composition data, which are ad hoc reviews rather than regular annual updates. Although in the Netherlands the TFIFAC monitored compositional TFA changes annually, and provided industry data for the Dutch Food Composition Database (NEVO) until 2010, the NEVO 2011 used for our Dutch analyses may not be as up-to-date as the composition database underpinning the UK analyses. Industry data does not make up the majority of TFA values in NEVO 2011 (contributing to only 10% of the TFA values for cakes and biscuits for instance), which indicates post-reformulation data may not have been fully incorporated. Nevertheless, retail margarines and frying and cooking fats, which were reformulated before 2006 (15), are likely to have been incorporated. This demonstrates the importance of updated information in food composition databases; Dutch and UK product reformulation is voluntary, so although guidelines such as the UK PHRD (16) may exist, no mandatory or uniform programme is guaranteed. Regular rather than ad hoc reviews of relevant food categories would be necessary to ensure national diet surveys consistently report accurate TFA intakes on which sound conclusions and effective policy can be based.

Pre- and post-reformulation TFA intake comparisons have been made between UK surveys (Hutchinson et al.) (35) and also for the Netherlands using modelling techniques with young adult survey data (15). The analysis of both countries showed a decrease in average TFA consumption post-reformulation, and indicated total TFA intake comprised of fewer foods previously associated with iTFAs, and more ruminant products. However, our finding that a larger proportion of top 10% compared to lower Dutch TFA consumers consume cakes, buns and pastries contradicts the Temme finding that these foods contributed most to decreased TFA consumption. Nevertheless, iTFAs in these foods may have been reduced, with further reductions possible. Alternatively, TFA values in the Temme composition database may have used more-up-to-date TFIFAC information than that in NEVO 2011 (used in our analyses), though this may be unlikely.

Previous reviews have suggested that, globally, voluntary measures may be less effective than legislated limits in reducing TFAs in food products and inequalities in intake (13). Furthermore, where voluntary reformulation has been pursued, there have been reported difficulties in ensuring the participation of a critical mass of manufacturers and retailers, especially small and medium-sized enterprises (SMEs), which dominate the food sector (14). Thus, in some countries, a ban has been favoured to have maximum impact for all socio-economic groups and create a level playing field for companies. However, we found little evidence that higher TFA intake was associated with lower socio-economic status in both the Dutch and UK analyses. Although some associations were seen in relation to income in the UK multivariate analyses, those in the lowest income group were not more likely to be top 10% consumers than the highest income groups. This suggests there has been a sizeable response from industry across society. Indeed, the UK PHRD TFA voluntary pledge has over 90 signatories, including major large manufacturers and retailers (DH, 2014) and TFIFAC members in the Netherlands include major suppliers and customers of vegetable oils and fats in various sectors spanning a range of product categories (36). TFIFAC reductions from

2003-2009 in the Netherlands include processed oils and fats, bakery products and raw materials, pre- and deep-fried potato products, and snacks. TFA reduction is no longer a priority target for the Dutch National Agreement to Improve Product Composition 2014-2020 (37). However, we found non-native Dutch were more than twice as likely to be top 10% consumers as native Dutch, which may indicate that imported food into the Netherlands may contain more TFA, as found in Portugal (21), or that composition values are outdated. The latter may be more likely, as NEVO does not differentiate between imported and domestic foods, but takes an average. Therefore even substantial intakes of high-TFA imported products would be masked. In the UK analyses being a top 10% TFA consumer was not associated with ethnicity.

Direct comparisons were not made between Dutch and UK data due to the different methods used for data collection. The UK NDNS 2008-12 RP used a four-day consecutive food diary, with portion sizes estimated using household measures and food packaging labels (19). The DNFCS 2007-10 collected food data using two 24-hour dietary recalls on two non-consecutive days, and gathered demographic information by questionnaire. Portion sizes were established using either estimates based on household measures and/or pictorial formats or recalled weight of food prepared and consumed (18). In both surveys, the results are limited by self-reporting of intake, where no respondents weighed food intake (18, 19). There is evidence of under-reporting in both studies, (38, 39) by an estimated 30% in the UK study and 17% in the Dutch study (18). This may explain why energy intake, in addition to TFA intake, was lower in the UK NDNS than the DNFCS 2007-10. Sensitivity analysis to exclude under-reporters resulted in reduced top TFA consumer groups, particularly in the UK, which shrank by 50%. As expected, the reduced UK top TFA consumer group had less power to uncover associations – this is evident in the sensitivity analysis results, where the majority of changes in association were to non-significance. There were no significant socio-economic or related associations after excluding under-reporters. Under-reporters were not excluded in the original analysis to preserve power and following European Food Safety Authority (EFSA) guidance (40). However, the sensitivity analysis exposes under-reporting as an important limitation in drawing conclusions based on this survey data.

The TFA values used in the UK NDNS survey is an average of a small variety of popular foods from large manufacturers and retailers; this average could mask important TFA differences between foods regularly purchased by different groups in society. For instance, fewer large retailers and more SMEs in deprived areas may mean lower income groups consume more non-reformulated, low budget foods potentially higher in TFA than values in the NDNS obtained from average composite samples. Similarly for the Netherlands, the TFIFAC data in the NEVO tables is equally unlikely to include information on specific low budget foods from SMEs. In addition, unpackaged foods from local independent outlets may be prepared using fats procured business-to-business, containing an unknown quantity of TFAs e.g. pastry shortening (21) which are unlikely to be part of national voluntary reformulation efforts. Further research in this area is needed to explore whether low budget or niche brand / international foods from SMEs have higher TFA content than more popular products underpinning nutrient databanks in both countries.

7.6 Conclusion

According to the national dietary surveys of the Netherlands and the UK, both populations have low average TFA intakes, a state contributed to by successful voluntary national reduction programmes. Dutch people in the top 10% TFA consumers were more likely to be women and non-native. In the UK, the top 10% consumers were more likely to reside in the Midlands and had a more ruminant based TFA profile, whereas the Dutch appeared to obtain TFA from artificial as well as ruminant sources. It is possible that TFA intakes are underestimated in both countries due to under-reporting and the nature of food composition databases; inequalities in TFA consumption of certain vulnerable groups cannot be ruled out. This study demonstrates the need to investigate and evaluate the merit and impact of different iTFA removal policies, including voluntary reformulation, to ensure that no population groups have increased exposure via type or combination of food consumed. Regardless of policy approach, disaggregated consumption and updated food composition data should be used to determine whether high-TFA (including imported) products remain on the market.

Table 1: Socio-demographic characteristics of adult TFA consumers in the DNFCS 2007-10 and the UK NDNS 2010/11-2011/12

Top 10% TFA adults (aged 19-64) as % food energy	DNFCS 2007-10				NDNS RP 2010/11 to 2011/12 (years 3 & 4)			
	Total unweighted Numbers N=1933 (Weighted N=2870)	Top 10% TFA as % food energy N=188 (Weighted N=286)	Remaining 90% N=1745 (Weighted N=2583)	p value	Total unweighted Numbers N=848 (Weighted N=1277)	Top 10% TFA as % food energy N=88 (Weighted N=130)	Remaining 90% N=760 (Weighted N=1147)	p value
Trans fatty acid intake mean g/day (sd)		3.3 (1.2)	1.3 (0.7)	<0.001		1.9 (0.6)	1.0 (0.5)	<0.001
Age mean (sd)		43.4 (12.8)	41.8 (12.5)	0.09		42.9 (13.1)	41.1 (12.8)	0.3
Age (years):				0.1				0.5
19-34	810	29.9%	31.3%		245	29.0%	35.2%	
35-49	542	32.0%	38.3%		330	36.9%	36.2%	
50-64	581	38.0%	30.5%		273	34.1%	28.6%	
Male	964	42.2%	50.8%	0.04	484	55.4%	48.6%	0.3
Female	969	57.8%	49.2%		364	44.6%	51.4%	
Higher education[a]								
High	421	28.5%	23.7%	0.3	237	32.1%	27.8%	0.1
Medium	892	39.4%	45.7%		471	44.3%	56.3%	
Low	620	32.1%	30.6%		138	23.6%	15.9%	
In employment				1.0				0.5
Yes	1333	71.7%	71.8%		609	70.2%	73.7%	
No	568	28.3%	28.3%		239	29.8%	26.3%	
Household income[b]				0.9				0.4
Lowest income group	341	18.8%	16.6%		123	8.8%	13.4%	
2	368	17.3%	19.0%		141	23.3%	18.4%	
3	486	23.7%	24.0%		173	28.8%	22.3%	
4	334	16.4%	17.7%		142	16.3%	22.2%	
Highest income group	404	23.8%	22.8%		150	22.7%	23.8%	
Region[c]				0.4				0.2
1	301	18.2%	15.3%		201	23.8%	23.8%	

2	563	26.6%	29.8%		148	24.2%	14.5%	
3	206	8.6%	11.0%		352	39.0%	45.5%	
4	408	25.0%	20.3%		147	13.0%	16.3%	
5	455	21.6%	23.6%					
Number in household (sd)		2.49 (1.18)	2.63 (1.33)	0.2		2.82 (1.17)	2.98 (1.35)	0.2
Ethnic group:				0.01				0.4
White / Dutch native	1865	93.0%	97.1%		750	81.5%	85.6%	
Non-white / non-Dutch native	68	7.0%	2.9%		98	18.5%	14.4%	
Smoking status:				0.2				0.1
Current	513	19.4%	25.4%		204	33.0%	22.7%	
Ex-regular	578	33.6%	31.8%		167	13.2%	19.1%	
Never-regular	841	47.1%	42.8%		477	53.8%	58.2%	
Whether drinks alcohol:				0.7				0.6
No	599	32.2%	30.6%		287	37.6%	34.3%	
Yes	1333	67.8%	69.4%		560	62.4%	65.7%	

[a] Education for Dutch: High (University or higher vocational), medium (higher general secondary or Intermediate vocational), Lower (primary or lower vocational). For UK: High (Degree), Medium (Qualifications below degree), Lower (No qualifications or in FT education).

[b]Monthly net household income groupings for DNFCS 2007-10 are: less than EU1299, EU1300 to EU1899, EU1900 to EU2499, EU2500 to EU2899, EU2900 or more; Gross household income in last 12 months groupings for NDNS RP are: Less than £15000, £15000 to <20000, £20000 to <£35000, £35000 to <£50000, £50000 or more.

[c] 1) Dutch regions: 1) three largest West Netherlands cities, 2) Rest of the West, 3) North, 4) East, 5) South. UK regions: London, East & South England, 2) North England, 3) Midlands, 4) Scotland, Wales & NI.

NB – the means of continuous data were compared using t-tests and categorical data were compared using chi squared tests within country.

Table 2: Odds ratios (CI) of being in the top 10% adult TFA consumers by socio-demographic characteristic

Top 10% TFA adults (aged 19-64) as % food energy	Mutually adjusted odds ratios (CI) of being in the top 10% as % food energy			
	DNFCS 2007-10 N=1933 (Weighted N=2870)	p value	Y3 & 4 NDNS RP N=728 (Weighted N=1068)	p value
Age	1.01 (0.99, 1.02)	0.1	1.01 (0.98, 1.04)	0.4
Male	1		1	
Female	1.39 (0.99 1.94)	0.05	0.83 (0.47, 1.44)	0.5
Qualification[a]				
High	1		1	
Medium	0.74 (0.48, 1.13)	0.2	0.63 (0.33, 1.23)	0.2
Low	0.85 (0.53, 1.34)	0.5	1.55 (0.61, 3.95)	0.4
Household income[b]				
Lowest income group	1		1	
2	0.85 (0.49, 1.47)	0.6	2.46 (1.08, 5.61)	0.03
3	0.99 (0.58, 1.69)	1.0	2.25 (0.92, 5.52)	0.08
4	0.98 (0.56, 1.73)	1.0	1.49 (0.60, 3.69)	0.4
Highest income group	0.97 (0.56, 1.67)	0.9	1.76 (0.68, 4.59)	0.2
Region[c]				
1	1		1	
2	0.77 (0.47 1.27)	0.3	1.39 (0.65, 2.96)	0.4
3	0.69 (0.35, 1.36)	0.3	2.30 (1.11, 4.78)	0.03
4	1.09 (0.65, 1.82)	0.7	1.18 (0.49, 2.83)	0.7
5	0.82 (0.49 1.37)	0.4		
Ethnic group[d]				
Native /White	1		1	
Non-native/ Non-white	2.42 (1.16, 5.04)	0.02	1.28 (0.52, 3.20)	0.6
Number in household (sd)	0.95 (0.83, 1.08)	0.4	0.91 (0.77, 1.08)	0.3

[a] Education for Dutch: High (University or higher vocational), medium (higher general secondary or Intermediate vocational), Lower (primary or lower vocational). For UK: High (Degree), Medium (Qualifications below degree), Lower (No qualifications or in FT education).
[b] Household income groupings. For Dutch (net monthly): <EU1299, EU1300 to 1899, EU1900 to 2499, EU2500 to 2899, EU2900 and above. For the UK NDNS RP (Gross annual): less than £15000, £15000 to <20000, £20000 to <£35000, £35000 to <£50000, £50000 or more.

[c] 1) Dutch regions: 1) three largest West Netherlands cities, 2) Rest of the West, 3) North, 4) East, 5) South. UK regions: London, East & South England, 2) North England, 3) Midlands, 4) Scotland, Wales & NI.

[d] For Dutch: Native, Non-native. For UK: White, Non-white.

NB – the means of continuous data were compared using t-tests and categorical data were compared using chi squared tests within country.

Table 3: Diet-related characteristics of adult TFA consumers in the DNFCS 2007-10 and the UK NDNS 2010/11-2011/12

Top 10% TFA adults (aged 19-64) as % food energy	DNFCS 2007-10				NDNS RP 2010/11 to 2011/12 (years 3 & 4)			
	Total Numbers N=1933 (Weighted N=2870)	Top 10% TFA as % food energy N=188 (Weighted N=286)	Remaining 90% N=1745 (Weighted N=2583)	p value	Total Numbers N=848 (Weighted N=1277)	Top 10% TFA as % food energy N=88 (Weighted N=130)	Remaining 90% N=760 (Weighted N=1147)	p value
Intake		Mean (sd)	Mean (sd)			Mean (sd)	Mean (sd)	
Trans fatty acid g		3.28 (1.20)	1.29 (0.68)	<0.001		1.93 (0.59)	0.95 (0.46)	<0.001
Trans fatty acid intake % of total energy		1.22 (0.33)	0.48 (0.19)	<0.001		0.95 (0.21)	0.46 (0.17)	<0.001
Trans fatty acid intake % of food energy		1.26 (0.32)	0.50 (0.19)	<0.001		1.00 (0.20)	0.49 (0.17)	<0.001
Total energy kcal		2444 (728)	2403 (817)	0.5		1853 (556)	1827 (556)	0.7
Food energy kcal		2365 (666)	2303 (744)	0.3		1762 (514)	1735 (519)	0.7
Fat intake %FE[b]		38.0 (5.8)	34.2 (6.6)	<0.001		39.0 (4.5)	33.8 (6.1)	<0.001
Saturated fat %FE[b]		15.5 (3.3)	12.7 (3.0)	<0.001		16.8 (3.2)	12.0 (2.9)	<0.001
Sugars[c] %FE[b]		19.6 (6.6)	20.2 (7.2)	0.3		10.2 (5.7)	12.2 (6.5)	0.01
Vitamin C mg/1000kcal FE[b]		43.3 (29.9)	46.3 (31.9)	0.3		39.5 (21.9)	46.9 (37.1)	0.02
Vitamin D µg/1000kcal FE[b]		1.6 (0.8)	1.6 (1.0)	0.8		1.5 (1.2)	1.6 (1.1)	0.3
Vitamin E mg/1000kcal FE[b]		5.9 (2.3)	6.0 (2.4)	0.4		4.6 (1.3)	5.6 (2.4)	<0.001
Percentage consuming		% consumers	% consumers			% consumers	% consumers	
Beef [d]	579	32.2%	31.0%	0.8	514	63.4%	58.2%	0.4
Lamb	38	3.4%	1.7%	0.1	123	34.3%	12.2%	<0.001
Burger	180	7.6%	9.4%	0.4	105	10.3%	14.4%	0.3
Sausages	890	44%	46.5%	0.5	319	33.5%	37.9%	0.5
Butter	379	30.1%	18.6%	<0.001	266	52.8%	28.5%	<0.001
Cream	327	33.9%	15.9%	<0.001	167	26.8%	19.5%	0.1
Whole milk	99	7.2%	5.0%	0.2	167	25.8%	18.7%	0.1
Ice cream	270	13.5%	14.5%	0.7	157	15.2%	19.8%	0.3

Crisps & savoury snack	768	36.9%	38.7%	0.6	477	33.3%	51.5%	0.003
Biscuits	1052	52.0%	55.4%	0.4	522	54.1%	61.1%	0.3
Buns, cakes, pastries	1078	84.6%	53.9%	<0.001	411	54.3%	49.1%	0.4
Cheese	1609	86.2%	82.8%	0.3	531	83.1%	61.7%	<0.001
Battered/coated/fried fish	54	2.6%	2.8%	0.5	186	23.4%	23.7%	1.0
Chips/fried potato etc.	729	40.4%	37.5%	0.5	528	58.6%	64.1%	0.4
Chocolate/confectionary	1300	68.6%	67.0%	0.7	349	42.2%	41.8%	1.0
Dairy desserts	549	33.8%	28.3%	0.1	335	25.8%	40.2%	0.02

T tests were used to determine p value for differences in intake, and chi squared tests for % consumers

[a] Regression analyses adjusted for age and gender

[b] Diet only, does not include supplements/supplementation

[c] Dutch survey shows results for all mono and disaccharides, UK NDNS shows Non-milk extrinsic sugars.

[d] Beef, lamb and processed red meat consumption includes composite dishes in the NDNS RP.

NB – the means of continuous data were compared using t-tests and categorical data were compared using chi squared tests within country.

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Chapter 8 Portion Size of Energy-Dense Foods among French and UK Adults by BMI Status

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Abstract: Evidence links consumed food portion size (FPS) and excess weight via increased energy intake. Policies to regulate on-pack serving sizes may be needed; determining consumed FPS of popular energy-dense foods for normal weight and overweight or obese (OWOB) adults, as reported here, may provide evidence to assist this. Data were analysed from national cross-sectional surveys, the French Étude Individuelle Nationale des Consommations Alimentaires2 2005–2007 (n = 2117), and UK National Diet and Nutrition Survey 2008–2014 (n = 3413). The impact of body mass index (BMI) on FPS is also investigated, adjusting for age, sex and under-reporting. Effects of under-reporting on relationships between FPS and BMI; and BMI on consumption frequency (UK only) were explored. OWOB reported larger FPS than normal-weight individuals in many, but not all food subgroups; however, there were only two significant FPS differences. In adjusted analyses, French individuals consumed 1.0 g (99% CI 0.01–2.1 p = 0.01) greater FPS in cakes for 1 point difference in BMI. 'Other cakes' and 'dark chocolate' were also significantly positively associated with BMI. High-fat bar snacks, but no UK main food groups, were positively associated with BMI. There was limited evidence of links between

FPS and BMI in UK and French national cross-sectional data, possibly due to data limitations such as under-reporting. Future work should explore this and relationships between consumed FPS and on-pack suggested serving sizes to provide evidence to assist obesity-prevention policies.

Keywords: food portion size; BMI status; energy-dense foods; national diet surveys; WHO European region; nutritional epidemiology

8.1 Introduction

Europe is the World Health Organization (WHO) region most severely affected by non-communicable diseases (NCDs), which, alongside related conditions including overweight and obesity, have significant and growing economic and social costs. It is accepted that obesity is one of the biggest health problems facing the European population; it accounts for 2–8% of WHO European health costs (1) and is estimated to cause 320,000 deaths annually in Western Europe alone (2). In 87% (46) of WHO European countries, over half of adults are overweight or obese (OWOB); in France 47% adults and in the UK 67% men and 58% women are OWOB (3, 4). However, despite OWOB rates being lower in France, prevalence has stabilised in the UK and increased in France in the last decade (5).

Evidence indicates an indirect link between food portion size (FPS) and excess weight via increased energy intake, and suggests that limiting FPS contributes to reduced energy intake and, therefore, reduced weight gain (6-8). Both Ledikwe, et al. (6) and Bhupathiraju and Hu (9) link large FPS, particularly of energy-dense foods, with rising adult obesity levels in America via elevated energy intakes. European studies of adults are lacking, although Albar et al. (10) found positive associations between body mass index (BMI) and FPS of biscuits and cakes in UK adolescents, and Lioret et al. (11) found similar positive associations in croissants and sweetened pastries in French children. The evidence supports the WHO stance that ‘energy dense, micronutrient poor foods’ high in energy, saturated fats, trans fats, sugar and salt should be limited for a healthy diet (2). There is some recognition of FPS as a policy tool to deliver this, forming part of the UK’s ongoing calorie reduction drive. The Public Health Responsibility Deal calorie reduction pledge included FPS reduction in its suite of options and Public Health England highlight it in their recent calorie reduction plans (12, 13). However, more policy focus is needed; based on a systematic review Marteau et al. argue that policy does not adequately reflect the importance of consumed portion size in excess weight and that effective interventions could potentially reduce energy intake in UK adults by 12–16% (14, 15).

The positive association between FPS and food intake is known as the ‘portion size effect’ (16). In their meta-analysis of experimental studies, Zlatevska et al. (17) found that although the association was not linear or uniform across all population groups, overall energy intake increased by 35% when FPS doubled. Kelly et al. (18) also found that adults consumed higher portions of pre-packed foods when food was presented as larger portion sizes, although this was a pilot study and potentially underpowered.

Evidence suggests that UK commercially available FPS have increased in some energy-dense food categories in the 20 years since government-based FPS guidelines (19) were released (20). Although some varieties of traditional packet items like biscuits and crisps changed little during this time, other food categories have increased, including fast food and confectionary (21-23). Although there is little corresponding literature on changing French FPS over the same 20-year period, the rise in French OWOB levels over the past decade (5) suggests that increased FPS may be a possibility.

National diet survey (NDS) methodologies are developed primarily to assess the nutritional status of a population (24), so are a suitable means of investigating overweight and obesity across Europe. In addition to both being developed Western European countries with similarities in food consumption, the French and UK NDS use similar dietary assessment methodology and their data were available for analysis. This makes them a good comparative case, and provides some, if limited, insight into continental Europe. In their review of recent developments regarding portion size mechanisms, interventions and the portion size effect, Steenhuis and Poelman (20) conclude that there is extensive evidence for the portion size effect on energy intake, but portion size policies and their acceptance by the public is an understudied area. Therefore, more information on consumed FPS, such as reporting by BMI status, and the effects of under-reporting, could add to the body of knowledge needed to fill this gap. These are complex issues that require detailed understanding of food groups and culture; here we present a comparison of two countries—further work could explore others.

Using their respective NDS (25-27), this paper will identify commonly consumed energy, fat and sugar-dense snack-type foods in French and UK adults, and determine their consumed FPS. Providing estimated consumed FPS for these energy-dense foods could be useful for policymakers regarding decisions around setting on-pack serving sizes, which are not currently regulated or standardised. Consumed FPS of normal weight, feasible reporters may be the most suitable reference when setting on-pack serving sizes, and focusing on frequently consumed energy-dense, high-fat and sugar snack foods may have the greatest impact on population overweight and obesity. The aim of this research is to examine how FPS might vary with BMI, and explore how FPS may be affected by under-reporting. FPS of the two countries will be reported, and associations between consumption frequency and BMI considered.

8.2 Materials and Methods

Two government-funded NDS were obtained and analysed for consumed FPS for selected food groups in relation to BMI in adults aged 19–64 years. Consumed FPS was defined as the total weight (in grams) of a particular food consumed in one eating occasion.

8.2.1 National Diet Survey (NDS) Data

Data collected for the French Étude Individuelle Nationale des Consommations Alimentaires 2 (INCA2) from 2005–2007 were used in the analyses (25). The study population was taken from randomly selected primary geographical, then household units, using the 1999 Institut National de la Statistique et des Etudes Economiques (INSEE) national census, and weighted by sex, age, profession, head of household social category, season, region, size of household and urban area. Food data were collected from individuals aged 3–79 years via a consecutive 7-day diary, and FPS given either by grams per unit, household measures or using a photograph manual. Foods were coded using the INCA2 nomenclature, compatible with the CIQUAL food composition database (28). Demographic information was gathered by a computer-assisted personal interview (CAPI) delivered by a trained professional, who also weighed and measured participants to calculate BMI. Nutrient intakes were derived from dietary data using the CIQUAL food composition database (25).

UK data were analysed from the National Diet and Nutrition Survey (NDNS) Rolling Programme (RP) years 1–4 and 5–6 (2008–2012 and 2012–2014) (26, 27). The two datasets were appended and sample weightings adjusting for unequal selection probability and non-response were reassigned. Existing weightings for the Y1–4 and Y5–6 datasets were rescaled to ensure the two datasets were in the correct proportion to produce approximately nationally representative results; separate weightings for adults aged 19–64 years were created using this process (29) (see Supplementary Material 1). Similar to the French INCA2, multi-stage random probability sampling from UK postcode address files with postal sectors as the primary sampling units was used to select individuals for the UK NDNS. Food data were collected from individuals aged 1.5–100 y via a 4-day consecutive food diary, and portion sizes estimated using household measures, photographs and food packaging labels (30). Demographic information was also collected by a trained interviewer via a CAPI and measured height and weight gathered for BMI. Nutrient intakes were derived from dietary data using the McCance and Widdowson's composition of foods integrated dataset (26, 27).

Data from 2117 French and 3413 UK adults aged 19–64 years were used for the overall analyses. Underweight adults with a BMI <18.5 were excluded from analyses; this constituted 98 individuals in the French INCA2 and 46 in the UK NDNS. In addition, 25 adults with missing BMI values were excluded from analyses in the INCA2 and 203 adults with missing BMI or infeasible BMR:energy intake values excluded from the NDNS.

8.2.2 Preparation of Variables

The NDNS 2008–2014 dataset was used to identify popular energy, fat and sugar-dense foods in the UK. The main NDNS food groups were listed by total number of eating occasions for adults aged 19–64 years and the tertile with the lowest number of eating occasions were excluded. The average energy, fat and total sugar density was then determined for each remaining food groups and those with above average density in all three nutrients were selected for analysis—these were biscuits, buns, cakes, pastries and fruit pies (hereby referred to as ‘Cakes’) and chocolate confectionary (hereby referred to as ‘Chocolate’). Although crisps and savoury snacks (hereby referred to as ‘Crisps’) did not have above average sugar density, it was also selected due to a high salt content, which is a WHO Europe nutrient of concern (2).

To facilitate comparisons between countries and because energy density data were not available in the French data, the equivalent snack-based food groups were selected in the INCA2. However, because the French and UK foods did not match exactly (see Supplementary Material 2), analyses were undertaken in their separate datasets rather than merged into one; therefore differences between the two countries could not be statistically compared together. The main food groups analysed in the INCA2 were pâtisseries et gateaux (hereby referred to as ‘Cakes’), biscuits sucrés ou salés et barres (hereby referred to as ‘Biscuits and Crisps’) and chocolat (hereby referred to as ‘Chocolate’). Other studies have considered such foods energy-dense; Werle et al. (31) use cakes and crisps as examples of ‘highly caloric’ items and Wansink and Huckabee refer to the “the indulgent ‘C’ foods—cookies, cake, crackers, chips and candy” (32).

Within each of the selected main food groups homemade items were excluded in order to focus on commonly consumed, commercially available products, which have greater potential for FPS standardisation as part of potential future policy initiatives. This was done in the UK NDNS by searching for and excluding items with ‘homemade’ in the title on either the ‘SubFoodGroupDesc’ or ‘FoodName’ variable level. Homemade items were not always distinguished from those commercially available in the INCA2, therefore not all homemade items could be identified in the French data.

The remaining food items at the ‘FoodName’ level were then categorised based on product type, into newly created subgroups within each of the four main UK NDNS food groups selected. This was repeated for the three selected main food groups in the French INCA2 and food subgroups created to mirror those in the UK data where possible (see Supplementary Material 2). Miscellaneous items were categorised as ‘other’; for example ‘other’ cakes is made up of rum baba and blinis in the INCA2 and Chinese cakes and pastries, rice flour cakes and plain pastry in the NDNS. ‘Cookies’ included both ‘traditional’ cookies and ‘luxury’ American-style soft cookies, which tend to have larger FPS (10, 21). The energy density of each food subgroup was calculated to provide accompanying information which, coupled with estimated consumed FPS, could provide insights into the potential energy contributions of certain foods and, therefore, the setting of on-pack serving sizes.

8.2.3 Statistical Methods

In both the French and UK data the weighted mean consumed FPS and standard deviation (SD) per eating occasion for adults aged 19–64 years consuming each food subgroup were calculated and tabled. SDs more than half the mean FPS were used to indicate a wide spread of FPS within a food category. The food subgroup FPS per eating occasion was calculated within the French and UK datasets and defined as the total weight of food consumed in each subgroup divided by the consumption frequency per person. Each consumer contributed a single mean portion weight to the population mean for each food subgroup; this avoided means being skewed by non-consumers, who were excluded, or those who ate certain foods more frequently than others. The main food group FPS was calculated as the mean of all the mean food subgroup FPS. Analyses were restricted to adults aged 19–64 years to prevent distortion of results from children or the elderly, who may consume smaller portions; the underweight were also excluded from all analyses. Socio-demographic and dietary characteristics of those sampled from both surveys were determined and tabled. Normal weight was defined as having a BMI 18.5–25 kg/m^2 and OWOB as ≥25 kg/m^2. The difference in FPS reported by normal weight compared to OWOB adults aged 19–64 years consuming each food subgroup was t-tested in unadjusted analyses with BMI as a categorical variable. Two regression models were used, adjusting for sex and age and also under-reporting, age and sex to test for significant differences between FPS as the dependent variable and continuous BMI as an independent variable (predictor). To better utilise the detail provided in the datasets, continuous BMI was used in the adjusted regression analysis. STATA

SE v14 and 15 (33, 34) was used to analyse all data, which were weighted as explained above, and statistical significance set at $p < 0.01$ due to the large number of statistical tests performed.

Consumption frequency was defined as the total number of eating occasions of each food group per participant (including non-consumers), averaged to one day by dividing the consumption frequency per person by the number of completed diary days. An eating occasion was defined as any consumption incidence, regardless of FPS or number of units eaten. Analyses of consumption frequency was only possible in the UK data, as the INCA2 data had no means of identifying which individuals completed all seven diary days and, if not, how many days were completed; therefore, consumption frequency per person per day could not be calculated. Adjusted regression analysis was used to test for statistically significant associations between consumption frequency as the dependent and (continuous) BMI as the predictor after adjusting for age and sex (model 1) or adjusting for age, sex and excluding under-reporters (model 2).

A sensitivity analysis was conducted by repeating the analyses after identifying and excluding under-reporters. Under-reporters were included in the main analyses, following recommendations to minimise selection bias (35-37). However, including under-reporters could potentially confound any relationship between FPS and BMI, as under-reporting is itself associated with higher BMI (7). For this reason under-reporters were excluded as a sensitivity analysis and adjusted for in the main analyses. Under-reporter identification was based on energy intake of the whole diet rather than the specific food groups selected for review. Under-reporters were identified using participant height and weight data to generate basal metabolic rate (BMR) and BMR:energy intake ratio variables following the Oxford equations detailed in Henry (36). These BMR and BMR:energy intake ratio variables were used to generate a low cut-off via the Goldberg method (38) using a physical activity level (PAL) of 1.55 across all individuals. 1.55 is an accepted value for a sedentary lifestyle in the populations used (39-41) and makes analysis of a large number of individuals more feasible because a common value is applied to all participants, and the large proportion with missing physical activity data can still be included. It also avoids the complexities and pitfalls of calculating individual PAL values; such as measures of moderate-vigorous activity being insufficiently accurate to estimate individual PAL values (41).

8.3 Results

There were 2117 adults aged 19–64 years in the French INCA2 and 3413 in the UK NDNS (excluding those with missing BMI or infeasible BMR:energy intake values). In the BMI analyses, 55% were normal weight and 40% OWOB (*n* = 1251; 866 respectively, *n* = unweighted) in the French and 37% normal weight and 61% OWOB (*n* = 1222; 2191 respectively) in the UK surveys (Table 1). In the INCA2 4% (*n* = 98) and in the NDNS 2% (*n* = 46) underweight adults aged 19–64 years were excluded from BMI analyses.

OWOB adults analysed in the INCA2 were significantly older, with a greater proportion of males, 32% higher weight, higher BMI and were less likely to have a degree compared to normal weight individuals. The profile of those analysed in the NDNS was similar; OWOB adults were older, had a greater proportion of males and were 34% heavier. However, French and UK nutritional profiles differed. French OWOB adults had a lower carbohydrate and total sugars consumption (41%Energy intake (%E) and 17%E respectively compared to 43%E and 18%E in normal weight adults), whereas UK OWOB adults only had a slightly lower total sugars consumption (19%E compared to 20%E in normal weight adults). In both countries under-reporters were more likely to be OWOB; in the INCA2 32% and in the NDNS 44% OWOB adults were estimated to be under-reporters of overall energy intake compared to 18% and 23%, respectively, of normal weight adults (Table 1).

Table 1. General and dietary characteristics of all adults aged 19–64 y * in the French INCA2 and UK NDNS (Y1–6) dietary surveys.

FRANCE INCA2	ALL (n = 2117)			NORMAL WEIGHT (n = 1251)			OWOB (n = 866)			p-Value
	Mean	95% CI		Mean	95% CI		Mean	95% CI		
General characteristics										
Age (year)	41	41	42	38	38	39	45	44	46	<0.001
Female (%)	50	47	53	55	51	58	43	39	47	<0.001
Height (cm) †	169	169	170	169	168	170	169	169	170	0.6
Weight (kg) †	72	71	73	63	63	64	83	82	84	<0.001
BMI (kg/m^2) †	25	25	25	22	22	22	29	29	29	<0.001
Ethnicity (% white)	91	90	92	91	89	92	92	89	94	0.4
Education (% with degree)	17	15	19	21	18	24	11	9	14	<0.001
Under-reporters (%)	24	22	26	18	15	20	32	28	31	<0.001
Dietary characteristics										
Total energy (kcal)	2011	1978	2044	2001	1957	2044	2025	1975	2076	0.5
Fat (%E)	37	37	38	37	37	38	38	37	38	0.3
Carbohydrates (%E)	42	42	43	43	43	44	41	40	42	<0.001
Total sugars (%E)	18	17	18	18	18	19	17	16	17	<0.001
Salt (g)	6.9	6.7	7.0	6.7	6.5	6.9	7.0	6.8	7.3	0.02
Under-reporter energy intake (kcal)	1351	1315	1388	1256	1210	1302	1424	1371	1476	<0.001

UK NDNS	ALL (n = 3413)			NORMAL WEIGHT (n = 1222)			OWOB (n = 2191)			p-Value
	Mean	95% CI		Mean	95% CI		Mean	95% CI		
General characteristics										
Age (year)	41	41	42	37	36	38	44	43	44	<0.001
Female (%)	50	48	52	57	53	61	46	43	49	<0.001
Height (cm) †	169	169	170	170	169	170	169	169	170	0.4
Weight (kg) †	79	78	79	65	64	66	87	86	88	<0.001
BMI (kg/m^2) †	27	27	28	23	22	23	30	30	31	<0.001
Ethnicity (% white)	88	87	90	88	85	90	88	86	90	1.0
Education (% with degree)	28	26	30	34	31	38	25	22	27	0.02
Under-reporters (%)	36	34	38	23	20	26	44	41	47	<0.001
Dietary characteristics										
Total energy (kcal)	1861	1835	1887	1899	1852	1947	1838	1807	1869	0.03
Fat (%E)	33	33	33	33	33	34	33	32	33	0.004

Carbohydrates (%E)	46	46	46	46	45	47	46	45	46	0.7
Total sugars (%E)	19	19	20	20	19	20	19	19	19	0.002
Salt (g)	5.6	5.5	5.7	5.6	5.5	5.8	5.6	5.5	5.7	0.8
Under-reporter energy intake (kcal)	1368	1342	1394	1250	1207	1292	1404	1374	1435	<0.001

* Underweight adults with a BMI < 18.5 and adults with missing BMI or infeasible BMR: energy intake values were excluded from analyses. † Analyses exclude those adults with missing values.

8.3.1 Food Portion Size (FPS)

There was a large spread of FPS in certain food groups, particularly in France. All three selected French main food groups, but only Biscuits and Chocolate in the UK, had a SD greater than half the mean. In the INCA2 64% (*n* = 7) of Cakes subgroups had a SD greater than half of the mean FPS for all adults aged 19–64 years; for Biscuits and Crisps this was 100% (*n* = 12) and for Chocolate 89% (*n* = 8). In the UK NDNS 27% (*n* = 4) of Cakes subgroups had a SD greater than half of the mean FPS for all adults aged 19–64 years; for Biscuits this was 50% (*n* = 5); for Crisps this was 38% (*n* = 3) and for Chocolate 77% (*n* = 10).

In the French INCA2 the three food subgroups with the highest mean FPS for normal weight adults 19–64 years in Cakes were ‘fruit pie’ (181 g [SD 76 g]), ‘tart’ (170 g [60 g]) and ‘pastries’ (130 g [93 g]). For OWOB individuals this was ‘tart’ (182 g [SD 58 g]), ‘pastries’ (155 g [85 g]) and ‘fruit pie’ (154 g [44 g]). For Biscuits and Crisps in normal weight individuals this was ‘filled chocolate’ (61 g [40 g]), ‘unfilled coated biscuits with inclusions’ (52 g [51 g]) and ‘filled non-chocolate’ (47 g [32 g]) and for OWOB individuals this was ‘filled chocolate’ (60 g [39 g]), ‘unfilled coated biscuits with inclusions’ (43 g [29 g]) and both ‘cookies’ (42 g [23 g]) and ‘other’ (42 g [26 g]). For the Chocolate group in normal weight individuals this was ‘Mars-type bar’ (52 g [40 g]), ‘wafer bar’ (49 g [22 g]) and ‘chocolate spread’ (41 g [42 g]) and for OWOB individuals this was ‘wafer bar’ (46 g [19 g]), ‘Mars-type bar’ (38 g [15 g]) and ‘chocolate spread’ (31 g [25 g]) (see Table 2; for information on all adults see Appendix A).

In the UK NDNS the three food subgroups with the highest mean FPS for normal weight adults 19–64 years in Cakes were ‘pastries’ (93 g [30 g]), ‘fruit pie’ (91 g [38 g]) and ‘éclairs’ (89 g [46 g]) and for OWOB individuals this was ‘pastries’ (110 g [58 g]), ‘fruit pie’ (92 g [46 g]) and ‘doughnut’ (84 g [48 g]). For Biscuits in normal weight individuals this was ‘cookies and flapjack’ (47 g [37 g]), and ‘unfilled coated/inclusions’ (33 g [18 g]), ‘filled non-chocolate’ (33 g [24 g]) and ‘cereal bars’ (33 g [13 g]). For OWOB individuals this was ‘cookies and flapjack’ (43 g [30 g]), ‘jaffa cakes’ (42 g [49 g]) and ‘filled non-chocolate’ (35 g [19 g]). For Crisps in normal weight individuals this was ‘nuts’ (63 g [28 g]), ‘popcorn’ (50 g [31 g]) and ‘tortilla chips’ (44 g [39 g]) and for OWOB individuals this was ‘popcorn’

(123 g [98 g]), was ‘nuts’ (76 g [34 g]) and ‘tortilla chips’ (40 g [32 g]). For Chocolate in normal weight individuals this was ‘coated nuts/fruit’ (81 g [64 g]), ‘Mars-type bar’ (49 g [17 g]) and ‘other’ (48 g [28 g]) and for OWOB individuals this was ‘coated nuts/fruit’ (66 g [69 g]), ‘Mars-type bar’ (47 g [17 g]) and ‘honeycomb/crunch’ (44 g [37 g]) (see Table 3; for information on all adults see Appendix B). Food subgroups with the largest FPS were not necessarily the most energy dense (Appendix C); but there was also little variation in the energy density of the majority of the subgroups within each main food group, particularly in Chocolate.

There was little evidence of statistically significant FPS differences by BMI status (Tables 2 and 3). However, on average the mean FPS of Cakes reported by French OWOB individuals was 14% larger than that reported by normal weight individuals—this was statistically significant. Little difference by BMI status was observed for the main UK Cake group. In contrast, French OWOB individuals reported smaller FPS than normal weight individuals in the majority of Biscuit, Crisps and Chocolate subgroups, although differences were not statistically significant. However, FPS of short biscuits reported by OWOB UK adults were significantly 30% larger than those reported by normal weight adults.

Table 2. Mean portion size of energy-dense foods by BMI status for consumers aged 19–64 years in the French INCA2.

FOOD GROUP	NORMAL WEIGHT					OVERWEIGHT/OBESE					OWOB FPS as % of Normal Weight FPS
	n †	% Individuals Consuming **	Mean Food Portion Size (FPS) per Person (g)	99% CI		*n* †	% Individuals Consuming **	Mean FPS per Person (g)	99% CI		
CAKES											
TOTAL ‡	**1772**	**N/A**	**117**	**111**	**124**	**1120**	**N/A**	**133**	**125**	**141**	**14 ***
Other cakes and patisserie	17	1.0	83	60	105	15	0.6	119	70	168	44
Pancakes and brioche ‡	225	9.6	121	102	140	124	4.8	136	112	160	12
Chocolate cake and gateau	234	10.0	90	80	99	131	5.8	97	84	110	8
Cake and gateau non-chocolate ‡	285	13.5	102	90	114	173	7.2	119	103	136	17
Doughnut ‡	42	2.2	68	42	94	29	1.4	54	33	75	−21
Eclairs ‡	72	3.5	88	78	97	36	1.8	119	71	166	35
Fruit cake ‡	52	2.3	63	46	80	45	2.0	70	46	93	11
Fruit pie	19	0.7	181	120	242	7	0.3	154	109	200	−15
Muffins and mini cakes ‡	174	8.2	66	56	76	98	4.6	67	52	82	1
Pastries ‡	188	6.6	130	109	151	114	4.4	155	129	182	20
Tart	353	15.3	170	161	180	271	12.8	182	171	194	7
BISCUITS & CRISPS											
TOTAL ‡	**1215**	**N/A**	**37**	**33**	**42**	**663**	**N/A**	**35**	**30**	**40**	**−5**
Other biscuits and crisps ‡	24	0.8	38	23	53	11	0.4	42	20	64	10
Unfilled uncoated biscuits ‡	128	5.8	40	32	47	59	2.7	34	23	45	−15
Cereal bars ‡	58	2.6	37	26	47	34	1.4	30	24	37	−17
Cookies ‡	40	1.6	44	31	56	24	1.6	42	24	60	−4
Savoury biscuits plain ‡	199	9.2	26	22	30	139	6.7	27	22	32	3
Filled chocolate biscuits ‡	109	4.8	61	50	71	59	2.8	60	43	77	−1
Filled non-chocolate biscuits ‡	44	1.8	47	33	61	19	1.0	36	19	53	−24
Potato crisps std. ‡	151	7.7	28	13	43	96	4.9	27	17	37	−5
Savoury biscuits flavoured ‡	53	2.2	37	25	50	28	0.8	33	22	44	−12
Short biscuits ‡	80	4.0	38	21	55	48	2.0	31	19	43	−19
Tortilla chips‡	13	0.8	24	-6	55	6	0.3	14	2	27	−41
Unfilled coated biscuits with inclusions ‡	94	4.4	52	34	70	34	1.4	43	29	58	−17
CHOCOLATE											

TOTAL ‡	**1009**	**N/A**	**27**	**24**	**31**	**517**	**N/A**	**25**	**22**	**29**	**−7**
Chocolate spread ‡	183	8.8	41	28	55	72	3.3	31	22	46	-24
Chocolate with additions ‡	117	5.5	31	21	41	60	2.6	30	22	37	-5
Dark chocolate ‡	163	7.0	12	10	15	94	4.3	17	12	22	40
Honeycomb/crunch ‡	23	1.0	25	11	39	5	0.1	27	-9	63	8
Mars type bar ‡	65	3.0	52	37	67	22	1.0	38	29	47	-27
Milk chocolate ‡	304	13.0	19	16	22	176	7.4	22	16	27	16
Truffles ‡	103	3.5	23	14	31	59	2.0	30	13	46	32
Wafer bar	39	1.7	49	38	59	23	1.1	46	35	56	-6
White chocolate ‡	12	0.7	37	3	70	6	0.3	18	6	30	-50

* p =< 0.01. † Unweighted number of individuals consuming each food subgroup. The total n value represents all Cake/Biscuit and Crisp/Chocolate types consumed by the sample, so may be larger than the number of individuals in the sample (as detailed in Table 1), as some individuals will consume multiple subgroups. ** Percentages will not total 100%, as the weighted percentage is of all adults aged 19–64 rather than just those particular food groups. ‡ standard deviation (SD) greater than half the mean FPS per person for all adults aged 19–64 years.

Table 3. Mean portion size of energy-dense foods by BMI status for consumers aged 19–64 years in the UK NDNS (Y1-6).

FOOD GROUP	NORMAL WEIGHT					OVERWEIGHT/OBESE					OWOB FPS as % of Normal Weight FPS
	n **†**	**% Individuals Consuming ****	**Mean FPS per Person (g)**	**99% CI**		***n*** **†**	**% Individuals Consuming ****	**Mean FPS per Person (g)**	**99% CI**		
CAKES											
TOTAL	**1028**	**N/A**	**69**	**64**	**75**	**1555**	**N/A**	**68**	**64**	**73**	**−1**
Other ‡	31	1.2	42	21	64	41	1.2	66	49	83	56
Teacakes	69	2.2	62	52	71	115	3.1	64	56	71	4
Cake and gateau non-choc ‡	82	2.1	56	36	74	146	3.9	49	42	55	−12
Swiss roll ‡	35	1.0	49	28	69	70	1.6	61	37	86	26
Doughnut	61	2.0	71	61	82	80	2.6	84	60	109	18
Croissant	84	2.8	72	57	87	82	2.3	70	57	84	−2
Muffins and cupcakes	75	2.3	67	55	79	108	3.0	70	57	83	4
Chocolate cake and gateau	79	2.6	76	50	102	75	2.0	67	56	77	−12
Bars and slices	51	1.1	46	34	59	79	2.1	39	33	46	−15
Fruit pie	66	2.0	91	74	108	110	2.5	92	78	107	2
Éclairs	22	0.6	89	54	124	38	1.3	68	56	81	−23
Tart	40	1.1	61	46	76	67	2.0	75	62	89	24
Scones, pancakes and sweet dough ‡	94	1.8	73	49	97	154	2.6	67	53	80	−9
Pastries	44	1.5	93	79	107	69	2.1	110	84	137	19
Fruit cake and malt loaf	30	0.9	64	53	76	57	1.5	70	54	85	8
BISCUITS											
TOTAL ‡	**1368**	**N/A**	**32**	**29**	**34**	**2236**	**N/A**	**33**	**31**	**34**	**3**
Unfilled coated/inclusions	239	6.2	33	29	37	402	9.5	33	30	37	2
Unfilled uncoated ‡	214	5.7	29	21	37	433	9.9	27	24	30	−6
Filled non-chocolate	153	4.3	33	27	38	245	6.2	35	31	38	6
Cereal bars	118	3.1	33	30	37	175	4.3	33	30	35	−3
Cookies and flapjack ‡	130	3.7	47	34	60	167	4.5	43	36	50	−9
Short biscuits ‡	108	3.0	21	17	24	178	4.5	27	22	32	30 *
Savoury biscuits plain ‡	246	7.2	27	24	30	378	9.2	28	25	32	6
Savoury biscuits flavoured	56	2.0	24	19	29	69	2.2	24	19	30	0
Jaffa cakes ‡	53	1.4	32	27	36	77	1.4	42	25	58	30
Filled chocolate	44	1.2	32	25	39	87	2.2	31	27	35	−3
CRISPS											

TOTAL	**741**	**N/A**	**32**	**29**	**35**	**1301**	**N/A**	**30**	**29**	**32**	**−6**
Potato and vegetable crisps std.	422	12.2	31	28	35	756	19.7	30	28	31	−6
Corn/maize snack	78	2.1	23	18	28	119	3.2	26	21	30	11
Potato snack shapes and puffed	96	2.9	24	21	28	201	5.8	26	23	29	7
Tortilla chips ‡	62	2.0	44	30	58	77	2.1	40	28	52	−9
Potato crisps crinkle	45	1.4	39	32	46	88	2.0	38	33	42	−3
Popcorn ‡	9	0.3	50	27	72	12	0.3	123	12	233	147
High-fat bar snacks ‡	22	0.6	21	13	30	39	1.4	33	20	46	53
Nuts	4	0.2	63	11	114	5	0.2	76	20	133	22
CHOCOLATE											
TOTAL ‡	**994**	**N/A**	**37**	**34**	40	**1321**	**N/A**	**39**	**36**	**43**	**5**
Other ‡	15	0.3	48	27	69	32	0.8	33	23	43	−32
Milk chocolate ‡	271	7.9	33	28	38	287	7.3	38	30	46	14
Mars type bar	185	5.7	49	44	53	288	7.3	47	44	50	−3
Wafer bar	109	2.8	29	25	33	179	5.3	33	29	36	13
Caramel ‡	78	2.2	33	25	41	108	2.5	37	27	47	12
Sugar coated ‡	37	1.1	41	13	69	32	0.8	28	17	38	−33
Dark chocolate ‡	58	1.7	25	11	40	60	1.9	32	7	57	24
Honeycomb/crunch	49	1.7	35	26	43	75	1.6	44	30	58	25
Crème filled ‡	52	1.1	38	25	51	99	2.1	36	28	44	−6
Truffles ‡	41	1.2	26	19	33	47	1.3	26	13	39	1
White chocolate ‡	22	0.7	29	9	49	22	0.6	28	-1	56	−5
Chocolate with additions ‡	46	1.6	37	25	49	68	2.0	45	35	56	22
Coated nuts/fruit ‡	31	0.9	81	43	119	24	0.9	66	20	112	−18

* *p* =< 0.01. † Unweighted number of individuals consuming each food subgroup. The total *n* value represents all Cake/Biscuit/Crisp/Chocolate types consumed by the sample, so may be larger than the number of individuals in the sample (as detailed in Table 1), as some individuals will consume multiple subgroups. ** Percentages will not total 100%, as the weighted percentage is of all adults aged 19–64 rather than just those particular food groups. ‡ SD greater than half the mean FPS per person for all adults aged 19–64 years.

8.3.2 Adjusted Analyses of the Relationship between FPS and Body Mass Index (BMI)

When adjusting both for sex and age (model 1) and under-reporting, age and sex (model 2) in the regression analyses, there were just two French food subgroups with significant associations between FPS and BMI used as continuous variables, whereas there were none in the unadjusted analyses. Only total Cakes was statistically significant in both the unadjusted and the adjusted analyses and retained the same direction of association. Overall, after adjusting for sex and age (model 1), for every point increase in BMI between individuals, a difference of 3.1 g (99% CI 1.0 to 5.2 p =< 0.001) in their consumed FPS of 'other cakes' and 1.0 g (99% CI 0.1 to 1.9 p = 0.004) in 'dark chocolate' was observed in the same direction. In addition, the Cakes main food group FPS was significantly associated with BMI, where FPS increased by 1 g (99% CI 0.01 to 2.1 p = 0.01) with every BMI point increase. When adjusting for under-reporting, age and sex (model 2) FPS was positively associated with BMI in the same subgroups (see Supplementary Material 3 for all associations).

In the UK regression analysis (model 1), FPS was significantly associated with BMI in high-fat bar snacks only, which increased in FPS by 3.3g (99% CI –0.1 to 6.7, p = 0.01) with every point increase in BMI after adjusting for sex and age. The same was true when adjusting for under-reporting, age and sex (model 2), where 'high-fat bar snacks' increased by 3.2g (99% CI 0.2 to 6.3, p = 0.01) with every point increase in BMI. Unlike the French analyses, none of the main UK food groups were significantly associated with BMI (see Supplementary Material 4 for all associations).

8.3.3 Sensitivity Analysis Excluding Potential Under-Reporters

Of those who reported consuming Cakes in the French INCA2, 16% (n = 489 unweighted) under-reported overall energy intake and were excluded in the sensitivity analysis. In Biscuits and Crisps this was 12% (n = 247) and in Chocolate 15% (n = 211). In the adjusted analyses 'other cakes' lost significance after excluding under-reporters, likely due to lower number of individuals consuming foods in this subgroup and loss of power, but 'dark chocolate' remained significantly associated with higher FPS in OWOB individuals (data not shown). The Cakes main food group also retained and strengthened its association, with FPS increasing by a greater amount after excluding under-reporters.

In the UK NDNS, sensitivity analysis identified 23% (*n* = 635 unweighted) Cakes consumers as under-reporters of overall energy intake. In Biscuits consumers this was 31% (*n* = 1170), in Crisps 30% (*n* = 661) and in Chocolate 22% (*n* = 551) of consumers. 'High fat bar snacks' retained a higher FPS in OWOB individuals after excluding under-reporters, and like in the French INCA2, there was no change in the direction of association (data not shown).

8.3.4 Consumption Frequency

Analysis of consumption frequency as the dependent variable and BMI as the predictor was only possible in the UK data, as the INCA2 had no means of identifying how many diary days were completed for each individual from the available data, and therefore consumption frequency per day could not be calculated. When adjusting for age and sex (model 1) for every point increase in BMI, consumption frequency per day of Cakes and Chocolate decreased (Cakes: −0.006 99% CI −0.01 to −0.003 *p* =< 0.001; Chocolate −0.008 99% CI −0.01 to −0.004 *p* =< 0.001). When adjusting for age and sex after excluding under-reporters (model 2) Cakes was no longer significant, but for every point increase in BMI, consumption frequency per day still decreased in Chocolate −0.008 99% CI −0.01 to −0.001 *p* = 0.003) (Table 4). So although the higher an individual's BMI, the less often these foods were consumed, in real terms there was negligible association.

Table 4. Association between consumption frequency (CF) of energy dense food groups in adults aged 19–64 years and BMI in the NDNS. Model 1 adjusted for age and sex. Model 2 adjusted for age and sex after excluding under-reporters.

MAIN FOOD GROUP	MODEL 1 (*n* = 3413)				MODEL 2 (*n* = 2142)			
	Difference in CF *	99% CI		*p*-Value	Difference in CF *	99% CI		*p*-Value
Cakes	−0.006	−0.01	−0.003	<0.001	−0.004	−0.01	0.001	0.05
Biscuits	−0.005	−0.01	0.0009	0.03	0.005	−0.004	0.01	0.2
Crisps	0.0003	−0.003	0.004	0.8	0.004	−0.002	0.009	0.07
Chocolate	−0.008	−0.01	−0.004	<0.001	−0.008	−0.01	−0.001	0.003

* Difference in consumption frequency (number of times eaten per day) with each point increase in BMI.

8.4 Discussion

These analyses constitute a detailed examination of FPS and how these might vary with BMI in two large, nationally representative groups in energy, fat and sugar-dense snack foods. Of the main food groups analysed, only Cakes in the French INCA2 had a significant association between FPS and BMI, where FPS increased with each BMI point increase. There were very few significant associations between FPS and BMI in the energy-dense food subgroups analysed from the French and UK national dietary surveys, and these categories differed between the countries. The lack of UK and French similarities between the types of foods with significant associations suggests that French and UK diet preferences of OWOB individuals may differ across the selected main food groups. 'Pastries', 'fruit pie' and 'Mars-type' chocolate bars had the largest FPS for both normal and OWOB adults aged 19–64 years in both the French and UK analyses (Tables 2 and 3). The consumed FPS information generated from these analyses is useful for our aim of adding to the body of knowledge that may help inform investigations into under-studied aspects of portion size, such as portion size policies and their acceptance by the public (20). It could also help inform decisions around setting on-pack serving sizes, which have not been updated in the UK in over 20 years (22). To set realistic on-pack serving sizes it would be helpful to know how much individuals consume in one sitting as a frame of reference, even if these do not necessarily become the on-pack serving size.

On-pack serving sizes are not currently regulated or standardised and, unlike the requirement to state pack-size, providing serving-size information is not currently mandatory in the UK (42). Without an on-pack serving-size, consumers may substitute pack-size as a unit of consumption, in a 'unit bias' that risks resulting in over-consumption and excess energy intake. This 'unit bias' could also result in individuals underestimating their consumed portion size, where they recognise that the whole unit is larger than an appropriate portion, but still eat the whole unit (43). This is particularly relevant in snack foods, which are the focus of these analyses, and demonstrates the value of providing information that could help set on-pack serving sizes. Updated guidelines are, therefore, required, but should be realistic and formulated with sensitivity in order to avoid encouraging consumers to further increase consumed portion size. There is a fine balance to be struck in creating realistic, consistent on-pack serving-size guidance without encouraging consumers to eat larger portions or multiple units.

Mean FPS in the high FPS subgroups varied in their proximity to UK government FPS guidance, which was last updated in 1993 (19). The three Cakes subgroups, ‘tortilla chips’ and ‘Mars-type bar’ were lower than the average suggested FPS in the guidance, whereas the Biscuits subgroups and remaining Chocolate and Crisps subgroups were higher (19). However, with the exception of ‘Mars-type bar’, French mean FPS were higher than the UK guidance. This could be due to genuine differences in dietary patterns, or a function of under-reporting, which was higher in the UK. There was also a large spread of FPS within the food subgroups, particularly in the INCA2, which could be indicative of the lack of up-to-date FPS guidance in Europe (43, 44) as there are no set guidelines for manufacturers or consumers to follow.

The few significant associations present were positive, showing that adults with higher BMIs reported consuming larger FPS. The extent to which this is a valid finding or one resulting from methodological limitations and misreporting cannot be fully determined. Studies have variously found few associations between FPS and adiposity (45), concluded that under-reporting masks associations between FPS and measures of adiposity (46) and found positive associations in certain energy-dense foods in adolescents after excluding misreporters (10). Under-reporting masking associations could explain the few associations found in our adjusted analyses. In these associations, only small increases in FPS with each BMI point increase in the few food subgroups were seen; yet even small effect sizes could result in weight gain caused by increased energy intake over time.

Herman et al. (47) claim evidence is lacking to support excess energy intake via elevated FPS as a causal factor in the obesity epidemic, citing other factors, including consumption frequency, as potentially more significant. Mattes (48) found evidence that, in addition to FPS, consumption frequency also influences energy intake and, therefore, adiposity. Others have also found consumption frequency and energy intake to be positively associated, though this did not necessarily result in positive associations with BMI (49-53), potentially due to under-reporting. Conversely, in our adjusted analyses consumption frequency was negatively associated at negligible levels with BMI in Cakes and Chocolate, and in Chocolate after excluding under-reporters. Whilst unexpected, this highlights the difficulties presented by high under-reporting levels and other limitations with the cross-sectional data generated from NDS. Murakami and Livingstone (54) support this, citing differences in dietary assessment methodology, consumption frequency definitions, and approaches to under-reporting as explanations for the lack of consensus.

Under-reporting clearly presents a limitation in using NDS to assess FPS, affecting the number and variety of food main and subgroups with associations between FPS and BMI. Using the Goldberg method, under-reporting in the present analysis was estimated to be 1.5 times higher in the UK than in France, at 35% and 23% respectively. This is similar to levels previously reported, at 32% and 22.5% respectively (41, 55). This is possibly due to the greater proportion of OWOB individuals in the NDNS, with OWOB being associated with under-reporting in this analysis and elsewhere (37). Compared to the overall under-reporting rates for the NDSs, there were lower percentages of under-reporters of energy intake who consumed the main energy-dense food categories analysed, indicating that under-reporters of energy intake are less likely to consume, or report consuming these snack type foods.

Vanrullen et al. (41) also found that snacking was associated with lower levels of under-reporting. This could be explained by social desirability bias; research suggests that foods perceived as less healthy, such as energy-dense snack foods, may be less likely to be reported (37, 56). Vanrullen et al. (41) also found that under-reporting was more attributable to consumption frequency than FPS. This suggests that including under-reporters would impact less on the accuracy of analyses because the under-reporting error would be concentrated more in individuals' reporting of the consumption frequency rather than the FPS. This uncertainty in the extent and effect of under-reporting is problematic, as true consumption cannot be determined, creating challenges for effective policy formation across Europe.

8.4.1 Strengths and Limitations

A limitation of our current study is the low number of consumers in some of the food subgroups, which may mean the analyses are underpowered to find associations at this level. An additional limitation is that it uses cross-sectional survey data, which cannot demonstrate the direction of association and, therefore, a causal relationship (35). Nevertheless, our intention was not to imply that a single product could cause an individual to become OWOB, but to explore how reported FPS might vary with BMI. Longitudinal, prospective studies to track weight over time, with physical activity data to more accurately determine under-reporters, are part of the triangulation needed to understand the causal relationship between FPS and BMI. Most previous studies of FPS have focused on, or included short-term intake from a small number of participants in experimental studies, or used commercially available rather than average consumed FPS from large NDS samples (14, 17, 21, 22, 57, 58).

In terms of strengths, the categorisation of foods by product type broadly matching the UK and French subgroups and examining FPS of similar products as they would be sold in a commercial environment and subsequently consumed by individuals, allows a more meaningful assessment of FPS than previous categorisations. Previous studies tend to use broader or incompatible food groups (23, 44-46), where the diversity of foods in each group is higher and, therefore, comparability is lower. Future work could consider other energy-dense food and drinks such as fast food, breakfast cereals, ice cream, sugar-sweetened beverages or alcohol, as foods other than snack foods are related to BMI. Our focus on commercially available products provides information on FPS, split by BMI status, which could provide valuable evidence for policy development targeted at industry. Policies to reduce consumed FPS are needed now, and may have greater, more immediate impact across the population if targeted at popular, commercially available foods (15).

A further strength is that there are few studies exploring FPS across Europe, and the literature focuses primarily on America. However, as only two Western European countries were investigated, the ability to make Europe-wide assertions is limited; quality raw NDS data (as distinct from summary reports) with the necessary food code variables were not readily available to analyse from other countries. Nevertheless, the French and UK NDS used similar dietary methodologies of consecutive, self-reported food diaries (albeit with a different number of collection days) with estimated FPS, making them good comparative cases to report together.

Energy density and consumption frequency averaged to one day was not available for the French INCA2, so the main food groups selected for analysis were based on those chosen in the UK NDNS, and consumption frequency analysis limited to the UK. This made comparisons easier. Additionally, they are both developed Western European countries with some similarities in foods consumed and with similar dietary methodologies; however, different French and UK dietary patterns may result in differences in the most frequently consumed main food groups. This has implications for future extension of the analyses to other countries if their NDS lack consumption frequency data or methodologies differ. There is a need for better quality, harmonised NDS methodology and implementation across Europe, potentially achievable with new technologies, in order to generate robust data on which policy can be based.

Further methodological limitations include the use of a 1.55 PAL across all individuals rather than being estimated individually, which limits the accuracy with which under-reporters can be identified, although 1.55 is an accepted value for a sedentary lifestyle in the populations used (39-41). The French and UK data collection periods also differ, which limits the ability to make valid comparisons and highlights the need for regular, standardised data collection. In addition, French homemade items were not all demarcated, so could not be fully excluded, which may distort FPS and limit comparisons to the UK. This accentuates the possibility that the consumed FPS data do not necessarily represent commercially available industry-set FPS, thereby potentially losing some policy-making application to create realistic FPS guidance. Future work will explore how closely consumed FPS relate to pack-size and on-pack serving sizes in order to provide evidence to assist obesity-prevention policy decisions on reducing FPS and energy intake.

8.5 Conclusions

FPS for commonly consumed high-energy, -fat and -sugar foods were generated for two countries, which could provide important information for food policy work. There was limited evidence of associations between FPS and BMI of energy dense foods, and although the few significant associations found were positive, the subgroups with significant associations differed across the two countries. The limited evidence may be due to the cross-sectional nature and other limitations of the NDS data, such as the high estimates of under-reporting and the small number of individuals in some food subgroups. Excluding under-reporters impacted upon results; levels were higher in the UK, potentially due to the higher number of OWOB individuals previously associated with under-reporting. Future work should further explore data limitations like under-reporting, and investigate relationships between consumed FPS and on-pack serving sizes, which could help to inform future obesity-prevention policies.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Table S1: Combining data from Years 1–4 and Years 5 and 6, Table S2: Food subgroups in the selected main food groups in the French INCA2* and UK NDNS, Table S3: Associations between portion size of energy-dense foods and BMI for adults aged 19–64 y in the French INCA2. Model 1 adjusted for sex and age. Model 2 adjusted for under-reporting, sex and age, Table S4: Associations between portion size of energy-dense foods and BMI for adults aged 19–64 y in the UK NDNS (Y1–6). Model 1 adjusted for sex and age. Model 2 adjusted for under-reporting, sex and age.

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Appendix A

Table A1. Mean portion size of energy-dense foods for all consumers aged 19–64 years in the French INCA2.

FOOD GROUP	*n* †	% Individuals Consuming (Weighted) **	Mean FPS per Person (g)	SD	99% CI	
CAKES						
TOTAL ‡	**3078**	**N/A**	**123**	**66**	**118**	**128**
Other cakes and patisserie	33	1.7	96	45	70	122
Pancakes and brioche ‡	368	15.2	128	101	113	144
Chocolate cake and gateau	397	17.0	91	45	84	98
Cake and gateau non-chocolate ‡	481	21.8	108	69	98	117
Doughnut ‡	77	3.7	64	52	46	81
Eclairs ‡	116	5.6	98	52	80	115
Fruit cake ‡	105	4.6	65	41	51	78
Fruit pie	29	1.1	169	73	126	212
Muffins and mini cakes ‡	302	14.2	66	43	58	73
Pastries ‡	318	11.8	139	90	123	154
Tart	657	29.5	175	60	168	183
BISCUITS & CRISPS						
TOTAL ‡	**2020**	**N/A**	**36**	**31**	**33**	**39**
Other biscuits and crisps ‡	42	1.5	41	28	28	55
Unfilled uncoated biscuits ‡	201	9.0	38	29	32	44
Cereal bars ‡	97	4.2	34	24	27	41
Cookies ‡	72	3.5	42	29	31	52
Savoury biscuits plain ‡	353	16.8	26	21	23	29
Filled chocolate biscuits ‡	177	7.9	61	40	52	70
Filled non-chocolate biscuits ‡	71	3.1	42	29	32	52
Potato crisps std. ‡	267	13.5	28	39	18	37
Savoury biscuits flavoured ‡	86	3.2	36	24	27	46
Short biscuits ‡	142	6.5	36	40	25	47
Tortilla chips ‡	24	1.4	24	27	5	43
Unfilled coated biscuits with inclusions ‡	142	6.4	49	46	36	62
CHOCOLATE						
TOTAL ‡	**1632**	**N/A**	**27**	**25**	**24**	**29**
Chocolate spread ‡	272	12.9	38	38	29	48
Chocolate with additions ‡	194	8.8	31	30	24	37
Dark chocolate ‡	274	12.0	14	13	12	16
Honeycomb/crunch ‡	32	1.3	26	24	14	38
Mars type bar ‡	92	4.2	47	36	36	58
Milk chocolate ‡	514	21.6	20	22	17	23
Truffles ‡	167	5.8	25	33	17	33
Wafer bar	67	3.0	47	21	40	54
White chocolate ‡	20	1.0	32	30	7	56

† Unweighted number of individuals consuming each food subgroup. ** Percentages will not total 100%, as the weighted percentage is of all adults aged 19–64 rather than just those particular food groups. ‡ SD greater than half the mean FPS per person for all adults aged 19–64 years.

Appendix B

Table A2. Mean portion size of energy-dense foods for all consumers aged 19–64 years in the UK NDNS (Y1–6).

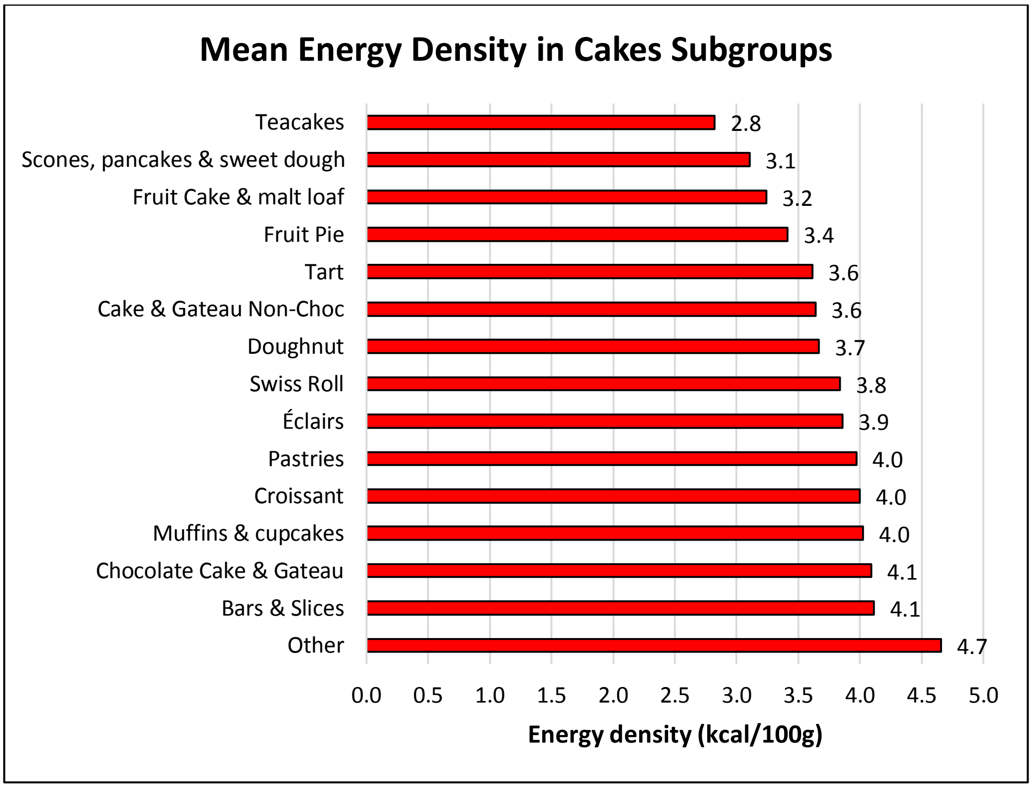
FOOD GROUP	*n* †	% Individuals Consuming (Weighted) **	Mean FPS per Person (g)	SD	99% CI	
CAKES						
TOTAL	**2739**	**N/A**	**69**	**28**	**66**	**72**
Other ‡	78	2.5	53	29	39	67
Teacakes	197	5.6	63	23	58	69
Cake and gateau non-choc ‡	241	6.3	51	26	43	58
Swiss roll ‡	110	2.8	55	34	40	70
Doughnut	151	4.9	78	29	64	92
Croissant	177	5.6	71	30	62	81
Muffins and cupcakes	194	5.7	69	23	60	77
Chocolate cake and gateau	161	4.8	71	30	56	86
Bars and slices	138	3.5	42	17	36	48
Fruit pie	186	4.8	93	35	83	103
Éclairs	62	1.9	77	32	61	93
Tart	112	3.3	73	33	62	84
Scones, pancakes and sweet dough ‡	263	4.8	68	35	56	80
Pastries	117	3.7	104	41	87	120
Fruit cake and malt loaf	95	2.6	68	28	58	78
BISCUITS						
TOTAL ‡	**3823**	**N/A**	**33**	**17**	**31**	**34**
Unfilled coated/inclusions	678	16.7	33	16	31	36
Unfilled uncoated ‡	685	16.4	28	20	25	31
Filled non-chocolate	425	11.4	34	15	31	37
Cereal bars	316	8.0	33	8	31	35
Cookies and flapjack ‡	312	8.8	45	24	38	52
Short biscuits ‡	301	7.9	25	14	22	29
Savoury biscuits plain ‡	657	17.4	28	14	26	30
Savoury biscuits flavoured	134	4.4	24	10	21	28
Jaffa cakes ‡	139	3.0	37	24	29	45
Filled chocolate	139	3.6	32	10	28	36
CRISPS						
TOTAL	**2178**	**N/A**	**31**	**14**	**30**	**33**
Potato and vegetable crisps std.	1260	34.1	30	12	29	32
Corn/maize snack	215	5.9	25	10	22	29
Potato snack shapes and puffed	306	9.1	26	8	23	28
Tortilla chips ‡	146	4.3	42	25	34	51
Potato crisps crinkle	145	3.6	38	10	35	42
Popcorn ‡	25	0.7	85	53	31	140
High-fat bar snacks ‡	64	2.1	30	20	21	39
Nuts	9	0.4	70	27	36	105
CHOCOLATE						
TOTAL ‡	**2457**	**N/A**	**39**	**21**	**36**	**41**
Other ‡	50	1.2	38	28	47	45
Milk chocolate ‡	590	16.1	35	26	31	40
Mars type bar	502	13.7	48	13	45	50
Wafer bar	306	8.5	31	10	29	34
Caramel ‡	197	4.9	35	18	29	41
Sugar coated ‡	71	2.0	36	20	19	53
Dark chocolate ‡	127	4.0	30	29	16	44
Honeycomb/crunch	133	3.6	40	19	32	48
Crème filled ‡	162	3.4	37	24	30	43

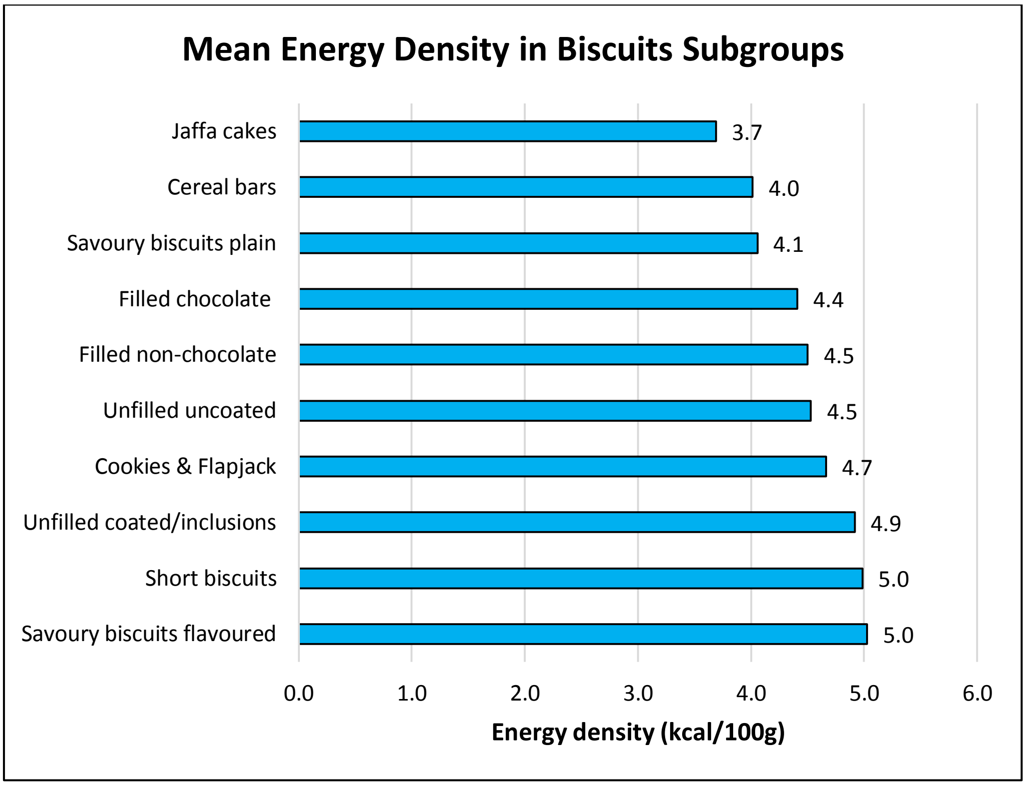
Truffles ‡	93	2.7	26	18	19	32
White chocolate ‡	47	1.3	30	18	14	46
Chocolate with additions ‡	121	3.8	44	26	35	53
Coated nuts/fruit ‡	58	1.9	73	56	44	102

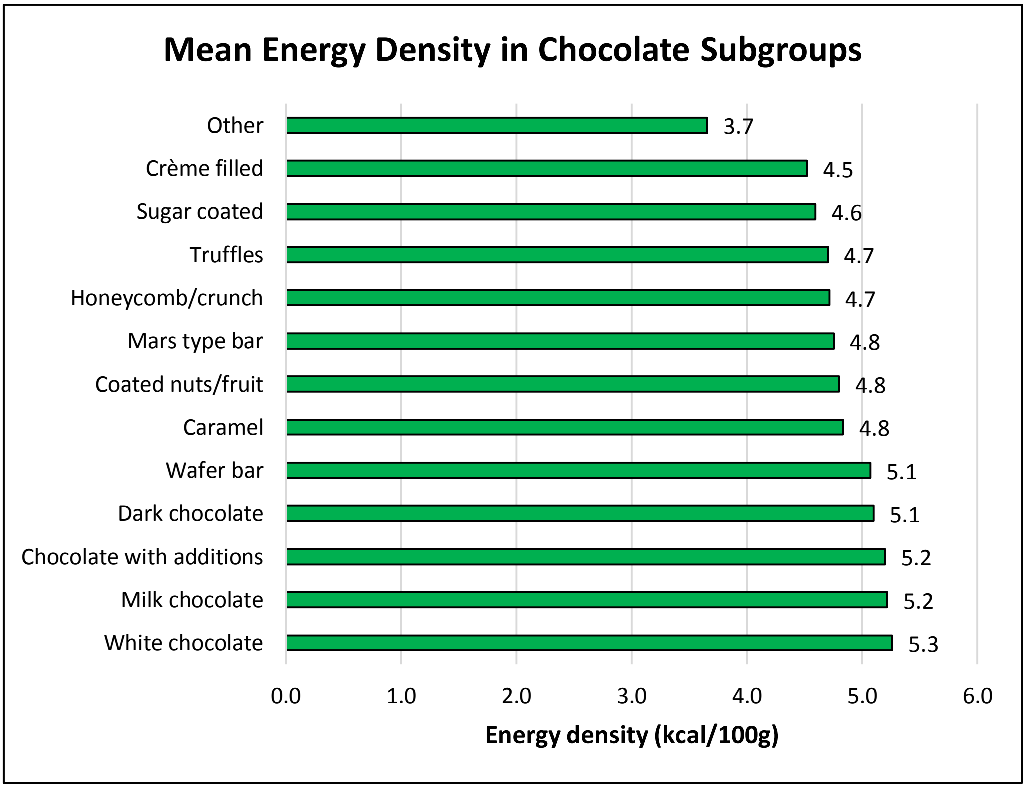
† Unweighted number of individuals consuming each food subgroup. ** Percentages will not total 100%, as the weighted percentage is of all adults aged 19–64 rather than just those particular food groups. ‡ SD greater than half the mean FPS per person for all adults aged 19–64 y.

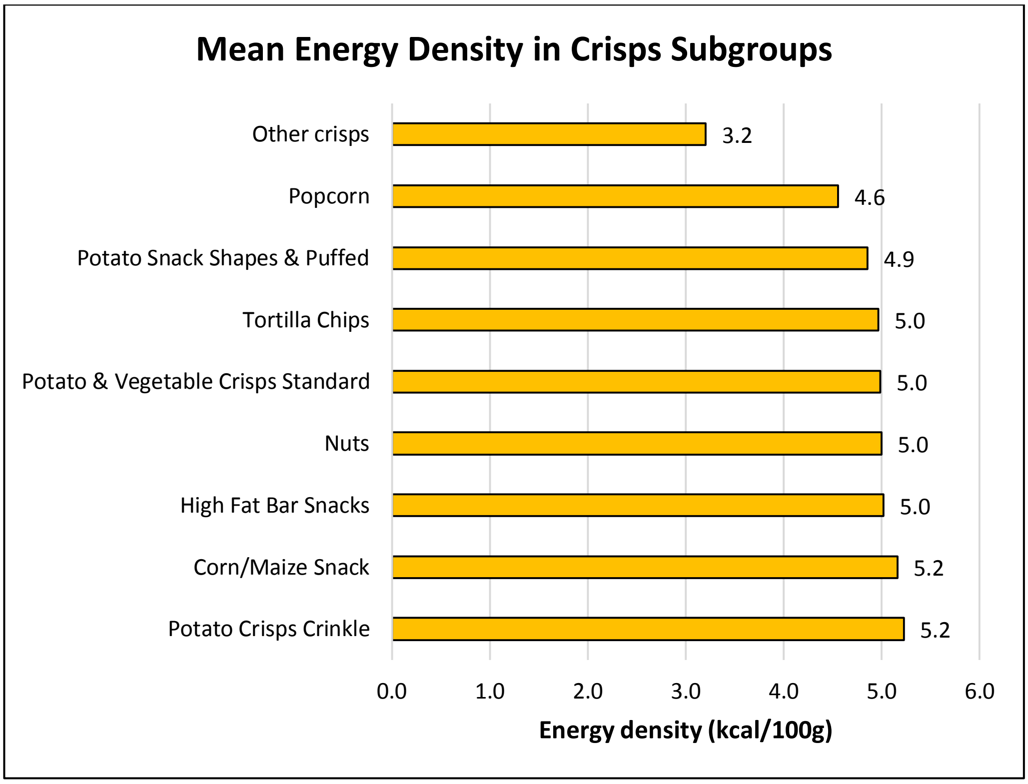
Appendix C

Figure A1. Mean energy density in food subgroups in each of the selected main food groups in the UK NDNS.




Mean Energy Density in Biscuits Subgroups
Jaffa cakes
3.7
Cereal bars
4.0
Savoury biscuits plain
4.1
Filled chocolate
4.4
Filled non-chocolate
4.5
Unfilled uncoated
4.5
Cookies & Flapjack
4.7
Unfilled coated/inclusions
4.9
Short biscuits
5.0
Savoury biscuits flavoured
5.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Energy density (kcal/100g)


Mean Energy Density in Chocolate Subgroups
Other
3.7
Crème filled
4.5
Sugar coated
4.6
Truffles
4.7
Honeycomb/crunch
4.7
Mars type bar
4.8
Coated nuts/fruit
4.8
Caramel
4.8
Wafer bar
5.1
Dark chocolate
5.1
Chocolate with additions
5.2
Milk chocolate
5.2
White chocolate
5.3
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Energy density (kcal/100g)



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Chapter 9 Comparison of consumed portion sizes and on-pack serving sizes of UK energy dense foods

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9.1 Abstract

Studies indicate a ‘portion size effect’ association between increased portion size and energy intake, but direct links with obesity remain unproven. UK portion size guidance is outdated and evidence suggests that on-pack serving-sizes have increased in some energy-dense foods. Serving-sizes are compared with consumed portion sizes in popular energy, fat and sugar-dense foods, and patterns explored. Data was analysed for adults aged 19-64y (excluding under-reporters) from the UK National Diet & Nutrition Survey 2008-2014 (n=2377) for consumed portion sizes and a commercial product database of major UK retailers provided serving-sizes. Popular energy-dense food groups were split into 45 product-based subgroups. Means of consumed portion size and on-pack serving-size were calculated and compared and nutrition per 100 g and per serve was explored. Just 57% products had serving-size compared to 97% with pack-size information. Serving-size ranges were wide and varied across food groups. Consumed portion sizes were significantly higher than on-pack serving-size in all main food groups and most subgroups. The greatest difference between consumed portion size and on-pack serving-size was Crisps (44%), and within this, ‘popcorn’ (151%). In Chocolate and Crisps, food subgroups with the largest on-pack serving-sizes were also the most macronutrient dense. Serving-size was unavailable for many products. However, where available, consumed portion sizes were higher than on-pack serving-size in all main food groups and most subgroups. The results could inform updated portion size guidance of energy-dense foods. Further work is needed to clarify whether smaller serving and pack sizes lead to lower total consumption and energy/nutrient intake.

Keywords:

Food portion size

Serving size

Energy dense foods

Portion size guidance

National diet surveys

Nutritional epidemiology

Abbreviations:

WHO – World Health Organisation

NDNS (RP) – National Diet & Nutrition Survey (Rolling Programme)

PHRD – Public Health Responsibility Deal

CAPI – Computer Assisted Personal Interview

DLW – Doubly Labelled Water

EFSA – European Food Safety Authority

NCD – Noncommunicable Diseases

9.2 Introduction

Obesity is one of the biggest health problems facing the European population; it accounts for 2-8% of World Health Organisation (WHO) European health costs (1) and is estimated to cause 320,000 premature deaths annually in Western Europe alone (2). NCDs and related conditions, including overweight and obesity, have significant and growing economic and social costs; therefore diet improvement via reduction in ‘energy dense, micronutrient poor foods’ high in energy, saturated fats, *trans* fats, sugar and salt, is needed across Europe to minimise this burden (2).

In 87% (46) of WHO European countries over half of adults are overweight or obese (OWOB); in the UK this is over two thirds (67%) adult men and almost 60% (58%) women aged over 16y (3). There is no established *causal* relationship between consumed portion size and obesity, only an association between increased consumed portion size and energy intakes and evidence that limiting consumed portion size contributes to reduced energy intake and therefore reduced weight gain (4). Ledikwe et al. (5) and Bhupathiraju & Hu (6) associated increasing on-pack serving sizes, particularly of energy dense foods, with rising obesity levels via elevated energy intakes. Although both studies refer to America, Albar et al. (7) found positive associations between BMI and consumed portion size of biscuits and cakes in UK adolescents aged 11-18y after excluding misreporters. Experimental literature also suggests that individuals consume more when exposed to larger portions (8-10). Assuming consumed portion size influences energy intake (4), public access to appropriate portion size guidance, and on-pack serving-sizes that consistently reflect this, alongside decreased serving-sizes of discrete packaged foods may therefore be key to a healthy food and drink environment.

The positive association between on-pack serving-size and food intake is known as the ‘portion size effect’. In their meta-analysis Zlatevska et al. (11) found, at least in the short-term, that although the association was not linear or uniform across all population groups, overall energy intake increased by 35% when the offered serving-size doubled. Bhupathiraju & Hu (6) link the obesogenic environment, which includes availability of large serving-sizes of energy dense foods, with obesity and related diseases. Associations between consumed portion size of particular food groups and adiposity have been examined in previous UK National Diet and Nutrition Surveys (NDNS). Kelly et al. (12) found few associations in the NDNS 2000-2001, but concluded that adult BMI and waist activity level was associated with the consumption of large portions of specific foods, particularly after adjustment for under-reporting.

Based on this evidence, reducing on-pack serving-sizes forms part of the UK’s ongoing calorie reduction drive. The Public Health Responsibility Deal (PHRD) calorie reduction pledge included on-pack serving-size reduction, including of single-serve items, in its suite of options (13). Public Health England also highlight it as an objective of their recent calorie and sugar reduction plans, encouraging retailers to reduce the pack size of discrete, single-serve products in certain categories (14). However, UK Government guidance on consumed portion size has not been updated in over 20 years (15) and in Europe on-pack serving-sizes are set individually by manufacturers rather than standardised (16). Evidence suggests that UK on-pack serving-sizes have increased in some energy dense food categories. Looking at a combination of consumed portion size and on-pack serving size information, Wrieden et al. (17) found that although consumed portion sizes had not necessarily increased in all categories, fast food consumed portion sizes and availability of large confectionary serving-sizes had risen since government consumed portion size guidance was last issued in 1993 (18). Studies have repeatedly found that although on-pack serving-sizes of some varieties of traditional biscuit and crisp packet items have changed little in 20 years, other biscuit and crisp varieties and other food types have increased (15, 19). For example, Clift (15) found that ‘plain sweetmeal biscuits’ had increased by 17% and ‘American muffins’ by 81%. Even if on-pack serving-sizes or pack sizes of discrete single-serve products decrease, it is not clear what impact this would have on purchase and consumption. Consumers may buy more, thereby inadvertently increasing the total sales volume, or could consume multiples of the smaller portions, thus maintaining or potentially increasing energy and nutrient intake. A recent review (20) found that the effects of on-pack serving size labelling on consumed portion size remained unclear, but that there was a clear need for consistent terminology, consumer education and further research.

To begin exploration of these issues, this paper will report the average manufacturer-set on-pack serving-size of frequently consumed energy, fat and sugar dense snack food types in the UK and then compare with consumed portion size derived from the UK NDNS. It will explore patterns and similarities to determine whether consumers of such foods have consumed portion size above the serving-size recommended on pack, and consider whether on-pack serving-sizes of certain food types should be amended, as they could have a potential impact on excess energy intake and consequently obesity.

9.3 Methods

Almiron-Roig et al. (21) define ‘portion’ as the amount a person eats on one occasion and ‘serving’ as the suggested amount to be eaten on one occasion. For clarity, we have adopted this definition and use consumed portion size as distinct from on-pack serving-size of purchased foods.

9.3.1 Consumed Portion Size

The UK National Diet and Nutrition Survey (NDNS) Rolling Programme (RP) years 1-4 and 5-6 (2008-12 & 2012-14) (22, 23) was obtained and analysed to derive consumed portion size of selected food groups in adults aged 19-64y (excluding under-reporters). Multi-stage random probability sampling from UK Postcode Address Files with postal sectors as the primary sampling units was used to select individuals aged 1.5-100y. The two datasets were appended and sample weightings were reassigned using Stata versions 14 & 15 (24, 25). Existing weightings for the Y1-4 and Y5-6 datasets were rescaled to account for the different number of years and therefore respondents in each (see supplementary material 1). Food data was collected via a 4-day consecutive food diary. Participants were not expected to weigh food and drink consumed; consumed portion size was estimated using household measures (e.g. two digestive biscuits, 1 tbsp. chocolate spread), weights from food packaging labels e.g. 25g packet of crisps), or photographs. The food diary provided photographs of 15 frequently consumed foods as small, medium and large portion sizes, which participants could use to estimate portion sizes of similar foods consumed. Demographic and measured height and weight information was collected via a Computer Assisted Personal Interview (CAPI) (22, 23).

The NDNS 2008-14 dataset was used to identify popular UK energy, fat and sugar-dense foods. The main NDNS food groups were listed by total number of eating occasions for adults aged 19-64y and the tertile with the lowest number of eating occasions were excluded. The average energy, fat and sugar density was then determined for each remaining food group and those with above average density in all three were selected for analysis – these were Biscuits; Buns, Cakes, Pastries & Fruit Pies (‘Cakes’) and Chocolate Confectionary (‘Chocolate’).

Although the Crisps & Savoury Snacks (‘Crisps’) group did not have above average sugar density, it was also selected due to a high salt content, which is a WHO European nutrient of concern (2).

Within the four selected main food groups homemade items were excluded in order to focus on commercially available products. This was done by searching for and excluding items with ‘homemade’ in the title on either the ‘SubFoodGroupDesc’ or ‘FoodName’ NDNS variable level. The remaining food items were then re-categorised by product type into newly created subgroups within each of the four selected main food groups based on their characteristics. Miscellaneous items were categorised as ‘other’; for example ‘other’ cakes consisted of Chinese cakes and pastries, rice flour cakes and plain pastry.

The mean consumed portion size and SD per eating occasion for adults aged 19-64y consuming each food subgroup were calculated and tabled. These means were weighted to make them nationally representative for that age group by correcting for unequal selection and non-response. The food subgroup consumed portion size per eating occasion was defined as the total weight of food consumed in each subgroup divided by the consumption frequency per person. Each consumer contributed a single mean portion weight to the population mean for each food subgroup to prevent risk of skewing by non-consumers or those who ate certain foods more frequently. Analyses were restricted to adults aged 19-64y to prevent distortion of results from children or the elderly, who may consume smaller portions. Under-reporters were excluded to improve the relevance of findings, as the NDNS does not exclude under-reporters in its results (22, 23). Under-reporters (n=1285, 35%) and adults with missing BMI required to determine plausible/under-reporters (n=133, 4%) were excluded from the calculation of the mean consumed portion size. Under-reporter identification was based on energy intake of the whole diet rather than the specific food groups selected for review. Participant height and weight data were used to generate Basal Metabolic Rate (BMR) and BMR:energy intake ratio variables following the Oxford equations detailed in Henry (26). A low cut-off was generated via the Goldberg method (27) using a Physical Activity Level (PAL) of 1.55, as this is regarded as representative of a sedentary lifestyle in the UK and across

Europe (28, 29). Socio-demographic and dietary characteristics of those sampled from the NDNS were determined and tabled.

9.3.2 On-Pack Serving-Size

A commercial UK database was obtained from 2013, containing product information taken from packaging labels from six major UK retailers (Asda, Co-op, Morrisons, Sainsbury's, Tesco, Waitrose/Ocado) plus manufacturer data. The products were categorised into subgroups based on those created for the NDNS analysis of consumed portion size; these products were selected for analysis and the remainder excluded.

Pack-size and serving-size data as stated on the product packaging was then cleaned and harmonised so all values were displayed numerically in grams. Pack-size was defined as the weight declared on-pack for the entire pack contents; serving-size was defined as the weight provided on-pack as a suggested amount to consume per person in one eating occasion. Where serving-size was given as units of product e.g. 'two biscuits' or 'half a bar' the weight in grams was calculated, where possible, from the pack-size and product description. For example, a product with a serving-size of 'two biscuits', a pack-size of 150 g and a description of '12 jam-filled biscuits' would be given a serving-size of 25 g.

For each subgroup the number of products, number of products with pack-size and the number of products with serving-size information was totalled and the mean and SD of pack-size and serving-size in grams was calculated. The weighted mean consumed portion sizes (excluding under-reporters) were taken from the NDNS derived dataset and compared with the mean and confidence intervals of the on-pack serving-size in the commercial dataset. The difference between these values was tested for each food group using a one sample t-test. This, rather than an independent group t-test, was needed to compare the means due to the different observation types in each dataset; the consumer dataset unit observations were individual people, whereas those in the on-pack serving-size dataset were products. The percentage difference between these means was also reported. Statistical significance was set at $p<0.01$ due to the large number of statistical tests performed.

For each main and subgroup of foods studied here the mean nutrition per 100 g was determined for the macronutrients commonly available on back of pack (energy in kcal, energy in kJ, protein, CHO, total sugars, total fat, saturates, fibre, sodium/salt). This was calculated using back-of-pack nutrition information from the commercial database and finding the average value per nutrient from all products in each main and subgroup. The mean nutrition per 100 g and the mean serving-size was used to generate the average nutrition per serve for selected nutrients (energy in kcal, total sugars, total fat, saturates, salt) for each subgroup and the overall main food group. This process was repeated using the consumed portion size from the NDNS in place of the on-pack serving size to generate the commercial product mean nutrition per 100g and per serve based on consumed portion sizes. In this way the difference in nutritional content between the consumed portion size and the on-pack nutrition per serve was determined.

9.4 Results

9.4.1 Consumed Portion Size

Due to the number of food codes available in the NDNS, the NDNS-derived consumed dataset had 331 relevant foods across the selected four main food groups reported by the 2244 adults aged 19-64y (excluding under-reporters) analysed. Almost half of participants (49%) were female and the average age was 41y (table 1). The under-reporters excluded were significantly heavier, had a higher BMI and were less likely to have a degree; they also had significantly lower energy, fat and salt intakes and higher carbohydrate intakes.

The three food subgroups with the highest mean consumed portion size for all adults aged 19-64y in Cakes were ‘pastries’ (106 g [SD 42 g] 95%CI 92-121 g), ‘fruit pie’ (96 g [SD 35 g] 95%CI 87-105 g) and ‘éclairs’ (76 g [SD 36 g] 95%CI 63-90 g) compared to an overall mean for all Cakes of 71g (SD 16 g) (table 2). For Biscuits this was ‘cookies & flapjack’ (47 g [SD 25 g] 95%CI 40-53 g), ‘jaffa cakes’

(39 g [SD 25 g] 95%CI 31-46 g) and ‘filled, non-chocolate biscuit’ (34 g [SD 16 g] 95%CI 31-37 g) compared to an overall mean of 33 g (SD 7 g) for all Biscuits. For Chocolate this was ‘coated nuts/fruit’ (84 g [SD 59 g] 95%CI 59-108 g), ‘Mars-type bar’ (48 g [SD 13 g] 95%CI 46-50 g) and ‘chocolate with additions’ (45 g [SD 24 g] 95%CI 37-54 g) compared to an overall mean of 40 g (SD 15 g) and for Crisps this was ‘popcorn’ (86 g [SD 52 g] 95%CI 35-137 g), ‘nuts’ (77 g [SD 25 g] 95%CI 51-104 g) and ‘tortilla chips’ (46 g [SD 26 g] 95%CI 38-54 g) compared to an overall mean of 45 g (SD 24 g).

Table 1: General and dietary characteristics of all adults aged 19-64y in the UK NDNS (Y1-6) dietary survey

UK NDNS	ALL unweighted (n=3662)			Plausible reporters (n=2244)			Under-reporters (n=1285)			p-value
	Mean	95% CI		Mean	95% CI		Mean	95% CI		
General characteristics (weighted)										
Age (y)	41	41	42	41	40	42	41	40	42	0.4
Female (%)	50	48	52	49	46	51	52	49	56	0.1
Height (cm)	169	169	170	170	169	170	169	168	170	0.3
Weight (kg)	78	77	79	75	74	76	84	83	85	<0.001
BMI (kg/m²)	27	27	27	26	26	26	29	29	30	<0.001
Ethnicity (% white)	88	86	89	89	87	91	86	83	88	0.06
Education (% with degree)	28	26	30	31	29	34	22	19	25	<0.001
Under-reporters (% of all adults 19-64y)	35	33	37	N/A						
Dietary characteristics (weighted)										
Total energy (kcal)	1857	1831	1882	2127	2099	2156	1364	1338	1390	<0.001
Fat (%E)	33	33	33	34	33	34	31	31	32	<0.001
Protein (%E)	16	16	17	16	16	16	18	18	18	<0.001
Carbohydrates (%E)	46	46	46	45	45	46	48	47	48	<0.001
Sugars (%E)	19	19	20	20	19	20	19	19	20	0.1
Salt (g)	5.6	5.5	5.7	6.3	6.2	6.4	4.3	4.2	4.4	<0.001
Under-reporter energy intake (kcal)	1364	1338	1390	N/A						

9.4.2 On-Pack Serving-Size

In the commercial on-pack dataset there were 13,313 relevant products; 97% of products in the four selected main food groups had available pack-size information, but only 57% had on-pack serving-size information. Of the four selected main food groups, Crisps had the most products with serving-size information, at 79% (n=2234), and Cakes had over three quarters (n=2061) products with this information (table 2). However, only half (n=1731) of Biscuit products and 35% (n=1539) Chocolate products had serving-size information. The serving-size range was wide and varied across food groups. In Biscuits the SD in all subgroups except 'cereal bars' was over half the mean, compared to Crisps, where only the 'popcorn' subgroup SD was over half the mean. The subgroup composition influenced the mean on-pack serving-size; for example 'muffins and cupcakes' had a mean serving-size of 61g, but excluding cupcakes in a sensitivity analysis increased this to 74 g. Consumed portion size was higher than on-pack serving-size in all four main food groups and the majority of subgroups (figures 1-4).

Figure 1: Mean adult consumed portion sizes and on-pack serving sizes - Cakes

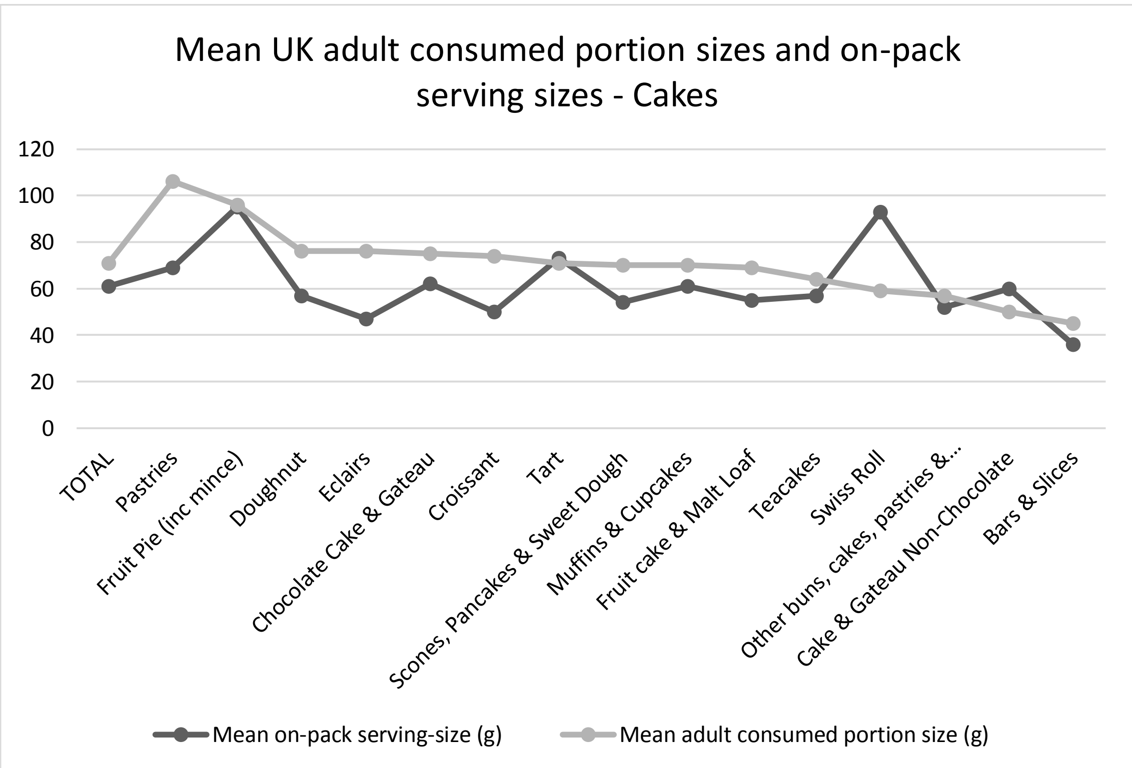

Figure 2: Mean adult consumed portion sizes and on-pack serving sizes - Biscuits

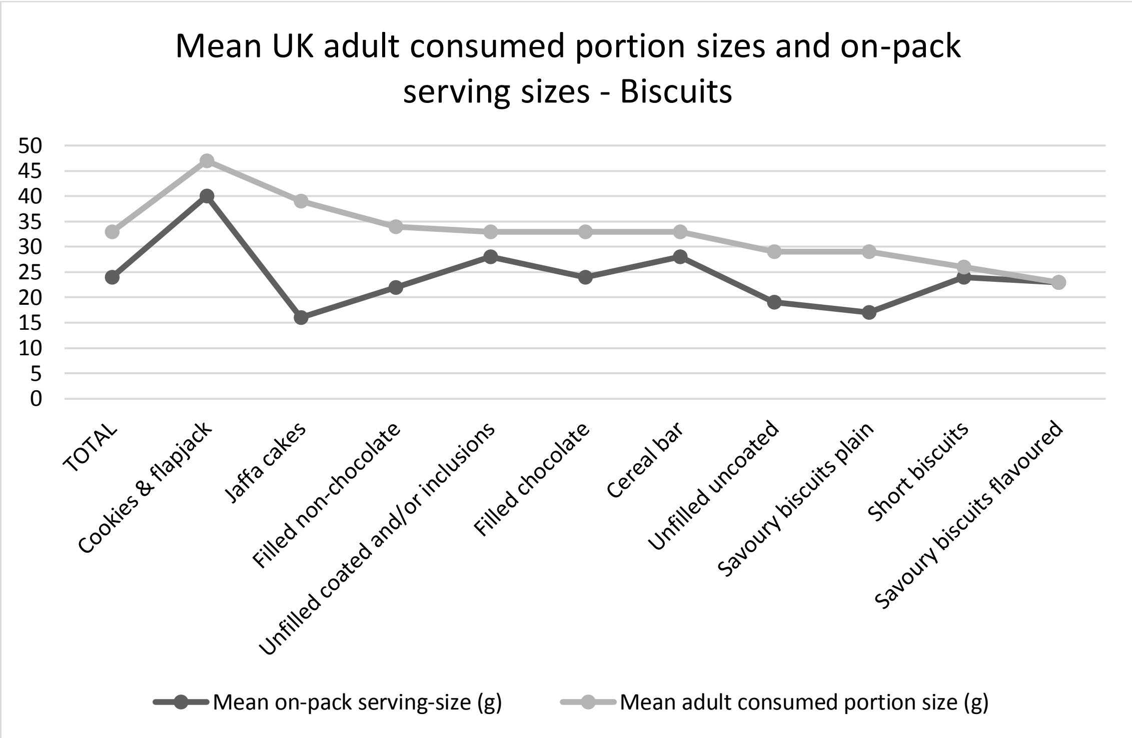

Figure 3: Mean adult consumed portion sizes and on-pack serving sizes - Chocolate

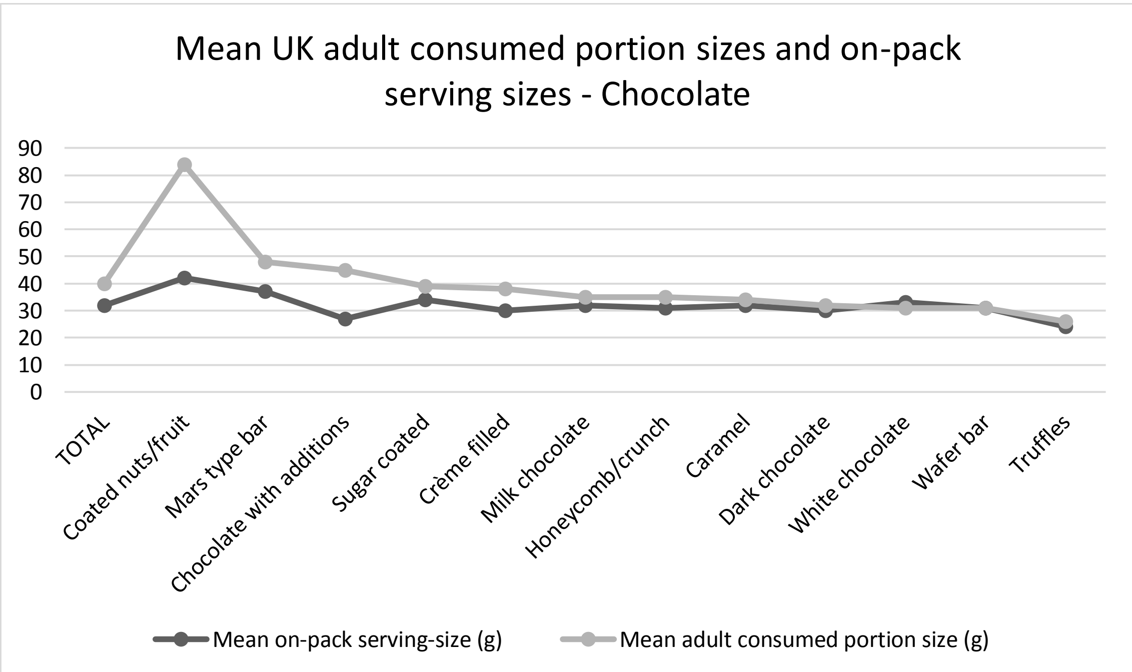

Figure 4: Mean adult consumed portion sizes and on-pack serving sizes - Crisps

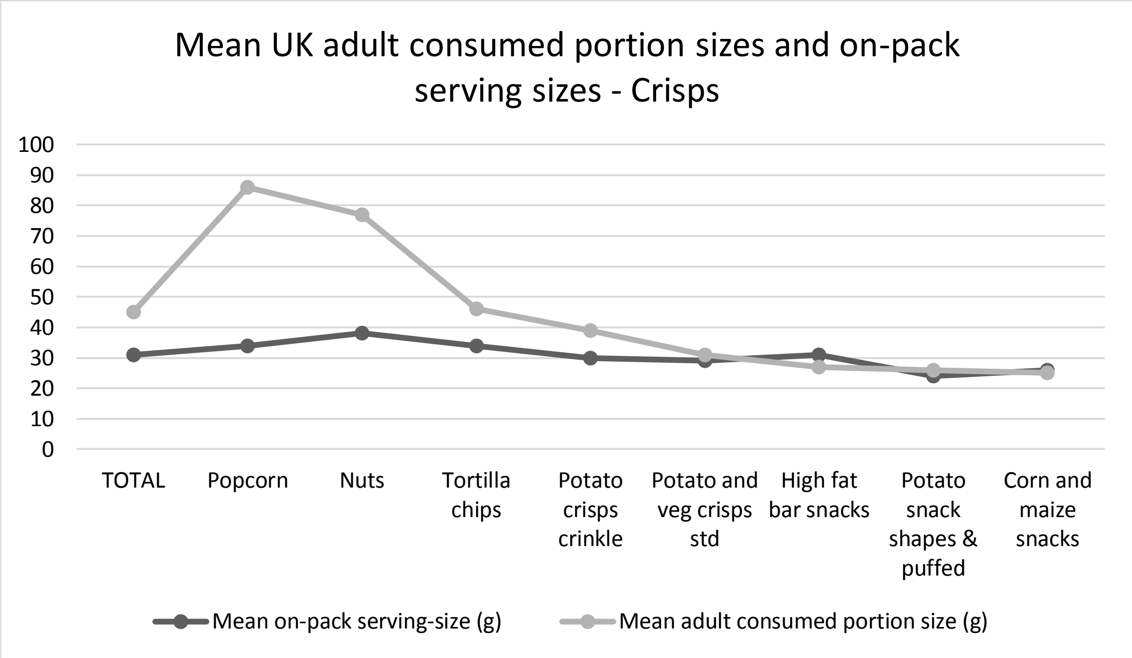

Table 2: Mean UK pack-size and on-pack serving size of selected product categories compared to mean adult (aged 19-64y) consumed portion size

Food group	No. products	No. products pack-size info	No. products serving-size	Mean pack-size (g)	Pack-size SD (g)	Mean serving-size (g)	Serving-size SD (g)	n * (2377)	Mean adult consumed portion size (g)	Adult consumed portion size SD (g)
Cakes	**Commercial database – on-pack information**							**NDNS – consumed portion size**		
TOTAL	**2669**	**2423**	**2061**	**330**	**421**	**61**	**31**	**2282**	**71**	**16**
Pastries	153	146	127	427	1001	69	32	117	106	42
Fruit Pie (inc mince)	223	211	176	364	255	95	37	186	96	35
Doughnut	57	56	50	113	116	57	26	151	76	22
Eclairs	25	25	24	113	71	47	36	62	76	36
Chocolate Cake & Gateau	279	238	209	479	549	62	28	161	75	33
Croissant	81	81	72	457	1250	50	20	177	74	30
Tart	300	289	216	356	489	73	38	112	71	35
Scones, Pancakes & Sweet Dough	268	265	190	386	514	54	27	263	70	35
Muffins & Cupcakes	252	248	218	239	497	61	36	194	70	22
Fruit cake & Malt Loaf	168	139	95	615	425	55	21	95	69	27
Teacakes	48	46	40	304	171	57	21	197	64	24
Swiss Roll	15	11	13	346	109	93	56	110	59	36
Other buns, cakes, pastries & fruit pie	12	12	9	111	98	52	29	78	57	31
Cake & Gateau Non-Chocolate	468	348	338	427	423	60	39	241	50	21
Bars & Slices	320	308	284	207	353	36	18	138	45	18

Biscuits	Commercial database – on-pack information							NDNS – consumed portion size		
TOTAL	**3431**	**3353**	**1731**	**184**	**189**	**24**	**17**	**3786**	**33**	**7**
Cookies & flapjack	436	423	212	192	157	40	25	312	47	25
Jaffa cakes	29	25	20	151	102	16	12	139	39	25
Filled non-chocolate	178	172	87	224	273	22	15	425	34	16
Unfilled coated and/or inclusions	824	810	410	191	158	28	18	678	33	15
Filled chocolate	306	294	193	157	174	24	14	139	33	10
Cereal bar	120	117	116	128	71	28	12	316	33	9
Unfilled uncoated	403	397	188	217	162	19	16	685	29	20
Savoury biscuits plain	381	377	155	197	514	17	14	657	29	15
Short biscuits	295	286	115	233	152	24	24	301	26	15
Savoury biscuits flavoured	459	452	235	149	122	23	15	134	23	9
Chocolate	**Commercial database – on-pack information**							**NDNS – consumed portion size**		
TOTAL	**4383**	**4359**	**1539**	**179**	**262**	**32**	**16**	**2399**	**40**	**15**
Coated nuts/fruit	188	187	60	213	395	42	20	121	84	59
Mars type bar	176	176	134	175	133	37	12	590	48	13
Chocolate with additions	240	239	108	146	104	27	14	47	45	24
Sugar coated	178	178	77	187	363	34	17	197	39	20
Crème filled	172	171	58	184	206	30	12	133	38	26
Milk chocolate	1593	1585	553	169	328	32	26	50	35	25
Honeycomb/crunch	220	216	116	192	299	31	13	127	35	13
Caramel	159	158	88	162	183	32	15	306	34	19
Dark chocolate	244	240	83	220	697	30	13	71	32	31
White chocolate	185	184	82	123	104	33	22	93	31	18

Wafer bar	85	85	72	156	155	31	12	502	31	11
Truffles	943	940	108	217	180	24	16	162	26	19
Crisps	**Commercial database – on-pack information**							**NDNS – consumed portion size**		
TOTAL	**2830**	**2773**	**2234**	**155**	**134**	**31**	**11**	**2170**	**45**	**24**
Popcorn	217	202	173	153	143	34	22	25	86	52
Nuts	872	846	558	233	263	38	15	9	77	25
Tortilla chips	107	105	82	191	71	34	10	146	46	26
Potato crisps crinkle	186	186	175	126	77	30	8	145	39	10
Potato and veg crisps std	833	828	705	148	138	29	10	1260	31	13
High fat bar snacks	65	63	47	133	115	31	10	64	27	15
Potato snack shapes & puffed	381	374	346	141	184	24	8	306	26	8
Corn and maize snacks	169	169	148	115	79	26	7	215	25	10

* Unweighted number of individuals consuming each food subgroup. There were 2377 individuals included in the analysis.

NB – the consumed portion sizes derived from the NDNS (2008-2014) were weighted to make them nationally representative of plausible reporters; there was no weighting factor applied to the on-pack serving-sizes.

In the Chocolate and Crisps groups the food subgroups with the highest macronutrients and salt per 100 g also had the highest per serve, though the subgroups in question varied depending on the nutrient (table 3). For example in Chocolate 'sugar-coated chocolate' had the highest sugar per 100 g and per serve (62 g, 21 g respectively); 'dark chocolate' had the highest fat and saturated fat content (38 g, 11 g and 23 g, 7 g respectively) and 'Mars-type bars' had the highest salt content (0.58 g, 0.21 g). In Crisps 'popcorn' had the highest sugar content (21 g, 7 g); 'nuts' had the highest fat and saturated fat content (49 g, 19 g and 8 g, 3 g respectively) and 'high fat bar snacks' had the highest salt content (2.18 g, 0.67 g). In Cakes this pattern was true in all nutrients except fat. In Biscuits, different subgroups had the highest levels per 100 g compared to those with the highest levels per serve in all nutrients except salt (table 3).

In all four main food groups the mean overall consumed portion size was statistically significantly larger than the mean overall on-pack serving-size (table 4). The consumed portion size was also larger than the on-pack serving-size in the majority of subgroups; only two subgroups had a statistically significant lower consumed portion size than on-pack serving-size: 'cake & gateau non-chocolate' and 'high fat bar snacks'.

Differences over 10% existed between consumed portion size and on-pack serving-size in most subgroups, with the majority of consumed portion sizes being higher than on-pack serving-size (Table 4). Only 'wafer bar' had the same consumed portion size and on-pack serving-size (31 g). The greatest difference between consumed portion size and on-pack serving-size was in Crisps (44%) and within this 'popcorn' (151%). For Crisps overall this equates to consumption of an extra 69kcal, 0.9 g sugar, 3.8 g fat, 0.6 g sat fat and 0.2 g salt per serve and for 'popcorn' 240kcal, 11 g sugar, 10.2 g fat, 2.5 g saturated fat and 0.48 g more salt than if consumers adhered to the recommended on-pack serving-size (table 4). Other subgroups with a consumed portion size over 50% greater than the on-pack serving-size were 'éclair' (60%) equating to a 109 kcal difference per serve; 'pastries' (53% 134 kcal) 'unfilled uncoated biscuits' (51% 47 kcal), 'filled non-chocolate biscuits' (53%, 55 kcal); 'savoury biscuits plain' (69%, 50 kcal); 'jaffa cakes' (149%, 87 kcal); 'chocolate with additions' (66%, 97 kcal); 'coated nuts & fruit' (101%, 205 kcal) and 'nuts' (105%, 238 kcal).

Table 3: Mean nutrition per 100g and per serve of selected product categories based on mean UK (2013) commercial on-pack food-label serving size and nutrition information

Food subgroup	Energy (kcal)	Total Sugar (g)	Total Fat (g)	Saturates (g)	Salt (g)	On-pack serving-size (g)	Energy (kcal)	Total Sugar (g)	Total Fat (g)	Saturates (g)	Salt (g)
Cakes	**Commercial database - nutrition per 100g**						**Commercial database - nutrition per serve**				
TOTAL	**377**	**27**	**17**	**8**	**0.48**	**61**	**231**	**17**	**10**	**5**	**0.29**
Teacakes	290	20	5	2	0.63	57	165	11	3	1	0.36
Cake & Gateau Non-Chocolate	375	36	15	6	0.30	60	225	21	9	3	0.18
Swiss Roll	367	27	13	7	0.45	93	341	25	12	7	0.42
Doughnut	364	19	19	9	0.58	57	207	11	11	5	0.33
Croissant	415	10	23	13	0.95	50	208	5	11	7	0.48
Muffins & Cupcakes	411	33	20	5	0.48	61	251	20	12	3	0.29
Chocolate Cake & Gateau	398	33	19	8	0.38	62	247	20	12	5	0.23
Bars & Slices	437	40	19	9	0.43	36	157	14	7	3	0.15
Fruit Pie (inc mince)	301	22	12	5	0.23	95	286	21	11	5	0.21
Eclairs	377	18	27	16	0.30	47	177	8	13	8	0.14
Tart	373	26	18	9	0.33	73	272	19	13	7	0.24
Scones, Pancakes & Sweet Dough	333	22	11	5	0.90	54	180	12	6	3	0.49
Pastries	362	19	19	10	0.50	69	250	13	13	7	0.35
Fruit cake & Malt Loaf	349	41	9	3	0.25	55	192	23	5	2	0.14
Other buns, cakes, pastries & fruit pie	501	47	22	16	0.48	52	261	25	12	8	0.25
Biscuits	**Commercial database - nutrition per 100g**					**On-pack serving-size (g)**	**Commercial database - nutrition per serve**				
TOTAL	**456**	**28**	**18**	**9**	**0.78**	**24**	**110**	**7**	**4**	**2**	**0.19**

Unfilled coated and/or inclusions	488	34	21	11	1.28	28	137	9	6	3	0.36
Unfilled uncoated	469	27	18	8	0.78	19	89	5	3	2	0.15
Filled non-chocolate	458	32	19	10	0.48	22	101	7	4	2	0.10
Cereal bar	406	35	12	5	0.45	28	114	10	3	1	0.13
Cookies & flapjack	476	31	22	11	0.63	40	190	12	9	4	0.25
Short biscuits	492	23	25	13	0.58	24	118	6	6	3	0.14
Savoury biscuits plain	415	4	12	4	1.33	17	71	1	2	1	0.23
Savoury biscuits flavoured	458	5	19	7	1.73	23	105	1	4	2	0.40
Jaffa cakes	378	53	9	5	0.15	16	60	8	1	1	0.02
Filled chocolate	523	38	25	14	0.40	24	126	9	6	3	0.10
Chocolate	**Commercial database - nutrition per 100g**					**On-pack serving-size (g)**	**Commercial database - nutrition per serve**				
TOTAL	**519**	**50**	**28**	**16**	**0.27**	**32**	**166**	**16**	**9**	**5**	**0.09**
Milk chocolate	535	54	31	19	0.23	32	171	17	10	6	0.07
Mars type bar	478	51	23	12	0.58	37	177	19	8	4	0.21
Wafer bar	540	50	26	15	0.20	31	167	15	8	5	0.06
Caramel	482	53	24	14	0.40	32	154	17	8	4	0.13
Sugar coated	498	62	23	14	0.15	34	169	21	8	5	0.05
Dark chocolate	550	36	38	23	0.18	30	165	11	11	7	0.05
Honeycomb/crunch	516	52	28	16	0.35	31	160	16	9	5	0.11
Crème filled	499	54	26	15	0.25	30	150	16	8	4	0.08
Truffles	557	47	34	20	0.20	24	134	11	8	5	0.05
White chocolate	548	56	32	20	0.25	33	181	19	11	7	0.08
Chocolate with additions	537	46	33	18	0.18	27	145	13	9	5	0.05
Coated nuts/fruit	489	45	26	12	0.30	42	205	19	11	5	0.13

Crisps	Commercial database - nutrition per 100g					On-pack serving-size (g)	Commercial database - nutrition per serve				
TOTAL	**499**	**6**	**27**	**5**	**1.44**	**31**	**153**	**2**	**8**	**1**	**0.44**
Potato and veg crisps std	485	4	27	3	1.40	29	141	1	8	1	0.41
Corn and maize snacks	481	4	22	5	1.73	26	125	1	6	1	0.45
Potato snack shapes & puffed	491	4	25	4	2.05	24	118	1	6	1	0.49
Tortilla chips	489	3	24	3	1.20	34	166	1	8	1	0.41
Potato crisps crinkle	502	3	28	3	1.55	30	151	1	9	1	0.47
Popcorn	461	21	20	5	0.93	34	157	7	7	2	0.31
High fat bar snacks	473	4	24	7	2.18	31	147	1	7	2	0.67
Nuts	610	8	49	8	0.48	38	232	3	19	3	0.18

Table 4: Difference in consumed portion size and on-pack serving size and estimated nutritional difference

Food subgroup	Mean consumed portion size and on-pack serving-size (g)						Nutritional difference between consumed portion size and on-pack serving-size**				
	Consumed portion size	On-pack serving-size	95% CI		% Difference	p-value	Energy (kcal)	Total sugar (g)	Total fat (g)	Saturated fat (g)	Salt (g)
Cakes											
TOTAL	**71**	**61**	**59**	**62**	**16%**	**<0.001**	**34**	**2.5**	**1.5**	**0.8**	**0.04**
Eclairs	76	47	32	62	60%	<0.001	109	5.2	7.9	4.6	0.09
Pastries	106	69	64	75	53%	<0.001	134	6.9	7.2	3.7	0.19
Croissant	74	50	46	55	47%	<0.001	100	2.4	5.4	3.1	0.23
Doughnut	76	57	50	65	33%	<0.001	69	3.6	3.6	1.7	0.11
Scones, Pancakes & Sweet Dough	70	54	50	58	30%	<0.001	53	3.5	1.8	0.8	0.14
Fruit cake & Malt Loaf	69	55	50	59	26%	<0.001	49	5.8	1.2	0.5	0.04
Bars & Slices	45	36	34	38	26%	<0.001	39	3.6	1.7	0.8	0.04
Chocolate Cake & Gateau	75	62	58	66	21%	<0.001	52	4.3	2.5	1.1	0.05
Muffins & Cupcakes	70	61	56	66	15%	<0.001	37	3.0	1.8	0.4	0.04
Teacakes	64	57	50	63	12%	0.03	20	1.4	0.3	0.1	0.04
Other buns, cakes, pastries & fruit pie	57	52	30	74	10%	0.6	25	2.4	1.1	0.8	0.02
Tart	71	73	68	78	-3%	0.4	-7	-0.5	-0.4	-0.2	-0.01
Fruit Pie (inc. mince)	96	95	90	101	1%	0.8	3	0.2	0.1	0.1	0.00
Cake & Gateau Non-Chocolate	50	60	55	64	-16%	<0.001	-38	-3.6	-1.5	-0.6	-0.03
Swiss Roll	59	93	60	127	-37%	0.05	-125	-9.1	-4.5	-2.4	-0.15
Biscuits											
TOTAL	**33**	**24**	**19**	**29**	**27%**	**0.003**	**39**	**2.4**	**1.5**	**0.7**	**0.07**
Jaffa cakes	39	16	10	21	149%	<0.001	87	12.1	2.0	1.1	0.03

Savoury biscuits plain	29	17	15	19	69%	<0.001	50	0.5	1.4	0.5	0.16
Filled non-chocolate	34	22	19	25	53%	<0.001	55	3.9	2.2	1.2	0.06
Unfilled uncoated	29	19	17	22	51%	<0.001	47	2.7	1.8	0.8	0.08
Filled chocolate	33	24	22	26	36%	<0.001	47	3.4	2.2	1.3	0.04
Unfilled coated and/or inclusions	33	28	26	30	18%	<0.001	24	1.7	1.1	0.6	0.06
Cereal bar	33	28	26	31	16%	<0.001	20	1.7	0.6	0.2	0.02
Cookies & flapjack	47	40	37	44	16%	<0.001	33	2.1	1.6	0.8	0.04
Short biscuits	26	24	20	28	9%	0.4	10	0.5	0.5	0.3	0.01
Savoury biscuits flavoured	23	23	21	24	0%	0.6	0	0.0	0.0	0.0	0.00
Chocolate											
TOTAL	**40**	**32**	**31**	**33**	**26%**	**<0.001**	**41**	**4.0**	**2.3**	**1.3**	**0.02**
Coated nuts/fruit	84	42	36	47	101%	<0.001	205	19.0	10.8	4.9	0.13
Chocolate with additions	45	27	25	30	66%	<0.001	97	8.3	5.9	3.2	0.03
Mars type bar	48	37	35	39	28%	<0.001	53	5.6	2.5	1.3	0.06
Honeycomb/crunch	35	31	28	33	15%	<0.001	21	2.1	1.1	0.7	0.01
Crème filled	38	30	27	34	26%	<0.001	40	4.3	2.1	1.2	0.02
Milk chocolate	35	32	30	34	10%	0.008	16	1.6	0.9	0.6	0.01
Caramel	34	32	29	35	6%	0.3	10	1.1	0.5	0.3	0.01
Truffles	26	24	21	27	9%	0.2	11	0.9	0.7	0.4	0.00
Sugar coated	39	34	30	38	15%	0.01	25	3.1	1.2	0.7	0.01
Wafer bar	31	31	28	33	0%	0.7	0	0.0	0.0	0.0	0.00
Dark chocolate	32	30	27	33	6%	0.2	11	0.7	0.8	0.5	0.00
White chocolate	31	33	29	38	-7%	0.3	-11	-1.1	-0.6	-0.4	-0.01
Crisps											
TOTAL	**45**	**31**	**30**	**32**	**44%**	**<0.001**	**69**	**0.9**	**3.8**	**0.6**	**0.20**
Popcorn	86	34	31	38	151%	<0.001	240	11.0	10.2	2.5	0.48
Nuts	77	38	36	39	105%	<0.001	238	3.0	19.1	3.0	0.19

Potato crisps crinkle	39	30	29	32	28%	<0.001	45	0.2	2.6	0.3	0.14
Tortilla chips	46	34	31	36	37%	<0.001	59	0.3	2.9	0.3	0.14
Potato snack shapes & puffed	26	24	23	25	8%	<0.001	10	0.1	0.5	0.1	0.04
Potato and veg crisps std	31	29	28	30	6%	<0.001	10	0.1	0.5	0.1	0.03
High fat bar snacks	27	31	28	34	-12%	0.01	-19	-0.1	-0.9	-0.3	-0.09
Corn and maize snacks	25	26	24	27	-2%	0.3	-5	0.0	-0.2	-0.1	-0.02

* Consumed portion size data was derived from the NDNS 2008-2014 dataset and the on-pack serving size from the commercial UK database (2013) as described in the methods section.

** This was calculated using back-of-pack per 100g nutrition information from the commercial database and finding the average per serve value from all products for each nutrient, using first the on-pack serving size and then the consumed portion size from the NDNS. The difference in the nutritional content between the consumed and the on-pack nutrition per serve was calculated by subtracting one from the other.

9.5 Discussion

In all four energy-dense main food groups over 90% of products had pack-size information, but in the Chocolate group only 35% products had available on-pack serving-size, rising to 79% for the Crisps category. This illustrates that lack of on-pack serving-size guidance is a widespread issue, particularly in some energy-dense snack foods. Unlike the requirement to state pack-size, providing serving-size information is not currently legally required in the UK (30) and without an on-pack serving-size consumers may substitute pack-size as a unit of consumption, resulting in over-consumption and excess energy intake. Additionally, this ‘unit bias’ could result in individuals underestimating their consumed portion size, where they recognise that the whole unit is larger than an appropriate portion, but still eat the whole unit (21). This is particularly relevant in snack foods, which are the focus of this analysis. Similarly, the nutrition information per serve as displayed on the front-of-pack labelling scheme currently recommended in the UK (31) would be based on a lower quantity than consumers are eating, leading to a misleading perception of macronutrient intakes.

Evidence suggests that increasing on-pack single-serves of commercially available foods may normalise larger on-pack serving-sizes, leading to overconsumption and larger consumed portion sizes in home-prepared meals (4). Consumed portion size was higher than on-pack serving-size in all four main food groups and the majority of subgroups (figure 1). This discrepancy could partly be explained by differences in the products included in the commercial database used to derive on-pack serving-sizes and those included as consumed in the NDNS survey. Yet consumers of these foods could be eating more than the on-pack serving-size, and perhaps consuming multiple single-serve packs in one eating occasion, demonstrating the need for policies and interventions aimed at setting product pack and serving-sizes that help individuals consume smaller portions. In the case of foods in discrete packs, such as single-serve chocolate bars, size reduction may be more effective than requiring consumers to judge appropriate consumed portion sizes. One means of achieving this could be government recommendations for standardised rather than industry-led pack sizes and on-pack serving-sizes, though this is not yet evident in recent discussions on sugar and calorie reduction (14, 32).

However, further consideration is needed on how consumers understand on-pack serving-size messaging and the interplay between this and front-of-pack labelling and overall pack size. In America, Zhang, Kantor & Juan (33) found that the different terminologies used in relation to on-pack serving sizes set by manufacturers and both government recommended and typical consumed portion sizes confused consumers. Similarly, Dallas, Liu & Ubel (34) found that the majority of their American study population incorrectly believed that on-pack serving size information referred to amount that should be consumed for a healthy diet, rather than the amount typically consumed by the average consumer. In addition, consumers exposed to labels with larger on-pack serving sizes ate more than those given the same product with smaller on-pack serving sizes. If on-pack serving sizes were increased to better reflect consumed portion sizes, individuals may increase consumption further, believing this to be in line with official dietary guidance. However, increased on-pack serving sizes that better reflect typical consumed portion sizes may enable consumers to more accurately estimate their energy intake. A recent review (35) found that consumer education to improve label understanding could potentially increase the effect of such information on dietary health. There is a fine balance to be struck in creating realistic, consistent serving-size guidance without encouraging consumers to eat larger portions or multiple units, particularly as consumers may not be using on-pack serving-sizes to guide their intake. Another recent review (20) concluded that there was insufficient evidence to determine the effect of on-pack serving size labels on consumed portion size. Further work is needed to consider sales volume in addition to eating occasion and intake, in order to fully understand whether smaller pack and serving-sizes lead to lower total consumption and energy/nutrient intake.

The greatest difference between consumed portion size and on-pack serving-size was in Crisps and within this ‘popcorn’, where consumed portion size was respectively 44% and 151% larger than on-pack serving-size. Both the consumed portion size and on-pack serving-size for popcorn are greater than the 25g 1993 government standard portion size. Consumers may have less ability to estimate appropriate consumed portion sizes in these foods, which are often sold in larger packs with no visual or practical serving-size indicator beyond a printed number on the pack. The potential for overconsumption is therefore high – the difference between the on-pack serving-size and consumed portion size for ‘popcorn’ equates to an extra 12% of an adult’s daily recommended energy intake (36, 37) per eating occasion.

Within each food group there was a wide on-pack serving-size range, particularly in Biscuits. This fits with the literature; Lewis et al. (38) found that UK serving-sizes were highly variable, which could cause consumer confusion. This degree of variability could be caused by the myriad definitions and measurement methods of portion size used in industry, non-Governmental organisations (NGOs) and health bodies (21). Industry-based serving-sizes were larger than those set by NGOs and healthcare professionals for biscuits, crisps and chocolate (38). Considering consumed portion size was generally higher than on-pack serving-size in these analyses, consumers may be over-eating to an even greater degree than initially thought. Updated guidelines are required, but should be realistic and formulated with sensitivity in order to avoid encouraging consumers to further increase consumed portion size.

Official UK portion size advice has not changed since 1993, and in the following 20 years, single-serve pack sizes for many types of cakes, biscuits, chocolate and crisps increased (15, 18). For example, an average American-style muffin was 85 g in the 1993 guidance and 72-130 g in 2013 (15). Our analyses grouped muffins and cupcakes, but when looking solely at muffins in a sensitivity analysis our findings were similar, at a 74 g average serving-size and 12-150 g range, suggesting that the upper serving-size limit has increased.

On-pack serving-size change has occurred at different rates and varies between manufacturers, leaving a lack of understanding of appropriate serving-size and consistent elevation of consumed portion size (15). However, the trend is not linear; recently there has been increasing spotlight on shrinking pack-size, particularly in chocolate confectionary (39). This could be a function of the PHRD calorie reduction pledge (13), or recent sugar reduction and wider industry reformulation discussions between industry and government, which have included on-pack serving-size reduction as a means of calorie reduction and 'calorie capping' (15, 32). This may have resulted in pack and serving-size reductions since the data used in these analyses was collected. However, this does not necessarily equate to reduced intakes; smaller units are often sold as multipacks and larger 'sharer packs' of some crisp products have become more common (19). Both could result in over-consumption; one industry report found that 40% of those aged <25y eat a whole 150 g 'sharing bag' of crisps (40); this 150 g pack size is 50% larger than the 1993 guidance (15, 18) and matches the mean pack-size in the present analyses. Additionally, people may consume multiple units from a multipack if a single unit is perceived to be too small.

In their study of six European countries, Hieke et al. (8) found evidence of a 'pack-size effect' where larger packs resulted in larger consumed portion size estimates. Although effect sizes were small, over time this could result in substantial increases in energy intakes, particularly given the extensive gaps in on-pack serving-size information for some food groups in these analyses.

Herman et al. (41) report that evidence to link excess energy intake to the obesity epidemic via elevated portion size is lacking, stating that other factors like eating frequency may be more significant. They claim most small experimental studies show that large consumed portion sizes increase energy intake by testing this in only one meal; larger studies of average intakes are also cross-sectional, which is insufficient to position portion size as a causal factor for obesity. However, Kelly et al.'s (42) small experimental study provides evidence for associations over a 4-day period, where adult food consumption and energy intake was significantly higher (14%), with little evidence of compensation, when consuming a larger portion of pre-packed foods. Rolls et al. (9) also found that energy intake increased, with no compensation, when larger portions of pre-meal snacks were consumed. This suggests that large on-pack serving-sizes in commercially available, particularly snack, foods potentially act as an environmental influence leading to increased energy intake and therefore weight gain.

9.5.1 Strengths and Limitations

This is an innovative analysis that links consumed portion size and on-pack serving-size. It uses detailed consumed portion sizes of energy dense foods for UK adults aged 19-64y and an extensive set of commercially available on-pack serving-sizes from six major UK food retailers, which are sufficiently representative to justify the conclusions made. We did not have access to data from small convenience stores or snack bars, so cannot guarantee that our analyses are representative of this sector. However, the commercial database used included manufacturer data for products that could potentially be stocked in outlets not included in the analysis. The categorisation of foods by product type for the consumed portion size and the on-pack serving-size of similar products as purchased is aligned as far as possible. It provides a more meaningful assessment of consumed portion size patterns than previous studies, which tend to use broader food groups, where the diversity of foods in each group is higher and therefore comparability is lower (16, 17, 43), or compare incompatible food groups from previous survey iterations, where the foods within these groups do not correspond across surveys (12).

According to WHO, regulatory policy is needed to reduce commercial serving-sizes in the food environment (4). Based on a systematic review (44) that included assessing interventions on on-pack serving-size and pack size, Marteau et al. (45) argue that policy does not adequately reflect the importance of consumed portion size in obesity and that effective interventions could reduce demand and supply of large pack and serving-sizes, potentially reducing energy intake in UK adults by 12-16% (45). Similar information from other European countries could be used to help build policy and updated portion size guidance in the UK and across Europe (4). However, this depends on comprehensive, accessible databases and retailer websites in other European countries. The data used is also cross-sectional, providing a snapshot in time, whereas commercially available products change regularly, leaving on-pack serving-size data outdated.

Another limitation is that this study covers a limited range of energy-dense foods; future work should consider other energy-dense food and drinks such as fast food, breakfast cereals, ice cream, sugar-sweetened beverages or alcohol. In addition, the consumed analyses were restricted to adults aged 19-64y to prevent distortion of results from children or the elderly, who may consume smaller portions. However, this was not possible for the on-pack analyses, where the majority of serving-sizes target all consumers.

Under-reporting presents a limitation in using NDS to assess consumed portion size. Doubly-labelled water (DLW) feasibility studies suggest energy intake in the NDNS 2008-2012 was under-reported by over 30% (46, 47). Evidence also suggests that under-reporting is higher for energy-dense foods (48-50), so the impact on these analyses may be greater than if other food groups had been selected. Therefore, updated guidance may be more robust if based on plausible reporters only, as used in these analyses. Additionally, as food photographs were provided to aid consumed portion size estimation in the NDNS, the risk of large portions being underestimated is reduced. This minimises the likelihood of the exclusion of under-reporters resulting in bias if they tended to consume and underestimate larger portions. There is also evidence that snack foods are associated with lower levels of under-reporting, and that under-reporters of energy intake are more likely omit reporting a food than report a smaller consumed portion size (50).

The accuracy with which under-reporters could be identified was limited by the use of a 1.55 PAL across all individuals in these analyses rather than being estimated per individual, as data was not available to do this. However, 1.55 is an accepted value for a sedentary lifestyle in the populations used (28, 29, 50) and makes analysis of a large number of individuals more feasible. In addition, Rennie et al. (51) found no significant difference in under-reporter identification when using individual PAL compared to a set cut-off. Yet the European Food Safety Authority (EFSA) continue to recommend including under-reporters to minimise selection bias (52), so there is likely to be continued discrepancies on the treatment of under-reporters.

9.6 Conclusion

This paper compares commercially available on-pack serving-sizes in commonly consumed energy, fat and sugar-dense snack foods with corresponding consumed portion sizes, by characteristic-based product categories. It explores patterns, highlights areas of difference and discusses the need to update on-pack serving-size or alter pack-size. Most products had pack-size information, but far fewer had on-pack serving-size, particularly Chocolate products. Consumed portion sizes were higher than on-pack serving-size in all four main food groups and the majority of subgroups. The greatest difference between consumed portion size and on-pack serving-size was in Crisps, and within this, ‘popcorn’. Future work could model scenarios based on the relationship between consumed portion size and on-pack serving-size, both nationally and in other European countries, and also in non-discrete foods.

Author Contributions

All authors have contributed to the concept and design of the research and to the writing and/or revision of the manuscript, and have approved the manuscript for submission.

Declaration of Interest

The authors declare no conflict of interest. The co-authors Joao Breda and Jo Jewell are staff members of the World Health Organization Regional Office for Europe; however, the authors are responsible for the views expressed in this publication and they do not necessarily represent the decisions or stated policy of WHO.

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Chapter 10 Overall Discussion and Conclusions

This chapter explores in greater detail the project's main research areas, and considers its impact. It discusses key points from each of the publication-based chapters, in the context of the themes presented in this work. Areas discussed include national dietary survey provision and their use in policy; national dietary survey characteristics, focusing on heterogeneity, nutrients reported and nutrient composition databases; under-reporting; and the role and uses of national dietary surveys when investigating both portion sizes and TFAs. Strengths and weaknesses of the research are also discussed, and potential future directions and relevance of the research are considered.

10.1 National dietary survey provision and use in policy

10.1.1 National dietary survey provision

This research found that less than two thirds of WHO European Member States had conducted nationally representative dietary surveys since 1990, and only 22 countries reported nutrient intake data since the year 2000 (1). This results in a lack of evidence on which to base nutrition policies, particularly in Central & Eastern Europe, where survey gaps for both adults and children predominate.

Work that has been done on nutrient intakes in these areas focuses on a narrow range of micronutrients, but this limited evidence suggests that Central & Eastern European countries are in need of dietary improvement policies, which should be based on robust monitoring of population nutrient intakes. Novakovic et al. (2) found that across all ages, but particularly in children, Central & Eastern European countries lacked comprehensive intake data in comparison to other areas of Europe. They found that adults in this region had poorer calcium intakes and that children had lower iodine, calcium, folate and vitamin D intakes; however, the authors included non-nationally representative and single-nutrient studies. Our research focused on nationally representative surveys of whole diets and found that age generally influenced child and adolescent nutrient intake patterns more than European region. However, in adults Central & Eastern European countries had lower iodine, iron and vitamin D RNI attainment, particularly in women, although low calcium intakes were evident across Europe (3, 4). This illustrates the need for national dietary surveys across the region, as the nutritional inadequacies reported in some Central & Eastern European countries could also be present in other neighbouring countries.

10.1.2 National dietary surveys and policy

Population health and dietary improvement can be seen where monitoring of nutrient intakes via national dietary surveys informs policy development. An example of this is in Hungary, where the 2011 Public Health Product Tax was introduced in response to adverse population intakes of certain nutrients, including sodium (5). Conducting further national dietary surveys would allow evaluation of the policy's population health benefits on a nutrient intake basis. Evidence from the UK and Finland also demonstrates that a rigorous salt-reduction programme can reduce population intakes, with UK salt intakes decreasing by 10-15% since measures were first implemented in 2003-2004 (5).

TFAs constitute another area where policy action stemming from high reported population intakes has resulted in positive health outcomes. The classic example is that of Denmark, which in 2004 became the first country globally to introduce a legislative maximum of 2g TFA/100g fat in certain foods. This all but eradicated artificial TFAs from the food supply and led to a reduction in deaths from CVD by 14.2 deaths per 100,000 per year in the three years after the policy was implemented (6). In addition, after Austria introduced a legislative ban in 2009 no artificial TFAs were present in food products in 2011 or 2013 (7). Our research also found that voluntary TFA-reduction policies implemented in the Netherlands and the UK contributed to the low intake levels, both below the WHO RNI, in their respective populations (8).

However, like national dietary survey provision, TFA-reduction has not been consistent throughout Europe; although 77% of products in the EU have TFA levels below 0.5g/100g fat, some high-TFA products remain in Europe, particularly in Sweden, Croatia, Poland, Bulgaria, Slovenia, Serbia, Montenegro, Macedonia, Yugoslavia and Bosnia-Herzegovina (7). It is telling that all but one of these countries are Central & Eastern European, again demonstrating the need for national dietary surveys in these countries to provide evidence on which TFA-reduction policies can be based. TFA reduction policies are likely to have more impact in this region than elsewhere in Europe, as TFA consumption and CVD rates are higher (6).

Additionally, the Central & Eastern region had fewest countries reporting TFA intakes in national dietary surveys (3). If nutrient intake information via national dietary surveys was more widely available, researchers and policymakers would be better able to assess regional trends across Europe and implement mutually beneficial measures across the WHO European Region.

10.2 National dietary survey characteristics

10.2.1 Heterogeneity in national dietary surveys

National dietary surveys were found to have different characteristics, such as sample size and age group, year of data collection, and dietary assessment methodology (see table 2, Chapter 3 and Appendix 1, Chapter 6). This hinders inter-country comparisons and inhibits the ability to determine patterns between countries, explore wider causes of nutritional issues, develop common policies and learn from measures taken in other countries. The heterogeneity observed across the national dietary surveys included in this project meant that a meta-analysis to calculate European average nutrient intakes from the raw survey data obtained was not feasible. This prevented the comparison of national intakes to a European average, which could have enabled useful insights into shared learnings and policy direction.

There is a need to encourage and facilitate national dietary survey harmonisation, particularly in the age groups sampled, dietary assessment methodology employed, range of nutrients covered and the underpinning food composition database. Efforts to pursue this have primarily been led by EFSA, but are largely limited to EU, mainly Western European, countries, focus more on risk assessment for toxicology, and are not fully adopted. It will be interesting to see the outcome of the EU Menu work in 2020 (9) and to assess whether any best practice principles can be translated across non-EU countries in Europe. However, the detailed EFSA recommendations on how to conduct nationally representative dietary surveys contradict European Food Consumption Validation (EFCOVAL) project guidelines, which are aimed at defining a harmonised European national dietary survey methodology for children aged 4-14y (10). Whilst EFSA states that information on children should be collected by food diary, EFCOVAL recommends the multiple 24hr recall method. This demonstrates a lack of unity even in stakeholders working towards the same aim, making the prospect of a harmonised dietary assessment methodology in national dietary surveys across Europe seem less likely.

Usual intake assessment constitutes another aspect of dietary assessment methodology providing a source of heterogeneity. The latest EFSA recommendations state that in addition to the 2-day non-consecutive collection of food consumption information via 24hr recall (adults) or food diary (children), a food propensity questionnaire (FPQ) should also be conducted to enable the estimation of usual intakes (9). The FPQ should include broad food supplement types and a short list of age-appropriate foods, including those consumed episodically; this information should then be used as a covariate to model the estimation of usual intake distribution in a population (9, 11). The Global Burden of Disease group used usual intake corrections on their dietary data (12); however, this thesis used nutrient intake values as reported to better show the disparities and limitations of the national dietary surveys available. Additionally, not all countries that conduct national dietary surveys assess usual intakes, and those that do may use different methods, creating further disparities and preventing inter-country comparisons. For example, Belgium, the Netherlands and Spain use the Statistical Programme to Assess Dietary Exposure (SPADE); the Irish pre-school survey (13) uses the National Cancer Institute method and Greece and Iceland state that FPQs are used to assess usual intakes, but do not specify by what method (1, 14).

Whilst EFSA recommend that information on food supplements should be collected in both the 2-day 24hr recall (adults) or food diary (children) and supporting FPQ (9), not all countries providing nutrient intakes included information on supplement use. For this reason, where surveys provided intakes both with and without supplements, this research used intakes excluding supplements. As mentioned in Chapter 5, where countries did not specify whether or not intakes included supplements, it was assumed that they did not. This eliminates another potential source of variation in national dietary surveys, making intake comparisons more valid. However, this may also underestimate true intakes of certain micronutrients where supplements are taken, therefore exaggerating the likelihood or burden of deficiencies. In addition, adolescents may have more trouble reporting supplement use (9), which may increase inaccuracies in reported micronutrient intake in this group. However, it was deemed preferable to follow a standardised approach and exclude supplements for all countries, rather than to include for those countries that reported intakes with supplementation.

10.2.2 Nutrients reported in national dietary surveys

This research found that the range of nutrients reported in national dietary surveys varied across WHO European Member States (1). When the type of nutrient intakes reported is inconsistent, it is harder to assess nutrient coverage and make inter-country comparisons, both regionally and across Europe as a whole. Population subgroups, particularly minorities and the disadvantaged, may experience nutrition-related issues without the monitoring infrastructure in place to identify and address them.

In addition to Central & Eastern European countries having the worst overall national dietary survey provision, these countries were least well represented in relation to measurement of sugars, which were amongst the most poorly reported macronutrients in adults, and a WHO nutrient of concern (3, 15). Although there were no such regional patterns in children and adolescents, reporting gaps were evident in nutrients of concern, including TFAs, omega fats, added sugars and iodine (4). This suggests that NCDs related to overnutrition and conditions linked with lack of iodine and omega fats, including reduced cognitive function (16) and raised CHD risk in adulthood (17), could continue unabated.

One explanation for the reporting gap in sugars, particularly added sugars, is the lack of clarity in how it should be reported. As the national dietary surveys available spanned multiple years, definitions of sugars that do not include those found within the cell wall or in milk have varied over time as well as national borders. Some countries use added sugars, some use the more recent 'free' sugars definition (18), whilst others use monosaccharides plus disaccharides. Many report only total sugars, which means inter-country comparisons of this nutrient of concern are less reliable or comprehensive.

Although this was reported by the majority of countries providing nutrient intakes, there are also difficulties in reporting sodium intakes, depending on the assessment methodology used. Some countries providing sodium intakes used 24hr urinary analysis, such as the UK, whereas others, like Bulgaria, relied on dietary intakes. Sodium intakes measured by dietary assessment are subject to error, bias and under-reporting, whereas urinary assessment minimises these limitations (19, 20). Sodium reduction to reduce the burden of NCDs is therefore partly limited by the lack of reliable and comparable data on sodium intakes (21). However, like this thesis, the GBD group use both dietary and urinary analyses to provide intakes (21), as this is preferable to no data at all.

In those countries that conducted national dietary surveys and reported nutrient intakes, attainment of WHO RNIs was poor, either through over or under-consumption depending on the nutrient in question, across the lifecourse and across the WHO European Region. This suggests that there are a wide range of potentially vulnerable individuals in addition to those groups whose poor intake levels may be hidden by lack of data, such as minority ethnic groups or those on lower incomes. The findings in Chapter 6 support this, showing that lower education groups had significantly lower intakes of specific nutrients, particularly micronutrients, and that higher education had a mitigating effect on poorer diet in lower income countries. It is concerning that the worst intakes were seen in the region with the most extensive gaps in reported intakes – this reinforces concerns that nutrition-related health issues could go unidentified and unaddressed in large sections of the European population.

Widespread overconsumption of carbohydrates, fats and sodium indicates unhealthy dietary patterns in the studied populations. To address this, increasing complex carbohydrate and fibre consumption and limiting sodium, total fat and saturated fat intakes should be a priority. Policy action is required to help build a healthier food environment to help facilitate this. The findings in this thesis support the identification by WHO of iron, iodine and vitamin D as micronutrients of concern, and also found evidence of potassium, calcium and total folate inadequacy (3). Chapter 6 also demonstrates a socioeconomic aspect to these suboptimal intakes, particularly as those with lower education in countries with lower GDP lacked the mitigating effect provided by higher education levels. Total folate was the nutrient most consistently associated with socioeconomic status, where both individuals with less education and countries with lower GDP had lower intakes. Total folate intakes are of particular concern in women of reproductive age, as inadequate intakes can increase the risk of neural tube defects in babies (18). The association between intakes and educational status is concerning, as a lack of knowledge of the health consequences of deficiency may perpetuate poor dietary intake and therefore health disparities.

As with adults, WHO RNI attainment in children and adolescents was low, again either through over or under-consumption depending on the nutrient in question; most countries that reported nutrient intakes met less than half of the RNIs for the age groups included in the surveys. Like adults, macronutrient attainment was universally poor, and micronutrient RNI attainment was especially low in girls and older children. Total and saturated fat, sodium, iron, total folate and vitamin D were the nutrients of greatest concern (4). This is worrying, as it appears from the results of this project that nutrient intakes worsen as children get older, fuelling nutrition-related problems and deficiencies that may remain as they find their independence and potentially establish unhealthy dietary habits that are likely to persist into adulthood (23). This is supported by the likelihood of overweight and obese children being overweight and obese in adulthood, and has worrying implications for population health and the wider burden on health and other social systems (24). In addition, micronutrient deficiency at a crucial life stage of development could have significant health consequences. Adolescent girls are at greater risk of iron-deficiency anaemia, and low iron intake is associated with reduced intellectual, immune and metabolic function (25). Low vitamin D levels are linked with the recent increased prevalence of rickets in Europe (26) and means that more children are at risk of impaired bone, muscle and immune function (27). Given that socioeconomic inequalities have been identified in relation to low adult micronutrient intakes (see Chapter 6), it is a real possibility that these disparities begin in childhood, highlighting children of lower socioeconomic status as a vulnerable group in need of targeted dietary improvement policies.

However, very few countries reported nutrient intakes by socioeconomic group at any life stage, and those that did reported using different indicators (3, 4). Consequently, disadvantaged groups across Europe may be at risk of nutritional deficiencies or disorders that may go unidentified and overlooked by policy on a national level, and therefore untreated on an individual level. Even where intakes can be determined, use of different indicators means comparisons are less feasible or valid, and commonalities between affected groups, problem nutrients and degree of severity cannot be determined. Analysing raw national dietary survey data to assess nutrient intakes by socioeconomic status allowed the use of education as a common proxy, which revealed inequalities on an individual and national level. These inequalities highlighted a lower dietary quality in individuals of lower education and in lower GDP countries, where micronutrient intake was lower and energy and macronutrient intake higher (see Chapter 6). This illustrates the need to implement robust and uniform monitoring tools that generate comparable and accessible data by means of a consistent national dietary survey programme.

10.2.3 Technology in national dietary surveys

An interesting observation from this review of national dietary surveys across the WHO European region is that two of the (Central & Eastern European) countries that provided raw nutrient intake data for analysis – Kazakhstan and Macedonia – did not produce or publish summary reports (1). One potential explanation for this discrepancy is a lack of resource, either in terms of finance or expertise, creating an obstacle to countries both producing and disseminating national dietary surveys. If this scenario were accurate, a potential solution could be the development of new technologies in dietary assessment, such as the web-based methods discussed in Chapter 2. By saving money and time in the establishment and implementation of surveys, countries may realistically retain sufficient budget to then undertake a complete analysis and full dissemination of the data obtained. These benefits come in addition to the ability to expand data collection to larger numbers over wider geographical areas on multiple days over different time periods, with lower measurement error and researcher burden (28).

10.2.4 Food composition databases

One of the most pressing obstacles in the harmonisation of national dietary surveys is that of the national food composition databases underpinning the nutrient intake values derived from food consumption data. Many countries lack local food composition tables, so use those of other countries, whose foods, particularly composite recipes, may have different nutrient values (29). This research found that food composition databases across Europe were inconsistent (1); some databases are more up to date than others, which could exacerbate differences and potential error in food energy and nutrient content, and consequently reported mean population intakes. Nutrient values may be derived from different analytical methods and the composite samples generating these values may vary in breadth. In addition, some databases may not account for fortification or product reformulation, particularly in certain nutrients like TFAs, making them less valid in representing population intakes (3, 4). The way energy and nutrients are calculated from food and the accuracy of food composition databases therefore needs to be updated.

Whilst attempts have clearly been initiated to address this major barrier to national dietary survey harmonisation, a comprehensive, compatible food composition database covering all areas of Europe has not yet been created. It would be beneficial for the various stakeholders to coordinate and pool their resources to achieve this common goal. It should also be remembered that whilst this is a major issue, it is not the sole barrier. Other differences in national dietary surveys, such as different age groups and dietary assessment methodologies also require harmonisation to achieve truly comparable data.

10.3 Under-reporting

10.3.1 Variation in under-reporting

In addition to the lack of harmonisation between countries, one of the biggest limitations of nutrient intake data gathered from national dietary surveys is that of under-reporting, which in itself varies across Europe. Chapters 4 & 5 show that there is no consensus on the treatment of under-reporters in national dietary surveys; Austria, Belgium, France and Norway explicitly excluded under-reporters; Cyprus, Denmark, Ireland, Italy, the Netherlands, Slovenia and the UK included under-reporters, and other countries did not specify (3, 4). This may artificially elevate certain countries' intakes rather than demonstrating genuine differences. Chapter 8 highlighted the difference in under-reporting levels between two countries – under-reporting in the French national dietary survey was 23% compared to 35% in the UK (30).

The reasons for under-reporting may differ between countries, as food culture and geography influence dietary habits (31). Under-reporting also varies depending on methodological and study population differences. For instance, the UK survey has a greater proportion of overweight and obese individuals, which is associated with greater under-reporting (32) than in the French survey, which may explain much of the difference between their levels of under-reporting.

In their dietary assessment guidelines, EFSA state that under-reporting levels are similar in 24hr recall and food diary methods (9). However, Rothausen (33) found that the proportion of acceptable, under and over-reporters differed significantly over dietary assessment method, with 24hr recall performing better at ranking individuals by energy expenditure. This has implications for the accuracy of national dietary surveys, as the different methodologies employed may impact on the level of under-reporting and consequently nutrient intake levels.

The lack of consensus on how to deal with under-reporting also contributes to the failure of national dietary surveys, a potentially rich data source, to provide meaningful, comparable information on associations between portion size and

BMI. This could partly explain why this research found few associations between portion size and BMI in France or the UK (30). More reliable information would be valuable in informing policy to address obesity, which is one of the biggest health problems currently facing the WHO European Region (34).

National dietary survey data shows a decrease in energy intake despite a rise in obesity; this suggests that either physical activity has further decreased, or under-reporting has increased (35). Under-reporting of energy intake is therefore an important factor that must be acknowledged in dietary assessment, as it is a common source of bias and can distort the relationship between dietary habits and health risks (31). Especially pertinent to this project is the risk of nutrient deficiencies being artificially magnified by under-reporting. In their review of under-reporting in (non-national) nutrient intake studies, Poslusna et al. (36) found mean under-reporting levels of 30%, with a 30% lower micronutrient intake in low-energy reporters. Under-reporting can also mask associations between portion size or consumption frequency and BMI (37), potentially contributing to the inconsistent evidence for associations between consumption frequency and adiposity (38).

Although the analyses in this project (see Chapter 8) found very few associations between portion size or consumption frequency and BMI regardless of how under-reporters were treated, Poslusna et al. (36) observed a positive association between BMI and under-reporting. They also found that under-reporting was higher in women and the elderly, but caution that men may under-report to the same level, but have higher energy requirements, so fewer males are identified as under-reporters. In this research, Chapter 4 showed that WHO RNI macronutrient attainment was poorer in adult women and the elderly (3); however, using this logic it could be possible that part of this finding is influenced by under-reporting.

10.3.2 Calculating under-reporting

EFSA recommend the identification of under-reporters using either the Oxford or Schofield equations to calculate basal metabolic rate (BMR), and then the Goldberg cut-off method to identify under-reporters. This in itself could introduce differences in national dietary survey reported intakes where countries exclude under-reporters, as different methods may be chosen to calculate BMR, thus impacting on the identification of under-reporters and the resulting mean nutrient intakes. However, EFSA advises against their exclusion, as this could introduce bias in estimates of dietary exposure due to unknown numbers of true under-reporters with high activity levels not being identified (9). In addition, those who under-report cannot be distinguished from those who under-eat (40).

The literature varies in its treatment of under-reporters – some include and adjust (31, 38, 41-43), whilst others exclude and/or address under-reporters in a sensitivity analysis (44-46), demonstrating that both these approaches, which are employed in this project, are accepted in the field. Mensink et al. (47) accounted for under-reporters in their review of micronutrient intakes in eight (mainly Western) European countries. However, they based their definition of under-reporting on the Schofield BMR equations, which have since been shown to overestimate BMR (48). For this reason, when excluding under-reporters in this project, the newer Oxford equations (48) were used to calculate BMR.

Another source of variation in the identification of under-reporters and therefore the resulting mean nutrient intakes is the physical activity level (PAL) used in the Goldberg formula to calculate the cut-offs for plausible and under-reporters. This research used a PAL of 1.55 as a sedentary base (reasons for which are discussed in Chapter 8), whereas some studies use different values to indicate a sedentary lifestyle and others use a PAL for each individual in the study population for greater accuracy (33, 40). Using a cut-off based on a single PAL can lead to misclassification in some participants and does not account for bias at the upper end of the energy intake/energy expenditure distributions (49). These analyses used a single population PAL, as it was not feasible to calculate per individual; however, this is a common practice in the literature (31, 50) and Rennie et al. (40) found no significant difference in sensitivity and specificity between the individual or population PAL methods of measuring under-reporting.

10.3.3 Under-reporting in children and adolescents

There are no cut-offs available specifically to identify child and adolescent under-reporters, which mean either that child under-reporters cannot be identified, or that adapted adult values must be used, which is less accurate and a further source of variation. This presents a limitation, as it has been ascertained that under-reporting in children also exists (9), particularly in older children (51).

Bornhorst et al. (52) used adapted Goldberg cut-offs to identify under-reporters in European children aged 2-9y, who had undertaken parent-completed dietary assessment via a multiple 24hr recall. They found misreporting levels of 8% in the total study group, but wide variations across country, gender and age group. This is lower than levels found in French or UK adults (30) or evident in the literature for adolescents. Lioret et al. (50) found that 4.9% of children aged 3-10y and 26% of adolescents aged 11-17y identified as under-reporters in the French INCA 2 survey and Lyons et al. (53) identified 32% children and 64% adolescents as under-reporters in the Irish national dietary surveys. In addition to adolescents having less structured food patterns, the difference in under-reporting between children and adolescents may be because under-reporting is more likely when subjects manage their own responses, as adults and adolescents do, whereas younger children have parental help. This may help explain that whilst under-reporting is evident in younger children, it occurs to a lesser degree than in adolescents and adults.

10.3.4 Implications of under-reporting

Under-reporting and resulting data accuracy issues are a growing problem as obesity levels rise across Europe, as the overweight and obese are more likely to under-report (54). In addition, trends for increased snacking and a higher proportion of food eaten outside the home has exacerbated under-reporting, as it is harder for participants to remember and describe a higher number of eating occasions, and foods eaten outside the home may be less likely to be included in food composition databases.

Consumption of certain foods may also be more susceptible to under-reporting due to food composition. In the UK NDNS misreporting of protein has been identified as less prevalent than that of other nutrients because mean protein intake in the UK has changed little over time and it is included in a wide range of core foods within the associated nutrient composition database (39). Consequently, foods consumed that do not include protein, such as cooking oils and fat spreads, soft drinks, confectionary and alcohol, may be more prone to under-reporting. This suggests that mean intakes of certain nutrients may be more subject to error, and that the nutrients in question may vary across different European countries depending on how their databases are compiled, and how comprehensive and up to date they are.

Under-reporting has implications for policy development; Gibney and Sandstrom (55) highlight the impact on food based dietary guidelines through distorted portion sizes and inaccurate consumption frequency estimates. Although portion sizes have increased in pre-packed and home-cooked foods, under-reporting in national dietary surveys remains an issue, particularly in certain foods. Poslusna et al. (36) found that portion sizes were more likely to be estimated incorrectly when large quantities were consumed and in foods high in volume but low in weight, and Ordabayeva & Chandon (56) found that consumers were more likely to underestimate portion size when pack size changed in more than one dimension i.e. widened *and* elongated. However, research shows that portion sizes of ‘healthy’ and ‘less healthy’ foods were the same in under and plausible reporters, suggesting that under-reporters may under-report less healthy foods to a greater degree, or that under-reporting may lie more in the omission of foods (frequency of consumption) than the amount eaten (portion size) (57, 58).

This project helps expose the hidden impact of under-reporting, which varies across Europe and creates an inaccurate portrayal of a country’s nutritional situation, derived from national dietary surveys. This has direct implications for the nutrition policies based on this information, and therefore the ability of governments and health bodies to address the most pressing health problems facing Europe.

10.4 National dietary surveys and TFAs

10.4.1 National dietary surveys and TFA reduction

National dietary surveys can provide a valuable means of assessing nutrition policy impact across WHO European Member States; TFAs present a good example of this. For those countries whose national dietary surveys report TFA intakes, these can be cross-checked against their chosen TFA-reduction strategies, or lack thereof. Further investigation is clearly necessary before any associations can be made, but the information provides a starting point for exploring whether and how well reduction strategies work and whether further action is needed to improve population health.

The WHO RNI for TFAs is <1%E, based on associations between TFAs and CHD risk, and both WHO and EFSA recommend TFA intakes be as low as possible within a nutritionally adequate diet. A ‘core indicator’ of the WHO framework for monitoring NCDs to 2025 is the adoption of national policies to ‘virtually eliminate’ partially hydrogenated oils (PHOs) and replace them with PUFAs, which has been described as one of the simplest public health measures to improve diet and reduce NCD risk (59, 60). This has set the scene for various TFA-reduction strategies being adopted across Europe, including legislative bans, mandatory labelling, voluntary reduction and awareness campaigns. The effectiveness of these policies should be measured not only by national TFA intake levels, but by how well they target all TFA-containing products, regardless of price-point, and the impact on all socio-economic groups. Policies should also consider implementation costs (61). For example, although limited to nine EU countries, an EC report showed evidence that although average TFA intakes met the <1%E WHO limit, levels could be higher for certain population subgroups, such as those on low incomes or younger adults and students (7, 62). The same report found that TFA reduction across Europe has not been consistent and that although most products within the EU have levels below the lowest mandatory limit of 2g/100g fat, some high-TFA products remain.

10.4.2 TFA reduction policies

The primary TFA-reduction policies adopted across Europe are legislative limits, mandatory labelling and voluntary reformulation, with the latter being most commonly employed (64). Voluntary TFA-reduction measures primarily focus on industry reformulation, sometimes with government collaboration, but also include standardised voluntary labelling for low-TFA products and industry-supported public education on the health risks associated with TFAs (61). Voluntary reformulation can be effective, as in the Netherlands and UK (8), but only apply to the companies and products involved. Products outside voluntary agreements may remain high in TFAs and the lack of parity may result in a price differential, widening health inequalities. WHO also suggest that the Netherlands is an atypical example, as the country has a unique history of successfully tackling social problems via such collaboration, which other countries do not share (59). Additionally, with countries pursuing reduction strategies on a national basis, TFA reduction may be unequal across Europe, leaving manufacturers little incentive to voluntarily reformulate if they operate on a European scale (7).

Stender et al. (64) conducted a European market basket investigation of TFA levels in baked goods and concluded that TFAs were present in popular foods across Europe, with certain population subgroups at risk of high TFA exposure. This may also occur to a greater degree than estimated, as the products tested were assumed to be regularly bought and consumed, nationally representative and an indication of unpackaged as well as pre-packed foods. Smaller, local retailers and street-food/takeaways were not studied, so true population TFA intakes may have been underestimated, particularly in certain countries and groups. Consequently, legislative measures were deemed the most effective TFA-reduction strategy and anything less as contradicting WHO recommendations to minimise TFA intake.

The positive impacts of the Danish and Austrian TFA legislation (6, 7) supports the EC view that legislative bans are more egalitarian and could be adopted as a harmonised European approach (7). Other European countries with a legislative ban include Switzerland (2008), Iceland (2011), Hungary and Norway (2014), and Sweden has made partial steps towards a ban. Restrepo & Rieger (6) suggest that a legislative TFA ban would be even more effective in Central & Eastern European countries, where TFA consumption and CVD rates are higher. Those countries with a legislative ban demonstrate the feasibility of removing TFA from the food supply for the whole population, with no apparent negative consequences for consumers. However, there is often political resistance, as in

Denmark, where the EU initially resisted a TFA ban due to fears it would create a trade barrier (59). This could explain why, despite growing public and political support for dietary improvement policies like legislative TFA limits, relatively few countries have successfully implemented them (29).

Mandatory labelling is not possible in the EU, as Regulation (EC) No. 1169/2011 does not include TFAs in the list of permitted nutrients on nutrition labels. The declaration of PHOs on the ingredients list is required, but this does not give exact TFA levels; neither does it distinguish between artificial and ruminant TFAs, so products containing ruminant TFAs, such as meat and dairy goods, may appear less healthy. Labelling artificial TFAs in products could give some products a ‘health halo’, leading to greater consumption and therefore greater TFA intake, even if levels are lower than in other products. It may also create a price differential between products with and without TFAs, potentially widening health inequalities if those on lower incomes cannot afford TFA-free products (7). Mandatory labelling would also apply only to pre-packed foods, leaving unpackaged foods and foods consumed outside the home unregulated. This could be a particular issue in lower and middle income countries where street food is more prominent in food culture and the main source of TFAs (59).

For non-EU countries where it is permissible, mandatory labelling may encourage industry reformulation. However, concurrent consumer education would be required to enable individuals to understand and use the information to make healthier choices and maintain pressure on manufacturers to reformulate (7, 63). For mandatory labelling to be effective, population awareness and understanding of both nutrition labels and the negative health effects of TFAs is necessary. This issue is more pronounced in lower and middle income countries and may dissuade manufacturers from reformulating if consumers are unlikely to avoid higher-TFA products through lack of understanding. More research is therefore needed to determine how such understanding could be used and improved (7).

In their systematic review examining global evidence for the effectiveness of different TFA-reduction policies, Downs et al. (59) found that the policy types discussed above were all associated with TFA-reduction, but that legislative bans had the greatest universal impact, whereas mandatory labelling and voluntary reduction had varying success rates depending on the food category. WHO concur, stating that legislative limits encompass all population groups and that ‘such a policy is unique in its combination of efficacy, cost-effectiveness and low potential for negative impact…one of the most straightforward public health interventions for reducing CVD risk and improving nutritional quality of diets.’ (61). In this research, Chapter 6 also shows that having any reduction strategy may be beneficial in decreasing TFA consumption; although no one TFA-reduction strategy was adopted by those countries with the lowest intakes, the country with the highest intake (Kazakhstan) had no central strategy before 2018 (65).

Martin-Saborido et al. (66) investigated the cost-effectiveness of TFA reduction strategies in Europe compared to a reference situation of no action. They concluded that TFA reduction via both legislative limits and voluntary reduction was cost-effective, but that the former provided the most health benefits at the lowest cost. Mandatory labelling resulted in health benefits in the form of disability adjusted life years (DALYs) avoided, but was not cost-effective. All TFA-reduction policies have monitoring costs, but legislative bans lack the collaboration costs to government and industry present in voluntary reduction, and the lab analysis, public education campaign and label updating costs associated with mandatory labelling.

10.4.3 Monitoring TFA intakes

Monitoring is a key priority in the process towards eliminating TFAs, represented by the ‘Assess’ branch of the WHO REPLACE roadmap (60). Not only can monitoring data from national dietary surveys provide population intakes, they can illustrate the characteristics of higher consumers. This research showed that TFA food sources in the top 10% of Dutch and UK TFA consumers differed, with TFAs largely coming from foods associated with artificial TFAs in the Netherlands, compared to ruminant sources in the UK (8).

However, heterogeneity in intake data obtained from national dietary surveys makes inter-country comparisons and change monitoring in the TFA content of food supplies problematic. Not all WHO European Member States conduct national dietary surveys, or measure TFAs, and for those that do, intakes are based on TFA levels ascribed to foods in nutrient composition databases, which, as previously discussed, may be outdated and/or incomplete. In addition, national dietary surveys typically do not distinguish between industrial and ruminant TFAs, making it hard to accurately measure the artificial TFA intakes targeted by WHO, other than by identifying dietary sources, as Wanders et al. (67) do. Whether or not these TFA forms have similar negative health consequences, ruminant TFAs are consumed at <1%E, so are not a population health risk *if* industrial TFAs are removed from the diet (68).

TFA levels should be monitored in all countries to ensure reduction progress continues, particularly in Central & Eastern European countries, which are less likely to have coordinated TFA-reduction strategies and whose populations may therefore be at greater risk of CVD through excess TFA intake (61). Further research is needed in these areas to identify specific challenges and policy solutions that impact on all population groups. This will improve the use of national dietary surveys in assessing reduction policies in TFAs and also in other nutrients of concern, such as sodium or free sugars.

10.5 National dietary surveys and portion sizes

10.5.1 Disparity between consumed portion size and on-pack serving size

Although data limitations impede inter-country comparisons and potentially compromise associations, national dietary survey information can be used to link consumed portion size with commercial on-pack serving size data, allowing comparisons of what people consume with what they are advised to consume on-pack. This connection is needed for a comprehensive solution to the contribution of portion size to obesity levels in Europe. The majority of dietary improvement policies currently lack wider context, neglecting the broader food system on a structural and stakeholder basis (29), and there is currently a lack of cohesive policy to reduce commercial serving sizes available to consumers (69). Marteau et al. (70) argue that existing policies neglect the importance of the impact of consumed portion sizes on obesity; they call for interventions that target both consumer demand for and market supply of large portion sizes in the food environment.

On-pack serving sizes are currently set by manufacturers rather than being based on government guidelines, which have not been updated in the UK since 1993 (71). On-pack serving sizes have consequently changed at different rates across manufacturers and product varieties, which has led to the wide range of on-pack serving sizes seen in commercially available foods (71, 72). This may create confusion in consumers and lead to inappropriate consumed portion sizes, over-consumption and an exacerbation of obesity-related health problems.

As manufacturer-set serving sizes are not based on a standardised, updated, evidence-based set of guidelines, voluntary measures by manufacturers to limit the availability of larger serving sizes may not have the desired effect of reducing consumed portion size in individuals. Marteau et al. (70) highlight that reductions have been made in chocolate bars (as discussed in Chapter 9), but that these measures have not been evaluated. It is therefore possible that consumed portion size could increase if individuals consume multiple units. Indeed, this project demonstrated that the mean consumed portion size was significantly larger than the on-pack serving size in chocolate bars and other energy-dense food categories (72) (see figure 10.5.1).

Figure 1: Difference in mean consumed portion size (left image) and on-pack serving size (right image) in selected energy dense products

Whilst on-pack serving sizes are not standardised in the UK or across Europe, US Reference Amounts Customarily Consumed (RACCs) have defined American portion sizes since 1993 (73). These RACCs are based on the National Health and Nutrition Examination Survey (NHANES) national dietary survey (74); American on-pack serving sizes are therefore based on typically consumed portion sizes rather than optimum portion sizes for a healthy diet. The US Food and Drug Administration updated these standardised portions in 2014, increasing on-pack serving sizes in approximately 20% of commercially available products to better reflect typical consumed portion sizes, rather than those deemed optimal for a healthy diet (75). This initiative was extended in 2016 with draft proposals to update serving sizes displayed on single-serve products, which would result in an increased on-pack serving size in many such products (74).

On-pack serving sizes that better reflect consumed portion sizes may enable people to more accurately judge their energy intake and therefore plan a healthy diet and avoid over-consumption. Yet Dallas et al. (75) found that consumers erroneously believed that on-pack serving sizes referred to the amount to be consumed for a healthy diet rather than a typically consumed portion size. In addition, when exposed to the new higher on-pack serving sizes, American participants ate 41% more cookies, which suggests that the higher on-pack serving sizes could result in increased consumption in certain food categories. However, this assumes that individuals were not already over-consuming and were adhering to on-pack serving sizes, which in Europe is not the case in certain energy-dense food categories (72). European evidence also suggests that increasing single-serving sizes in commercially available foods may condition individuals to believe that larger portion sizes are normal (76), leading to larger consumed portion sizes of home-prepared meals and therefore overconsumption. Consequently, although outdated government guidelines may no longer reflect currently consumed portion sizes in the UK and Europe, careful consideration is needed before embarking on policy development to update this.

10.5.2 Merits of on-pack serving sizes

Consumers view nutrition labels as a credible source of information, and there is a positive association between label use and diet quality (77). In the EU 60%

consumers rated their use of nutrition labels as high, but just 30% used serving size information, which suggests that consumer confusion or lack of awareness is a potential issue. In an online survey across six EU countries, the inclusion of nutrition information per serve on pack increased the accuracy with which consumers were able to estimate appropriate portion sizes (77) and in their review Bucher et al. (78) found that consumers generally follow on-pack serving sizes. A recent UK review also found that consumer education to improve label understanding could potentially increase the effect of such information on dietary health (79). This is supported by Ollberding et al. (80), who found that American adults who reported using serving size information had lower energy, fat, saturated fat, cholesterol and sugar levels than those who did not. These findings add weight to the case for the standardisation and increased availability of serving size information across Europe, which was found to be lacking in selected energy-dense food categories (72). Further, particularly ecological and focus group research is clearly needed into the effects of on-pack serving size labelling on consumed portion size, incorporating different socio-demographic groups to determine the best policy approach to reduce consumed portion sizes across populations.

10.5.3 Variation in portion size systems

The wide variation in definitions of portion size and the methods used to measure it have contributed to the failure within Europe to establish portion size recommendations that could help provide standardised guidance and prevent consumer confusion over what an appropriate portion size is. In Europe, portion size systems used in industry often differ from those used by government and NGOs in healthy eating recommendations, as the former reflect usual/expected intakes, whilst the latter are ideals. This could confuse consumers and result in over-consumption, as consumers make portion size decisions based on the environmental influences present (51), which are more likely to be those visible than outdated government guidelines.

The British Nutrition Foundation (BNF) recently released adult portion size guidance based on the UK Eatwell Guide, detailing the number of portions from each food group that should be eaten in a day, and also a portion size guide for selected foods within each group (81, 82). However, although this represents a combination of what individuals actually consume (using NDNS and industry data) and previous government guidance, these are not official government recommendations, so adds to the multiple portion size systems facing UK consumers.

Portion size guidance in Europe is often unspecific, inconsistent and not targeted at certain age groups, as with macro and micronutrient recommendations (51). There have been previous attempts to develop EU-wide food-based dietary guidelines, which include the setting of standard portion sizes (55), but this has not yet materialised and is limited to the EU, so excludes many WHO European Member States. A working party report highlighted methodological differences between national dietary surveys as detrimental to pan-EU comparisons and the formulation of food-based dietary guidelines; harmonisation would smooth the process and improve quality (55). However, recent research suggests that portion size standardisation could begin even before such harmonisation. Gibney et al. (57) examined the methodologically heterogeneous Irish National Adult Nutrition Survey (NANS) and EU Food4Me study and found that portion sizes had high agreement, suggesting that despite the differences in European national dietary surveys, a standardised European approach to portion size setting may be a viable policy option. However, survey harmonisation would still be beneficial, as defining food categories across a standardised European portion size system may prove problematic, and nutrient composition databases needed to generate nutrient intakes from the food intake data may differ in their accuracy and completeness.

On a broader scale, not only is the inconsistent availability of information across Europe a potential limiting factor, disparity in the type of commercial portion size information held and how often it is updated could prevent wider European comparisons across the whole diet, including homemade and non-discrete packaged foods. O’Brien et al. (43) examined consumed portion size in a range of commonly consumed foods in the Irish National Adult Nutrition Survey 2008-2010, including non-discrete foods, and found variation in reported portion size trends. Coupled with the heterogeneity previously discussed in national dietary surveys, these sources of variation and potential information gaps mean that associations found between consumed portion size and on-pack serving size should be treated with caution. It also demonstrates the pressing need for extensive, detailed, readily available and frequently updated data with which to inform policy. Only then can the most effective obesity-reduction policies, acknowledging the structural food system and wider stakeholders, be developed on a national and European level with subgroup relevance and population-wide reach.

10.6 Strengths and Limitations

Each of the published chapters includes a separate discussion on strengths and limitations specific to that publication; this section will review the strengths and limitations of the project as a whole.

10.6.1 Strengths

This is a unique project that provides an updated and extended review of the current situation regarding national dietary survey provision across the 53 Member States of the WHO European Region. National dietary survey data provide the platform from which selected WHO priority aspects of population health – nutrient intakes, portion sizes and TFAs – are investigated. This research forms the first review of national dietary survey provision across the whole WHO European Region, multiple lifecourse stages, and with reference to obesity-related NCDs, nutrients of concern and disadvantaged groups.

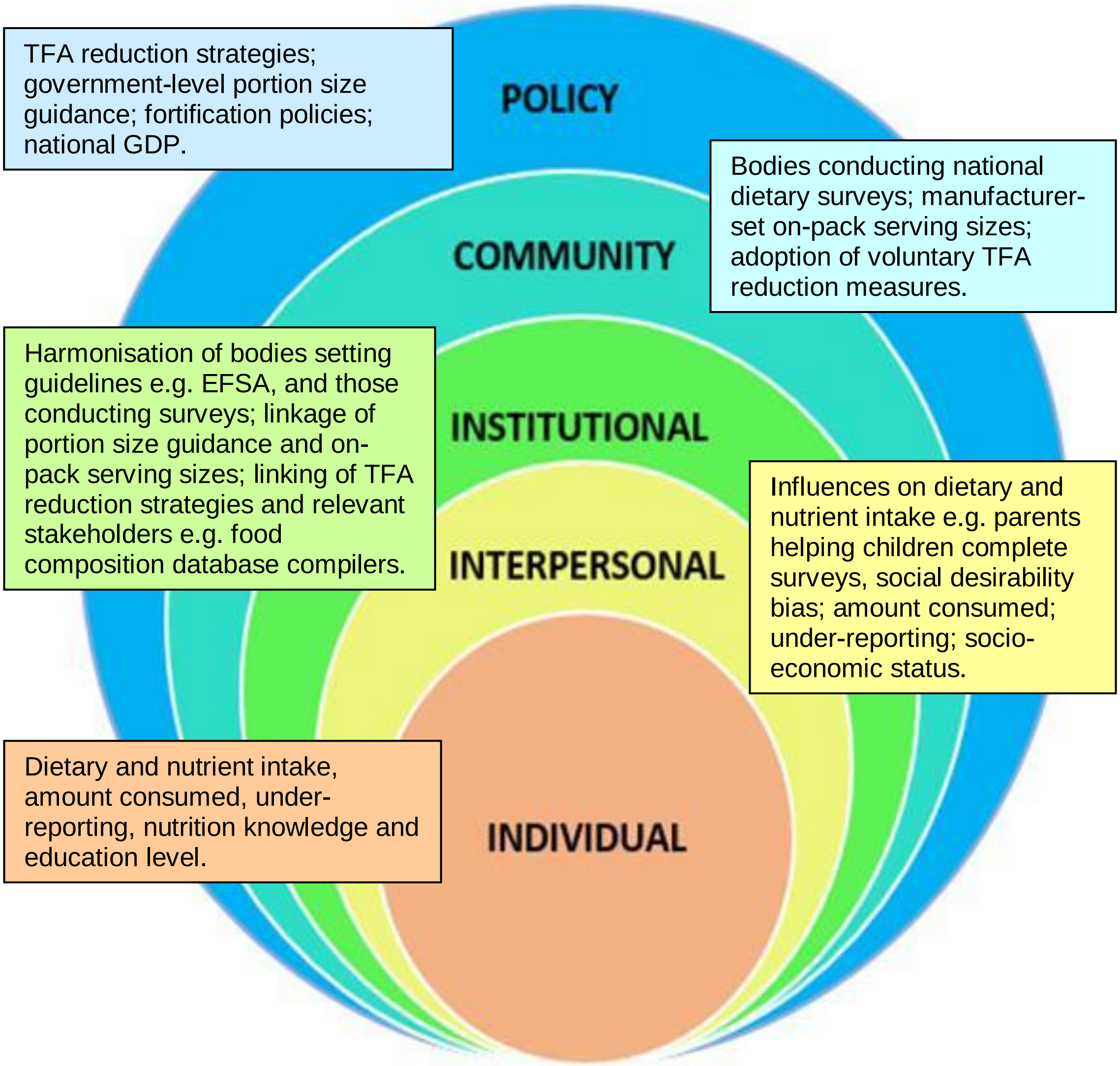
The national dietary survey review included in this work is comprehensive and moves beyond previous reviews of dietary surveys (83), extending beyond the Global Burden of Disease 2010 end-point. This project identifies gaps in national dietary survey provision, which highlights priority areas where efforts to fill these knowledge gaps are needed in order to create an evidence base for nutrition and health policies. It compares both adults and child nutrient intakes to WHO RNIs, which enables policymakers to identify those groups and nutrients that are the greatest areas of need. This vital information includes reference to socioeconomic inequalities, which remain prevalent across Europe. It is considered from a multi-nutrient and diet quality standpoint and also focuses on TFAs as a specific nutrient of concern.

This research also demonstrates the use of national dietary surveys as a means of investigating the food environment. By using national dietary surveys to determine consumed portion sizes, in this project of commonly consumed energy-dense snack foods, associations with BMI have been explored, facilitating investigation into the link between portion size and obesity. Looking beyond the data, my background in retail nutrition was valuable in informing the approach taken in formulating product-based subgroups and the gathering and processing of commercial data. Consumed portion sizes were also compared to on-pack serving sizes, which highlighted the disparity between what UK consumers eat and the amount recommended on pack. This has great potential to inform policy measures to limit excess energy intake, thereby contributing to obesity-reduction efforts.

This project exposes the issues that prevent accurate inter-country comparisons of nutrient intakes and consumed portion sizes. The most pressing of these include the lack of a harmonised monitoring and surveillance system via national dietary survey data collection. This is particularly the case in Central & Eastern European countries, where many countries do not conduct national dietary surveys at all. For those countries that do conduct nationally representative surveys, the issues of under-reporting and inconsistent food composition databases provide additional uncertainty to the nutrient intake and portion size data generated, which further reduces the ability to compare the current situation between countries. This requires attention, as nutrition and health policies designed to prevent NCDs and obesity-related conditions may be based on incomplete or inaccurate evidence. These shortcomings also mean that the disproportionate problems faced by disadvantaged groups, such as potentially elevated TFA intakes, may go unnoticed. By highlighting these issues, this project encourages governments and health bodies to take much-needed steps towards rectifying and preventing them.

The various strands of this research, and the issues arising from it, can also be considered in a socio-ecological model (84). Figure 2 gives a visual representation of how various aspects of this thesis fit into the model, and cross multiple levels of the social system in which national dietary surveys operate.

Figure 2: Socio-ecological framework of thesis



10.6.2 Limitations

A limitation of this project in providing much-needed national evidence of dietary intakes relates to heterogeneity in national dietary survey provision and lack of harmonisation, which places a caveat on the conclusions that can be drawn and the inter-country comparisons that can be made. The raw datasets obtained from 12 Member States did not all contain a full set of nutrient intakes – for example, nearly half of the 12 countries did not measure TFAs. Even where all 12 countries provided intakes and trends were apparent for some nutrients, the simple national level regression analysis in Chapter 6 lacked sufficient power to adequately test for significance or estimate associations with great precision. However, utilising the harmonised and pooled individual-level data improved our ability to detect associations. Given greater time and financial resource than this doctoral project allowed, more countries could potentially be included in future work, expanding the size of the overall dataset and therefore the ability to explore associations and make inter-country comparisons.

Where countries did have common variables, these were not always aligned; for example, income variables were not classified in a uniform manner across datasets. To minimise this limitation, this project used variables with universal classifications, such as BMI, or those that could be harmonised into common categories, like education. However, this did not alleviate the degree of heterogeneity between surveys enough to produce meaningful meta-analyses of nutrient intakes with pooled estimates, to enable comparisons to European mean intakes and shared policy learnings between countries.

In addition to limitations in acquiring comparable, up-to-date national dietary survey data to provide an accurate and robust policy evidence-base, it is also difficult to access commercial serving size data across Europe. Databases often exist, but are not publicly available and can charge high prices for their use, precluding researchers from accessing the information. The resource budget in this project did not allow the purchase of large, private datasets, nor the time that would be needed to manually gather this information from retailer and manufacturer websites. Consequently, analyses of consumed portion sizes and on-pack serving sizes are limited to the UK and cover a selected range of food categories. However, this project does pave the way for work to be extended across other countries and food categories, if funding were present.

Moving beyond lack of alignment in national dietary survey datasets, the way in which foods are analysed to determine nutrient intakes also present a limitation. Crucially for this project, the standard laboratory analysis undertaken by the majority of food composition databases and food manufacturers does not distinguish between ruminant and artificial TFAs, specifically C18:2t, which can take both forms. Consequently, levels of artificial TFAs in products can only be estimated and conclusions regarding differential intakes in different population groups must be treated with caution, as the TFA source may differ. However, as evidence suggests that ruminant and artificial TFAs both have negative health effects (68), it is still a useful and valid exercise to assess intakes derived from nutrient composition tables. In addition, the composite samples used to estimate the nutrient content of foods may not be representative of the foods consumed by disadvantaged groups. Future work to evaluate and ensure the representativeness of composite samples used for nutrient composition tables would be beneficial. Finally, as this project was part-funded by WHO Europe, the parameter for comparing the top 10% TFA consumers with the remaining 90% was fixed, rather than being able to compare equal sized quantiles.

10.7 Future work

This project provides an updated picture of national dietary survey provision across Europe, and also exposes those areas where further research is needed. Harmonisation of national dietary surveys would help facilitate valid pooling of data to better enable exploration of variation between countries and also the investigation of nutrient intakes by demographic parameters, allowing assessment of inequalities in disadvantaged groups. Further work to enable this is therefore needed, particularly in Central & Eastern European countries, where data gaps are most prevalent.

Greater emphasis should be placed on harmonising socioeconomic variables within national dietary surveys. This would instigate greater focus on disadvantaged groups and enable detailed analyses in the areas covered by this thesis and more, potentially improving understanding of what polices are needed to alleviate diet-related health inequalities.

Data should also be made publicly accessible, which would promote transparency and allow more researchers across Europe to investigate nutrient intakes, for instance in disadvantaged groups. More work is also needed on keeping food composition databases updated and representative of all population groups whose diet it underpins. This could help build a bank of information to underpin policy development across Europe. It would also improve the use of national dietary surveys in assessing existing reduction policy options in TFAs and in other nutrients of concern, such as sodium or free sugars. With greater harmonisation of and accessibility to national dietary survey data, countries across Europe would have better scope to report these nutrients of concern, particularly free sugars, using common definitions.

This project exposes the hidden impact of under-reporting, which varies across Europe and has direct implications for nutrition policies based on national dietary survey data, and the ability of governments and health bodies to address the most pressing health problems facing Europe. Future work should therefore be undertaken to explore the mechanisms behind under-reporting, and under-reporting patterns across Europe, so that the effect on intake levels can be accurately accounted for.

Further research, particularly in natural settings, is clearly needed into the effects of on-pack serving size labelling on consumed portion size, incorporating different socio-demographic groups to determine the best policy approach to reduce consumed portion sizes across populations. Future work could also model scenarios based on the relationship between consumed portion size and on-pack serving-size, both nationally, across other European countries, and in a wider range of foods.

10.8 Conclusion

This project has reviewed the provision of national dietary surveys within the 53 Member States of the European office of the World Health Organisation and assessed results and challenges via selected topics of concern. These comprise an updated and extended review of nutrient intakes, alongside an investigation of TFA intakes and examination of portion sizes. Gaps in national dietary survey, and consequently information provision, were identified, and adult and child nutrient intakes compared to WHO RNIs to investigate the most pressing areas of need. Potential socioeconomic inequalities across Europe were investigated to assess whether disadvantaged groups are potentially more susceptible to nutrition-related problems, both on a broader diet quality level and focusing on TFAs as a nutrient of concern. National dietary surveys were used to determine consumed portion sizes in commonly consumed energy-dense snack foods. These were used to explore potential associations with BMI and also compared to UK on-pack serving sizes to explore whether obesity-prevention policies to create a healthy food environment should include the amendment of on-pack serving-sizes.

10.8.1 Key findings from published thesis chapters

- Less than two thirds of the 53 countries in the WHO European region have conducted national diet surveys since 1990 and less than half of countries reported energy and nutrient intakes.
- The main survey gaps for both adults and children lie in the Central & Eastern European countries, where nutrition policies may therefore lack an appropriate evidence base.
- TFAs, omega fats, sugars and iodine intakes were reported by the fewest countries, suggesting that NCDs and also conditions linked with lack of iodine and omega fats could continue unchecked.
- In adults WHO RNI attainment was generally poor, particularly for macronutrients, and in women. Micronutrient inadequacy was most prominent amongst elderly women and Central & Eastern European countries.
- In children and adolescents most countries met under half of WHO RNIs for the nutrients and age/gender groups reported. Macronutrient RNI

compliance was universally poor, and although micronutrients were slightly better, attainment was worse in girls and older children. Fat and saturated fats, vitamin D, sodium, total folate and iron had the lowest compliance.

- Lower education groups generally had lower intakes, particularly of micronutrients. Associations between lower education and higher intakes were concentrated in energy and macronutrients, potentially indicating poorer diet quality.
- Having a higher education may mitigate against the increased fats intakes seen with increased GDP, and having lower education may weaken beneficial increases in total folate.
- Only 13% of countries reported intakes by socioeconomic group and these were by different methods. Consequently, the majority of WHO European countries are unable to adequately assess nutrient deficiencies in disadvantaged socioeconomic groups.
- Different age groups, dietary assessment methodologies, nutrient composition databases and under-reporting are the main factors limiting inter-country comparisons.
- All European countries should be encouraged to conduct harmonised national dietary surveys reporting on a set range of nutrient intakes across all ages and by socioeconomic group.
- Successful voluntary national reduction programmes have facilitated low average Dutch and UK TFA intakes.
- The top 10% consumers of TFAs had a more ruminant based TFA profile in the UK, whereas Dutch consumers appeared to also obtain TFA from artificial sources.
- TFA intakes may be underestimated due to under-reporting and the nature of food composition databases; inequalities in TFA consumption of certain vulnerable groups cannot be ruled out.
- There was limited evidence of associations between consumed portion size of energy dense foods and BMI in either France or the UK.
- Pack-size information was much more common than on-pack serving-size information in commercially available UK products.

- Consumed portion sizes were higher than on-pack serving-size in the majority of foods studied.

10.8.2 Summary

Both the conducting and evaluation of national dietary surveys is necessary to inform and implement the most effective policies. However, it is clear that lack of harmonisation inhibits the ability to determine patterns between countries, explore wider causes of nutritional issues, develop common policies and learn from measures taken in different countries. There is a need to encourage national dietary survey harmonisation, particularly in the age groups sampled, dietary assessment methodology employed, nutrient range covered, the underpinning food composition database, and the treatment of under-reporters. If this is achieved, the potential for generating large amounts of high quality data is great.

This study demonstrates the need to investigate and evaluate the impact of different TFA removal policies, and to reduce the risk of high exposure remaining in some population groups. Monitoring intakes is therefore a crucial tool in the elimination of TFAs, and a harmonised national dietary survey system across Europe could facilitate this.

Whilst mean nutrient intakes determined from national dietary surveys provide a high-level view of a country’s nutritional situation, information gathered about the amounts and types of foods consumed is also useful. However, the wide variation in definitions of portion size and the methods used to measure it has contributed to the failure within Europe to establish standardised portion size guidance that could help prevent consumer confusion.

National dietary surveys are needed to underpin robust monitoring systems that will provide a fuller understanding of key nutrient intake levels and the amount of different types of foods consumed. These systems should be harmonised across all WHO European Member States to create a means of accurately assessing where dietary improvement is needed, on both a population and subgroup level. Only then can effective, coordinated policy be developed that can have a real impact on dietary improvement across Europe.

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Appendix 1 Chapters 8 & 9 Supplementary Material 1: Combining data from Years 1-4 and Years 5&6

The NDNS datasets for Year 1-4 and Year 5&6 can be combined for analysis of Years 1-6 but in order to produce valid results the two sets of weights need to be re-scaled. This will ensure that the two sets of data are in the correct proportion i.e. 2:1. A different calculation is required for each weight (individual, nurse, blood etc).

Re-scaling is necessary because there were more participants *per year* in years 1-4 than in years 5&6. In total, there are 6,828 participants in the Year 1-4 data but only 2,546 participants in Year 5&6 data. The ratio of these totals is (approx.) 2.68:1. Therefore, if the weights were combined into one variable without any further adjustment, years 1-4 would have more weight *per year* than years 5&6. To re-scale the weights correctly, it is necessary to perform the following calculations:

1. Divide each weight variable by its sum (i.e. the sum of the weights);
2. Multiply both by the total (combined) sum of the two weights;
3. Multiply the Year 1-4 weight by 2/3 and the Year 5&6 weight by 1/3.

You can then combine the resulting weights into one variable.

Example: individual weights

For example, to create new individual weights for analysis of the combined dataset, the steps would be as follows:

1. Divide Year 1-4 weight by 6828 and the Year 5&6 weight by 2546;
2. Multiply both weights by (6828 + 2546);
3. Multiply the Year 1-4 weight by 2/3 and the Year 5&6 weight by 1/3;
4. Combine the resulting weights into one variable.

To do all of this in in SPSS you could use the following syntax:

```
compute WTI_UKY1234r = WTI_UKY1234 * (6828 + 2546) / 6828 * (2/3).
compute WTI_UKY56r   = WTI_UKY56   * (6828 + 2546) / 2546 * (1/3).
compute WTI_UKY1to6  = sum (WTI_UKY1234r , WTI_UKY56r).
```

Running these commands will result in a new set of weights (WTI_UKY1to6) for analysing Years 1-6. They should have a mean of 1 and be non-missing for all 9,374 cases in the combined dataset. You can check this by running descriptives on the weights:

```
desc WTI_UKY1to6.
```

Notes:

1. The intermediate weights (WTI_UKY1234r and WTI_UKY56r) can be discarded/deleted.

2. In this example the sum of the weights is equal to the total sample size in each case. This will not hold for subgroups (see below).

Combining other weights

Analogous calculations can be performed for:

Nurse weights (WTN_UKY1234 and WTN_UKY56)

Blood weights (WTB_UKY1234 and WTB_UKY56)

RPAQ weights (WTR_UKY1234 and WTR_UKY56)

24-hour urine weights (WTU_UKY1234 and WTU_UKY5) {* see note below}

* Note that 24-hour urine samples were only collected in Years 1-5 so when combining these weights, the correct proportions to use are 4/5 and 1/5 (rather than 2/3 and 1/3).

Weights for combined sub-group analysis

The above explanation assumes that analysis will be performed for <u>all</u> cases i.e. all adults and children. If analysis of subgroups is required then analogous calculations should be performed on the combined dataset filtered to include only the subgroup of interest. This will produce bespoke weights for analysis of that particular subgroup (adults only for example).

One additional step is required but otherwise the procedure is the same:

1. Divide each weight variable by its sum (i.e. the sum of the weights);
2. Multiply both by the total (combined) sum of the two weights;
3. Multiply the Year 1-4 weight by 2/3 (4/5 for the 24 hour urine weights) and the Year 5&6 weight by 1/3 (1/5 for the 24 hour urine weights);
4. Combine the resulting weights into one variable;
5. Re-scale this weight to have a mean of 1.

The additional step (5) ensures that the resulting weights have a mean of 1.

Example: individual weights (adults only)

To create new individual weights for analysis of adults only in the combined dataset, you could use the following syntax in SPSS:

```
select if age>=19.

desc WTI_UKY1234 WTI_UKY56 / stat = sum.  {*}

compute WTI_UKY1234r = WTI_UKY1234 * (5391.3596 + 2012.2877) /
5391.3596 * (2/3).

compute WTI_UKY56r   = WTI_UKY56   * (5391.3596 + 2012.2877) /
2012.2877 * (1/3).

compute WTI_UKY1to6  = sum (WTI_UKY1234r , WTI_UKY56r).

desc WTI_UKY1to6.                        {*}

compute WTI_UKY1to6  = WTI_UKY1to6 / 1.562610.
```

* these lines are optional but required to produce the figures in the following commands.

The resulting weights (WTI_UKY1to6) should have a mean of 1 and be non-missing for all 4,738 cases in the combined dataset of adults. As above, you can check this by running descriptives on the weights:

```
desc WTI_UKY1to6.
```

Notes:

1. Again, the intermediate weights WTI_UKY1234r & WTI_UKY56r can be discarded/deleted.

2. If subgroup analysis is performed using weights produced for the whole dataset, years 1-4 and 5&6 may not be in the correct proportion.

Appendix 2 Chapter 8 Supplementary Material 2: Food subgroups in the selected main food groups in the French INCA2* and UK NDNS

FRANCE INCA2	UK NDNS
Pâtisseries et Gateaux	**Buns, Cakes, Pastries & Fruit Pies**
Pancakes and Brioche	Scones, pancakes & sweet dough
Chocolate Cake & Gateau	Chocolate Cake & Gateau
Cake & Gateau Non-Chocolate	Cake & Gateau Non-Chocolate
Doughnut	Doughnut
Eclairs	Éclairs
Fruit cake	Fruit Cake & malt loaf
Fruit Pie	Fruit Pie
Muffins and Mini Cakes	Muffins & cupcakes
Pastries	Pastries
Tart	Tart
	Teacakes
	Swiss Roll
	Bars & Slices
	Croissant
Other cakes and patisserie	Other cakes
Biscuits Sucrés ou Salés et Barres	**Biscuits**
Unfilled uncoated biscuits	Unfilled uncoated biscuits
Cereal bars	Cereal bars
Cookies	Cookies & Flapjack
Savoury biscuits plain	Savoury biscuits plain
Filled chocolate biscuits	Filled chocolate biscuits
Filled non-chocolate biscuits	Filled non-chocolate biscuits
Savoury biscuits flavoured	Savoury biscuits flavoured
Short biscuits	Short biscuits
Unfilled coated biscuits with inclusions	Unfilled coated biscuits with inclusions
Potato crisps std	Jaffa cakes
Tortilla chips	
Other biscuits and crisps	Other biscuits
Chocolat	**Chocolate Confectionary**
Chocolate spread	Other
Milk chocolate	Milk chocolate
Mars type bar	Mars type bar
Wafer bar	Wafer bar
Dark chocolate	Dark chocolate
Honeycomb/crunch	Honeycomb/crunch
Truffles	Truffles
White chocolate	White chocolate
Chocolate with additions	Chocolate with additions
	Caramel
	Sugar coated
	Crème filled
	Coated nuts/fruit
	Crisps & Savoury Snacks
	Potato & Vegetable Crisps Standard

Corn/Maize Snack
Potato Snack Shapes & Puffed
Tortilla Chips
Potato Crisps Crinkle
Popcorn
High Fat Bar Snacks
Nuts

* The French INCA2 data lacks the variables required to calculate energy density of particular food groups; therefore subgroups were created to match as closely as possible those created from the NDNS.

Appendix 3 Chapter 8 Supplementary Material 3: Associations between portion size of energy-dense foods and BMI for adults aged 19-64y in the French INCA2. Model 1 adjusted for sex and age. Model 2 adjusted for under-reporting, sex and age.

FOOD GROUP	MODEL 1				MODEL 2			
	Change in FPS (g) with each BMI point increase	99% CI		Adjusted p-value	Change in FPS (g) with each BMI point increase	99% CI		Adjusted p-value
Cakes								
TOTAL	**1.0**	**0.01**	**2.1**	**0.01**	**1.2**	**0.1**	**2.3**	**0.003**
Other cakes and patisserie	3.1	1.0	5.2	<0.001	4.4	1.5	7.4	<0.001
Pancakes and Brioche	1.3	-3.0	5.5	0.4	1.5	-2.8	5.7	0.4
Chocolate Cake & Gateau	1.3	-0.4	2.9	0.05	1.3	0.3	3.0	0.04
Cake & Gateau Non-Chocolate	1.2	-1.2	3.5	0.2	1.5	-0.7	3.8	0.08
Doughnut	-0.4	-5.4	4.6	0.9	-0.1	-5.0	4.9	1.0
Eclairs	2.6	-1.1	6.3	0.1	3.0	-1.1	7.2	0.06
Fruit cake	1.7	-1.5	4.8	0.2	1.6	-1.1	4.4	0.1
Fruit Pie	-2.4	-14.0	9.1	0.6	-3.2	-15.0	8.6	0.5
Muffins and Mini Cakes	0.04	-2.0	2.1	1.0	0.1	-1.8	2.0	0.9
Pastries	0.3	-2.9	3.4	0.8	0.3	-2.8	3.5	0.8
Tart	1.0	-1.0	3.1	0.2	1.3	-0.9	3.4	0.1
Biscuits & Crisps								
TOTAL	**0.1**	**-0.4**	**0.5**	**0.7**	**0.1**	**-0.5**	**0.6**	**0.8**
Other biscuits and crisps	-0.3	-4.0	3.4	0.8	-0.8	-4.4	2.8	0.6
Unfilled uncoated	0.1	-1.1	1.3	0.9	0.2	-1.1	1.4	0.8
Cereal bars	0.03	-0.6	0.7	0.9	0.1	-0.7	0.9	0.8
Cookies	0.5	-1.7	2.7	0.6	0.4	-1.9	2.7	0.6
Savoury biscuits plain	0.4	-0.3	1.0	0.1	0.5	-0.2	1.1	0.05

Filled chocolate	-0.05	-2.4	2.3	1.0	0.2	-2.1	2.5	0.8
Filled non-chocolate	-0.2	-1.6	1.1	0.6	-0.2	-1.7	1.3	0.7
Potato crisps std.	0.1	-0.7	0.9	0.8	-0.4	-1.5	0.7	0.3
Savoury biscuits flavoured	-0.2	-2.0	1.5	0.7	-0.6	-2.5	1.2	0.4
Short biscuits	-0.9	-3.2	1.3	0.3	-0.6	-3.0	1.7	0.5
Tortilla chips	-0.4	-2.7	2.0	0.7	-0.3	-2.7	2.1	0.8
Unfilled coated and/or inclusions	0.1	-2.4	2.6	0.9	0.1	-2.5	2.6	1.0
Chocolate								
TOTAL	**0.3**	**-0.4**	**0.9**	**0.3**	**0.3**	**-0.3**	**0.9**	**0.2**
Chocolate spread	-0.8	-3.1	1.5	0.4	-0.6	-2.8	1.6	0.5
Chocolate with additions	0.3	-1.3	2.0	0.6	0.3	-1.4	2.0	0.7
Dark chocolate	1.0	0.1	1.9	0.004	0.9	0.2	1.7	0.001
Honeycomb/crunch	-1.7	-4.5	1.0	0.1	-1.8	-4.7	1.1	0.1
Mars type bar	-1.6	-4.0	0.9	0.1	-1.6	-4.0	0.9	0.1
Milk chocolate	0.4	-0.6	1.3	0.3	0.3	-0.6	1.3	0.4
Truffles	1.7	-1.5	4.9	0.2	1.3	-0.9	3.4	0.1
Wafer bar	-0.4	-1.8	1.0	0.5	-0.6	-1.9	0.8	0.3
White chocolate	-1.7	-6.9	3.6	0.4	2.6	-2.5	7.8	0.2

Appendix 4 Chapter 8 Supplementary Material 4: Associations between portion size of energy-dense foods and BMI for adults aged 19-64y in the UK NDNS (Y1-6). Model 1 adjusted for sex and age. Model 2 adjusted for under-reporting, sex and age.

FOOD GROUP	MODEL 1				MODEL 2			
	Change in FPS (g) with each BMI point increase	99% CI		Adjusted p-value	Change in FPS (g) with each BMI point increase	99% CI		Adjusted p-value
Cakes								
TOTAL	**-0.1**	**-0.7**	**0.4**	**0.5**	**0.1**	**-0.5**	**0.7**	**0.6**
Other	2.0	-0.3	4.2	0.03	2.0	-0.2	4.3	0.02
Teacakes	0.2	-0.9	1.3	0.6	0.4	-0.8	1.6	0.4
Cake & Gateau Non-Choc	-0.4	-1.6	0.8	0.4	-0.6	-2.4	1.2	0.4
Swiss Roll	0.5	-1.8	2.9	0.6	0.9	-1.5	3.3	0.3
Doughnut	2.1	-1.6	5.8	0.1	1.9	-0.8	4.6	0.07
Croissant	0.4	-1.6	2.4	0.6	0.5	-1.6	2.6	0.5
Muffins & cupcakes	-0.2	-1.7	1.3	0.8	-0.1	-1.6	1.4	0.9
Chocolate Cake & Gateau	-0.7	-2.7	1.3	0.3	-0.5	-2.5	1.4	0.5
Bars & Slices	-0.8	-1.8	0.2	0.04	-0.5	-1.4	0.4	0.2
Fruit Pie	0.7	-1.2	2.6	0.3	1.1	-0.8	3.1	0.1
Éclairs	1.0	-0.9	2.9	0.2	1.3	-0.5	3.2	0.07
Tart	0.6	-1.2	2.5	0.4	0.9	-1.2	3.1	0.3
Scones, pancakes & sweet dough	-0.7	-2.3	0.9	0.3	-0.8	-2.8	1.3	0.3
Pastries	0.7	-1.3	2.8	0.4	1.8	-1.4	5.0	0.1
Fruit Cake & malt loaf	1.7	-0.3	3.7	0.03	1.7	-0.3	3.7	0.03
Biscuits								
TOTAL	**0.1**	**-0.1**	**0.4**	**0.3**	**0.2**	**-0.1**	**0.5**	**0.07**
Unfilled coated/inclusions	0.2	-0.3	0.6	0.3	0.2	-0.2	0.7	0.2
Unfilled uncoated	-0.01	-0.4	0.4	1.0	0.02	-0.4	0.4	0.9
Filled non-chocolate	0.4	-0.1	0.9	0.05	0.4	-0.1	0.9	0.06

Cereal bars	-0.3	-0.7	0.1	0.1	-0.3	-0.7	0.1	0.09
Cookies & Flapjack	0.1	-1.0	1.1	0.9	0.2	-0.9	1.3	0.7
Short biscuits	0.3	-0.2	0.7	0.1	0.3	-0.1	0.8	0.07
Savoury biscuits plain	0.02	-0.3	0.4	0.9	0.2	-0.2	0.5	0.2
Savoury biscuits flavoured	0.1	-0.6	0.7	0.8	-0.01	-0.6	0.5	1.0
Jaffa cakes	0.2	-1.1	1.4	0.7	0.3	-1.0	1.7	0.6
Filled chocolate	0.1	-0.6	0.9	0.6	0.3	-0.4	1.0	0.3
Crisps								
TOTAL	**-0.03**	**-0.4**	**0.3**	**0.8**	**0.05**	**-0.3**	**0.4**	**0.7**
Potato & Vegetable Crisps Std	-0.1	-0.4	0.2	0.4	-0.1	-0.4	0.2	0.6
Corn/Maize Snack	0.9	-0.4	2.3	0.07	1.0	-0.4	2.3	0.06
Potato Snack Shapes & Puffed	0.2	-0.3	0.8	0.3	0.3	-0.4	0.9	0.3
Tortilla Chips	-0.9	-2.7	0.9	0.2	-0.5	-2.2	1.3	0.5
Potato Crisps Crinkle	-0.1	-1.0	0.7	0.6	-0.1	-0.9	0.7	0.7
Popcorn	4.1	-1.0	9.2	0.04	4.1	-1.2	9.5	0.05
High Fat Bar Snacks	3.3	-0.1	6.7	0.01	3.2	0.2	6.3	0.01
Nuts	-6.3	-20.4	7.9	0.3	4.6	-9.7	18.8	0.4
Chocolate								
TOTAL	**0.1**	**-0.4**	**0.5**	**0.6**	**0.1**	**-0.4**	**0.6**	**0.6**
Other	-1.1	-4.0	1.7	0.3	-0.9	-3.4	1.9	0.4
Milk chocolate	-0.2	-0.8	0.5	0.5	-0.2	-1.0	0.5	0.4
Mars type bar	-0.1	-0.6	0.4	0.6	-0.2	-0.7	0.4	0.4
Wafer bar	0.1	-0.4	0.6	0.7	0.1	-0.5	0.6	0.8
Caramel	0.4	-0.7	1.5	0.4	0.3	-0.8	1.4	0.5
Sugar coated	-2.1	-5.4	1.2	0.1	-2.0	-5.2	1.2	0.1
Dark chocolate	1.8	-2.9	6.4	0.3	2.1	-2.6	6.9	0.3
Honeycomb/crunch	0.7	-0.7	2.2	0.2	-0.2	-1.3	0.9	0.6
Crème filled	-0.2	-1.8	1.3	0.7	-0.1	-1.7	1.5	0.9
Truffles	-0.1	-0.9	0.8	0.8	0.02	-0.9	0.9	1.0
White chocolate	-0.4	-2.7	1.9	0.6	-0.4	-2.7	1.9	0.6
Chocolate with additions	0.2	-1.0	1.4	0.6	0.4	-0.9	1.8	0.4
Coated nuts/fruit	-1.8	-7.8	4.2	0.4	-1.6	-7.4	4.1	0.5