Explaining Differences in Birth Size and Adiposity between Pakistani and White British babies

Jane West

Submitted in accordance with the requirements for the degree of Doctor of Philosophy

The University of Leeds

Academic Unit of Public Health
Leeds Institute of Health Sciences
Faculty of Medicine and Health

September, 2011

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 4 of this thesis is based on the following publication:

West J, Manchester B, Wright J, Lawlor D A, Waiblinger D. Reliability of routine clinical measurements of neonatal circumferences and research measurements of neonatal skinfold thicknesses: findings from the Born in Bradford study. Paediatric and Perinatal Epidemiology 2011; Volume 25, Issue 2, pages 164–171.

Jane West and Ben Manchester collected the data for this paper and undertook the analyses, Jane West wrote the paper with comments from Debbie Lawlor and John Wright. Dagmar Waiblinger participated in research measurement training.

Acknowledgements

I would briefly like to thank some of the many people who have supported me in completing this PhD.

I have been very fortunate to be supervised by Professor John Wright and Professor Debbie Lawlor. I thank them for supporting my fellowship, guiding me through my research and for their feedback and contributions to this thesis. I am grateful to Ben Manchester who undertook some of the analyses in Chapter 4. I thank Lesley Fairley for her statistical support and patience and thank Professor Tricia McKinney and Professor Darren Shickle for their comments and feedback on my work. I am also grateful to the MRC for my Special Training Fellowship.

Next, I thank all the families who took part in this study, the midwives, paediatricians, health visitors, the Born in Bradford team which included interviewers, data managers, laboratory staff (in Bradford and Glasgow), clerical workers, the members of the BiB Scientific Advisory Group, volunteers and managers. In particular, I am grateful to Dagmar Waiblinger and her team of study administrators who worked tirelessly to obtain anthropometric measurements for this thesis. I also thank Carolyn Clover for her word processing expertise and her friendship and Rachel Sunter for her help with formatting this thesis.

Finally, I thank Stuart, Laura and Tabatha for their unconditional support and I dedicate this work to my sister Ann and my Mum who were both here at the beginning of this thesis but are not here to see it completed.

Abstract

There is a growing recognition that being born small is associated with an increased risk of poorer adult cardiometabolic health in addition to its known adverse effects on perinatal and infant outcomes. Previous studies have shown markedly lower birthweight among infants of South Asian origin compared to those of White British origin and there is a suggestion that such differences may mask greater central adiposity in South Asians. In this thesis, differences in birth size between 2221 Pakistani origin and 1838 White British origin infants born in the same UK maternity unit are described and whether the magnitude of any differences changes depending on whether the parents (both mother and father) and grandparents of Pakistani infants were born in the UK or South Asia was investigated.

Marked differences in birthweight between Pakistani origin and White British origin infants persisted even after adjustment for a wide range of potential masking and mediating characteristics. Important differences remained whether both parents were UK born, one was South Asian born or both were South Asian born, suggesting that at least over two generations, environmental or lifestyle changes amongst parents who have migrated to the UK and spent all of their life here have not had a major impact on these differences.

Despite their smaller birthweight, South Asian infants had more total body fat than White British infants, as indicated by skinfold thickness and cord leptin, which has important implications for any public health interventions aimed at increasing birthweight in South Asian infants, as this could result in greater body fat and ultimately poorer cardiometabolic health.

Contents

List of Figures

List of Tables

List of abbreviations

ALSPAC	Avon Longitudinal Study of Parents and Children
BMI	Body Mass Index
BTHNHST	Bradford Teaching Hospitals NHS Trust
CHASE	Child Heart and Health Study
CI	Confidence interval
DH	Department of Health
DXA	Dual energy x-ray absorptiometry
EDD	Expected date of delivery
EDTA	Ethylenediaminetetraacetic Acid
ELISA	Enzyme linked immunosorbent assay
GDM	Gestational diabetes mellitus
GTT	Glucose tolerance test
HAPO	Hyperglycaemia and Adverse Pregnancy Outcomes Study
HSE	Health Survey for England
IMR	Infant Mortality Rate
IQR	Interquartile range
LSCS	Lower segment caesarean section
MCS	Millenium Cohort Study
MRC	Medical Research Council
MRI	Magnetic resonance imaging
MUA	Mid-upper arm
NIHR	National Institute for Health Research
NS-SEC	National Statistics Socio-economic Classification
PCT	Primary Care Trust
R	Reliability
sd	Standard deviation
SEP	Socioeconomic position
SFGA	Small for gestational age
SS/TR	Subscapular to triceps ratio
TEM	Technical error of measurement
UK	United Kingdom

UN	United Nations
UNICEF	United Nations Childrens Fund
VIF	Variance inflation factor
WHO	World Health Organisation

List of equations

Publications arising from this thesis

Chapter 4 of this thesis is based on the following publication:

West J, Manchester B, Wright J, Lawlor D A, Waiblinger D. Reliability of routine clinical measurements of neonatal circumferences and research measurements of neonatal skinfold thicknesses: findings from the Born in Bradford study. Paediatric and Perinatal Epidemiology 2011; Volume 25, Issue 2, pages 164–171.

The following presentations have arisen from this thesis:

Annual Scientific Meeting of the Society for Social Medicine 2011

West J, Lawlor D A, Fairley L, Wright J (2011). Birth size differences between White and Pakistani origin infants by generation: results from the Born in Bradford Cohort Study. J Epidemiol Community Health, 65 (suppl II): A29

IEA World Congress of Epidemiology 2011

West J, Lawlor D A, Fairley L, Wright J (2011). Birth size differences between White and Pakistani origin infants by generation: results from the Born in Bradford Cohort Study. J Epidemiol Community Health, 65(suppl I): A217

Annual Scientific Meeting of the Society for Social Medicine 2010

West J, Lawlor D A, Fairley L, Wright J (2010). Birth size differences between white & Pakistani origin infants by generation: Results from the Born in Bradford cohort study. J Epid & Comm Health, Vol 64 (Suppl I): A11

Chapter 1
Introduction

This PhD thesis is concerned with describing and understanding the causes of differences in birthweight and adiposity between infants born in the UK to Pakistani parents and those born to White British origin parents. This introductory chapter summarises why this is an important research topic, details the specific objectives and outlines the content of subsequent chapters.

Birthweight reflects intrauterine growth and wellbeing and is recognised globally as an indicator of fetal and infant health. A low birthweight has been associated with increased infant mortality and morbidity (Yasmin et al., 2001, Ashworth, 1998, Lira et al., 1996) and has indeed been described as the single most important factor affecting infant mortality (Kramer, 1987). Furthermore, there is a growing recognition that being born small is associated with an increased risk of developing several chronic diseases in later life, including cardiovascular disease and diabetes (Barker, 1992). These associations with cardiovascular disease and diabetes, are inverse and linear or reverse 'j' shaped across the whole birthweight distribution (Huxley et al., 2007). Low birthweight, defined according to World Health Organisation (WHO) criteria as a weight at birth below 2500g, is the result of either premature birth or restricted growth in utero. The aetiology of pre-term birth is known to be quite different to that of growth restriction and whilst there are probably ethnic differences in gestational length (McFadyen et al., 1984) this thesis is concerned with low birthweight as a consequence of growth restriction.

1.1 Differences in birth weight between South Asian babies and white babies and the generational effect

Worldwide mean birthweight is lower and the prevalence of low birthweight is more common in low and middle income countries compared with high income countries. High rates of low birthweight have been reported in Asia, particularly India, Pakistan and Bangladesh. The latest UNICEF and WHO report (2004) (WHO, 2004) indicated that south-central Asia had a higher proportion of low birthweight neonates than any other region in the world. This is in part thought to reflect poor maternal nutrition throughout their life course and through their pregnancy. However, babies born in high income countries, such as the UK and US to mothers of South Asian origin are considerably lighter than babies born to white mothers (Hayes et al., 2008, Margetts et al., 2002). This is perhaps not surprising in first generation mothers who will have been exposed to poverty and poor nutrition in their earlier lives, but little is known about how these differences change over generations. This is important as if birthweights of subsequent generations begin to move closer to the indigenous white population, it would suggest that host country environmental characteristics, such as better nutrition and antenatal care, explain the differences. By contrast if birthweights remain similar over generations it would suggest that differences are genetically or culturally programmed (i.e. directed by integrated patterns of human behaviour) and maintained over generations. Five studies have compared differences in first and second generation South Asian women in the UK. Four found no difference in birthweight (Draper et al., 1995, Harding et al., 2004, Margetts et al., 2002, Leon and Moser, 2010). Just one study found an increase in second compared to first generation offspring (Dhawan, 1995). Chapter 2 provides a detailed review of birthweight differences in South Asian compared to white indigenous populations amongst infants born in high income countries, including any that compare differences across generations of South Asian migrants.

1.2 Why is birthweight important?

1.2.1 Impact of low birthweight on early mortality and child health

Babies born weighing less than 2500g have higher perinatal mortality and morbidity (Gulmezoglu et al., 1997) and are more likely to experience developmental problems in childhood (Hediger et al., 2002). Indeed low birthweight has been associated with both cognitive and neurologic impairment (Paz et al., 1995, Taylor and Howle, 1989). Notably, infant mortality rates among South Asians living in the UK are considerably higher than those of the UK white population. In Bradford the infant mortality rate among Pakistanis in 2008 was 12.3 per 1,000 compared with an overall rate for the city of 8.0 per 1,000 and a rate for England and Wales of 5.1 per 1,000 (NHS Bradford and Airedale, 2010).

1.1.2 Association of low birthweight on later mortality and morbidity

A large number of studies have demonstrated inverse (sometimes 'J' shaped) associations of birth size (most commonly birthweight) with cardiovascular disease endpoints (Huxley et al., 2007) and risk factors, including type 2 diabetes (Whincup, 2008), fasting glucose (Salmi et al., 2008), insulin (Lawlor et al., 2003), total cholesterol (Lawlor et al., 2006), triglycerides (Gluckman[4] and Hanson, 2004, Owen et al., 2003) and positive associations with high density lipoprotein cholesterol (Gluckman[4] and Hanson, 2004). Conversely, birthweight is positively associated with BMI (Gillman et al., 2003) and with both total fat mass and lean mass assessed by DXA scan (Rogers et al., 2006). The strength of associations of lower birth weight with adverse cardiovascular disease events and risk factors is generally smaller, often considerably so, than those between risk factors measured in adult life and these outcomes. Furthermore, it is unclear what mechanisms underlie the associations of birthweight with later cardiovascular disease outcomes. Few investigators suggest that size at birth *per se* matters, rather that this is a proxy marker for some other causal risk factor or factors. The explanations that have been proposed for this association fall broadly into one of the following three areas:

- Intrauterine programming

It is suggested that factors affecting intrauterine nuitrition/growth provide signals to the developing fetus about the environment in which they will grow-up and develop, and as a result 'programme' the developing fetus for an environment of thrift or plenty (Bateson et al., 2004, Leon, 2004). Poor intrauterine nutrition results in poor intrauterine growth, and thus low birthweight, and also programmes the offspring for a life of thrift. If offspring subsequently experience a life of nutritional plenty, typified by high fat energy dense diets common in many high income countries and urban areas of low and middle income countries, they are at a particular increased risk of future cardiovascular disease. Epigenetic mechanisms are increasingly thought to mediate these processes (Waterland and Michels, 2007). For example, during intrauterine development there are significant changes to epigenetic states across the genome presenting the opportunity for environmental stresses, in particular maternal nutrition, to influence gene expression and thus phenotype (Ying Li et al, 2010).

- Genetic mechanisms (the fetal insulin hypothesis)

The fetal insulin hypothesis suggests that associations are largely due to the effects of genetic variants that have pleiotropic effects influencing both fetal growth and later insulin resistance and hence cardiovascular risk (Hattersley and Tooke, 1999, McKeigue, 1999).

- Confounding and bias

It has been suggested that the associations of birthweight with cardiovascular disease and its risk factors are largely due to confounding (for example, by socioeconomic position or shared familial behaviours such as smoking, physical activity and diet that could affect both perinatal outcomes and later disease risk in offspring), statistical artefact and/or publication bias (Huxley et al., 2002, Tu et al., 2005). Although recent systematic reviews (Whincup, 2008, Huxley et al., 2007), together with intergenerational and sibling studies (Lawlor et al., 2009) have suggested that such bias and confounding is unlikely to fully explain these associations.

Not only do South Asian individuals have lower birthweight in comparison to European origin individuals, they also have an increased risk of insulin resistance, type 2 diabetes and cardiovascular disease in adulthood and it is plausible that mechanisms underlying the associations of lower birthweight and an increased risk of cardiovascular disease and diabetes also contribute to ethnic differences in these health outcomes. For a given body mass index South Asian adults, particularly those who have migrated to South Asian urban areas or to Europe and the USA, have greater central adiposity and higher rates of diabetes and cardiovascular disease (McKeigue et al., 1991). This has led to the term 'thin-fat insulin resistant phenotype' to describe South Asian populations. If this phenotype already exists at birth, then lower mean birthweight in South Asian populations may mask proportionately greater adiposity at birth and this greater adiposity (particularly in postnatal environments of nutritional plenty) may be related to a later higher risk of diabetes and cardiovascular disease. There has been relatively little research on the existence of the thin-fat insulin resistant phenotype in infancy and childhood, particularly in migrant populations but relevant findings are summarised briefly below and are reviewed in more detail in Chapter 2.

A UK study of children aged 8-11 years found that South Asian children had lower ponderal indices than white children but the same waist circumference and waist:hip ratio on average, suggesting that at the same ponderal index South Asian children had greater central adiposity than white children (Whincup et al., 2002). BMI is highly correlated with total fat mass (determined by DXA scan) and waist circumference in European children and in these children all three measurements relate to cardiovascular risk factors with the same magnitudes of association, suggesting that in European children, BMI may be an accurate indicator of fat mass, central adiposity and cardiovascular risk in this population (Lawlor et al., 2010). However, a study comparing children of different ethnic backgrounds found that in South Asian children BMI underestimated centrally distributed fat and cardiovascular risk (Nightingale et al., 2010). Similar findings have been reported in a study that compared anthropometric measurements at birth in 157 urban Indian babies (born to parents living in Pune, India) and 67 UK babies born to white parents living in London (Yajnik[1] et al., 2002). For all anthropometric measurements the

Indian babies were smaller than the white babies. However, the magnitude of the differences was much smaller for triceps and subscapular skinfold thickness than for the other measurements. With adjustment for birthweight there was no difference in subscapular skinfold thickness indicating that the Indian babies tended to have more central adiposity for a given weight than white babies. These results suggest that even at birth South Asians may have a characteristic phenotype of proportionately greater central adiposity compared to white individuals.

Chapter 2 includes a detailed review of studies that contribute evidence for the existence of a thin-fat insulin resistant phenotype among South Asian infants.

1.3 Factors known to influence low birthweight

A range of factors are now recognised as influential to birthweight. These include maternal behavioural issues such as smoking, drugs and alcohol consumption, maternal pathophysiology, for example, maternal hypertension and hyperglycaemia, other maternal/family characteristics such as socioeconomic background, parity and maternal age, and fetal influences such as gender, insulin response and genetic variation. These risk factors for variation in birthweight may explain part or even all of the ethnic disparity in birth size but the exact relationships are likely to be complex and the precise mechanisms involved remain poorly understood. Further, several factors act as proxies for socioeconomic position (for example single parenthood and education) and it is possible that some of these characteristics mask even larger differences than those observed in some studies. Factors known to influence birthweight and whether effects vary across ethnic groups, are discussed in more detail in Chapter 2.

1.4 What questions arise from the existing evidence?

This is a growing area of research however a number of gaps remain. To tackle inequalities in birthweight, a better understanding of the causes of differences in birth weight between South Asian and white infants is clearly needed. This requires firstly a detailed exploration of potential masking and mediating characteristics for example social economic position, maternal size and maternal hyperglycaemia. Secondly, a detailed analysis of birthweight across generations of migrant UK South Asians is needed to examine whether birthweights of subsequent generations begin to shift towards those of the indigenous white population. In addition it is important to determine whether in a UK migrant population differences in birthweight mask greater adiposity in South Asians. This is crucial as knowing that birthweight reflects health and wellbeing and that a low birthweight can have a negative impact upon infant and later life, it is tempting to identify interventions that would increase birthweights in South Asian infants and reduce inequalities between them and European populations. However, in South Asians this could be too simplistic and potentially damaging as increasing birthweight may increase adiposity which may worsen long term health prospects (Muthaya et al., 2006). Therefore an in-depth analysis of the causes of differences in birthweight, whether they reduce over generations and a clearer understanding of ethnic variations in adiposity at birth are necessary before we can focus on possible interventions aimed at reducing ethnic inequalities in health.

To address these gaps in current research, a longitudinal birth cohort study is needed that includes a substantial number of South Asian parents (of different generations) and of European origin parents, together with detailed information on characteristics that are related to birth size and measurements of adiposity at birth, as well as birthweight (Eskenazi et al., 2005). The study used in this PhD – the Born in Bradford Study – provides such an opportunity.

1.5 The Born in Bradford birth cohort project

The Born in Bradford (BiB) (Raynor, 2008) project is a large birth cohort study based in Bradford, West Yorkshire, United Kingdom. It is tracking the lives of 13,776 babies whose mothers were recruited to the study between 2007 and 2010. The study was set up in recognition of the wide ranging health problems facing the city where deprivation, life expectancy, early death and infant deaths are significantly worse than the England average (Association of Public Health Observatories, 2008). It was also recognised that there were important health inequalities within the city. For example, men from the least deprived areas can expect to live eight years longer than those in the most deprived (Association of Public Health Observatories, 2008). Bradford is home to an ethnically diverse population, around 18% of the 483,600 people living in the city are South Asian (Bradford District Metropolitan Council, 2008). Almost 50% of the 5,500 babies born each year in the city are to parents of South Asian origin, 44% are of Pakistani origin. As a result of this ethnic and social diversity, the city provides an ideal research setting particularly as it offers the opportunity to obtain large numbers of Pakistani and white mothers, fathers and babies. Furthermore the South Asian population in Bradford has been relatively homogenous being largely from the Mirpur region of Pakistan thus reducing problems of heterogeneity within the South Asian population that might mask important ethnic differences. The current Pakistani community in Bradford first arrived in the 1950's and 1960's and since they are a relatively stable group it is anticipated that there are births to first, second and third generation women in the city. As such the BiB study provides rich and unique data to further our understanding of ethnic disparities in birth size and whether they are maintained in migrant Pakistani communities in the UK.

The BiB study, setting and participants are described in more detail in Chapter 3.

1.6 What is the central idea of this thesis?

1.6.1 Aim:

The aim of this thesis is to examine differences in birth size and adiposity between babies born to Pakistani and White British mothers at 37 or more weeks gestation at Bradford Teaching Hospitals NHS Trust. More specifically the main research questions were:

1. Are there differences in birth weight, mid-upper arm (MUA), abdominal and head circumference and sub-scapular and triceps skinfold thickness between Pakistani and White British babies born at 37 weeks gestation onwards and what are the magnitudes of any difference?

2. Are the magnitudes of any differences in birth size between Pakistani and white origin infants different depending upon whether the parents, grandparents and

great-grandparents of the Pakistani origin infants were born in South Asia or the UK?

3. Are Pakistani babies more centrally obese (as indicated by sub-scapular skinfold thickness) and do they have a greater proportion of fat mass at a given birth weight (as indicated by subscapular and triceps skinfold thickness and cord blood leptin analysis) than White British babies?

4. Do socioeconomic position and maternal pregnancy characteristics (including age, parity, BMI, maternal glucose tolerance, hypertensive disorders of pregnancy, smoking, alcohol) explain or mask any identified ethnic differences in birth size and adiposity?

Throughout this thesis the term White British refers to those originating from the UK and Ireland.

1.7 The organisation of this thesis

The chapters of this thesis are summarised below.

1.7.1 Chapter 2

This chapter consists of a literature review relevant to the research questions of this thesis, I review the literature relating to ethnic differences in birth size, factors with the potential to influence ethnic differences in birth size, generational differences in birth size in South Asians and the thin-fat insulin resistant phenotype in South Asian populations.

1.7.2 Chapter 3

This provides a description of the study methodology including design, setting, participants, data collection, outcome measures, generational classification and analysis plan.

1.7.3 Chapter 4

This includes the methods and results used to assess the reliability of anthropometric measurements used in this thesis.

1.7.4 Chapter 5

This chapter reports the results of the descriptive analysis, including distributions of outcome variables and the characteristics of the study population.

1.7.5 Chapter 6

This chapter reports the results of multivariable analyses of associations between ethnicity and birth size, and associations between generational status and birth size. It explores the extent to which differences are explained or masked by potential mediating/masking factors and examines whether South Asian infants have more (central) adiposity for a given birthweight.

1.7.6 Chapter 7

This discussion chapter includes a summary of the main findings, a review of strengths and limitations and a discussion of implications for practice and further research.

Chapter 2
Literature review

This chapter includes a review of the literature related to the research questions of this thesis. The first section describes ethnic differences in birth size. The second section discusses what factors may influence ethnic variations in birth size. This is followed by a review of generational differences in birthweight in South Asians born in high income regions. The final section discusses the evidence for the thin-fat insulin resistant phenotype among South Asian infants. The term 'South Asian' refers in this literature review to people originating from the Indian subcontinent i.e. India, Pakistan, Bangladesh and Sri Lanka (Agyemang and Bhopal, 2002) and was used for this review to ensure that all potentially relevant papers were identified however, the population studied in this thesis was specifically Pakistani only.

2.1 Literature search

The search strategy was developed by identifying subject headings/keyword terms to index articles deemed to be relevant. Searches were performed using OvidSP which includes various health related databases including MEDLINE and Embase. All identified titles and abstracts were checked for suitability and full papers obtained if considered potentially relevant. Further references were sourced from previous work in this area and through searching citation lists and citation histories (to identify papers citing the papers I had) of already identified papers. The full search strategies and keywords used are presented in Appendix A.

2.2 Ethnic differences in birth size

In this section literature relevant to ethnic differences in birthweight and size are discussed. This is relevant to the following thesis research question:

Are there differences in birthweight, MUA, abdominal and head circumference and sub-scapular and triceps skinfold thickness between Pakistani and White British babies born at 37 weeks gestation onwards and what are the magnitudes of any difference?

Birthweight is the first recorded weight of a baby and is usually measured within the first hour of life (World Health Organisation, 2005). A low birthweight is defined by the WHO as less than 2,500g (up to and including 2,499g). It is important to note that births before 37 weeks gestation are classified as pre-term but published data regarding birthweight and rates of low birth weight often fail to distinguish between pre-term and term infants (Harding et al, 2004, Leon and Moser, 2010).

Mean birthweights have increased and the proportion of low birthweight babies has fallen over the last century in high income countries (Chike-Obi et al., 1996, Alberman, 1991, Chowdhury et al., 2000). However, rates of low birthweight across low income countries remain high and this is important as low birthweight is strongly associated with increased infant mortality and morbidity (Yasmin et al., 2001, Ashworth, 1998, Lira et al., 1996) and as such contributes to the disease burden in low income countries. Around 20 million infants worldwide are born with a low birthweight (United Nations Children's Fund, 2004), 95% of whom are born within low income countries. There is however some variation between low income regions, for example sub-Saharan African nations have reported a lower percentage of low birthweight births than South Asia (see table 1) despite their UN classification of being 'least developed countries'. In fact half of all the low birthweight babies born in the world have been born within South Asia (United Nations Children's Fund, 2004) and the resulting impact upon mortality is substantial. Figure 1 is a global map drawn to reflect the proportion of infant deaths worldwide in 2002, countries with the highest number of infant deaths have been inflated in terms of area and those with low death rates are shrunken. India reported around 1.7 million infant deaths in 2002 or 24% of the world total and as such its size is vastly inflated on the map.

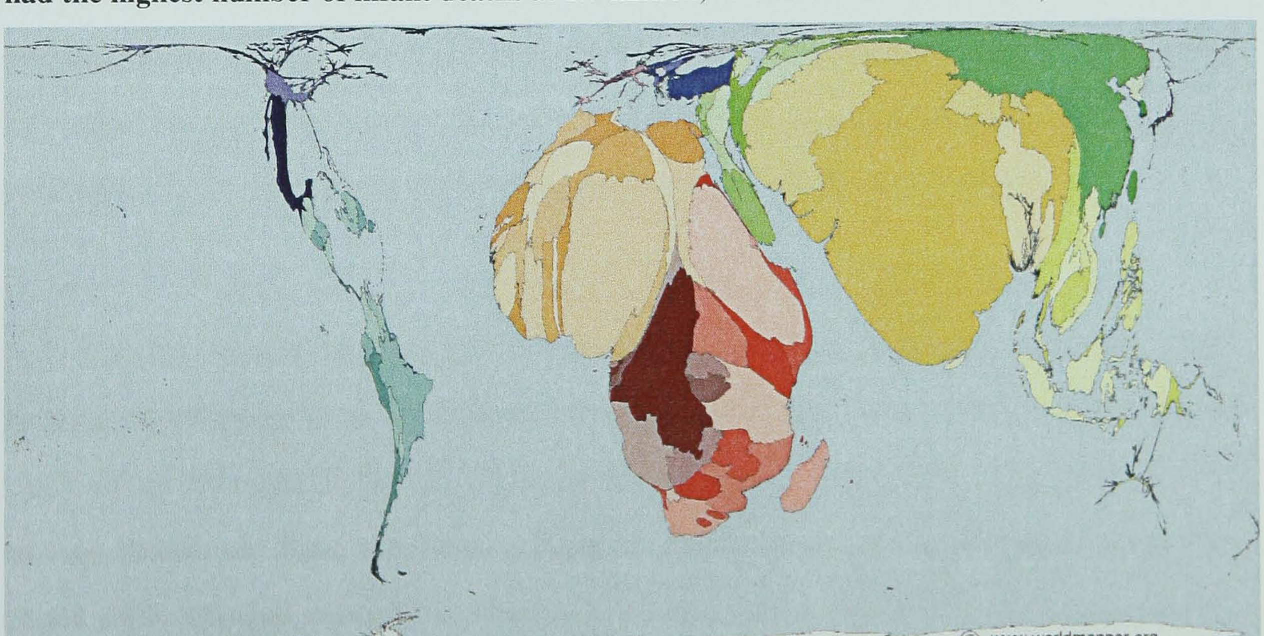
Table 1 UNICEF/WHO estimates of the incidence of low birthweight and infant mortality rates

Country	% of low birth weight infants (2000-2007)	Number of low birth weight infants (1,000s)	Infant mortality rate (2009)
Bangladesh	22	1268	40
Botswana	10	5	37
Eritrea	14	32	44
Ethiopia	20	427	70
Haiti	25	51	59
India	28	7,837	50
Pakistan	19	994	71
Sweden	4	4	2
UK	8	52	5
USA	8	323	7

UNICEF, Trends in infant mortality rates 1960-2010 (http://www.childinfo.org/mortality_imrcountrydata.php)

UNICEF, Low birthweight (http://www.childinfo.org/low_birthweight_table.php)

Figure 1 Infant mortality global map- territory size shows the proportion of infant deaths worldwide that occurred there in 2002 (Although the highest IMR's were seen in Africa, India had the highest number of infant deaths at 1.7 million, or 24% of the world total)



Thus, whilst low birthweight is generally thought to be a consequence of maternal nutrition and environment, differences across low income regions (Table 1) which are likely to experience equivalent nutritional challenges, suggest that ethnic disparities may be affected by other factors including maternal exposures during pregnancy, for example smoking, alcohol intake, maternal cardiovascular health and maternal glycaemia, and maternal size and genetic factors. This is supported by the persistence of ethnic differences in migrant populations. For example, babies born to South Asian mothers in the US, Europe, New Zealand and UK weigh significantly less than the indigenous population suggesting that exposures that persist with migration to high income countries are important. Within the US a number of studies have reported smaller mean birthweights and higher proportions of low birthweight among South Asians, particularly Asians of Indian origin (Hayes et al., 2008, Madan et al., 2002a, Fuentes-Afflick and Hessol, 1997). Interestingly, in the US, South Asian Indians are generally more affluent than other migrant groups but factors usually found to have a protective influence against low birthweight such as high levels of education and high social economic status, are reportedly not protective among US Asian Indians (Gould et al., 2003, Alexander et al., 2007). By contrast, other migrant groups in the US, for example Mexicans and Hispanics appear to have low rates of low birthweight despite seemingly unfavourable social and economic risks (Rosenberg et al., 2005, Gould et al., 2003). In these groups migrant status appears to confer some advantage in terms of birthweight whereas the continued lower birthweights of South Asians again suggests an element of genetic predisposition or persistent environmental exposures in the host country.

Similar trends were seen in other high income countries including New Zealand (McCowan et al., 2004) and Singapore (Hughes et al., 1986). In Europe, a study of birthweight in Norway identified the rate of low birthweight to be higher among Pakistanis than any other ethnic group (Vangen et al., 2002). In the UK, recent data reported mean birthweight as 3075g, 3082g and 3130g for Bangladeshis, Indians and Pakistanis respectively. This compares to a mean birthweight of 3393g in the White British population (Moser et al., 2008). Furthermore, rates of low birthweight in Indians, Pakistanis and Bangladeshis in the UK (10%) are almost double the rate for White British infants (5.6%). These data include births at all gestations and as such include pre-term births which may account for some of the difference. However, ethnic differences persisted when analyses were restricted to births at 40 weeks gestation (Moser et al., 2008) and similar differences were reported for term babies in the UK Millenium Cohort Study (Kelly et al., 2008) which also identified significant differences in the prevalence of term low birthweight between South Asians and White British populations, particularly between Pakistanis (6%) compared to White British (1.4%).

Generally ethnic comparisons have been based on birthweight alone as it is the most commonly reported measure of birth size and available in most countries of the world and for most ethnic groups within countries. However, birthweight alone cannot explain what contributes to differences in size. It reflects a number of components including bone, muscle, fat and fluids (Shields et al., 2006). Thus, a low birthweight does not inform as to whether for example, the infant is universally small, has a large head and a small body or is small but has a high percent body fat. Studies that extend their assessment of size to include additional anthropometric measurements such as head circumference or skinfold measures are less common but these can help inform underlying aetiology. Five papers were identified that have compared circumference and skinfold measurements among South Asian and UK populations (Chetcuti et al., 1985, Yajnik et al., 2002, Yajnik et al., 2003, Krishnaveni et al., 2005, Leary et al., 2006a) and all reported that South Asian infants were smaller in all measurements but that the magnitude of difference differed by measurement. Yajnik's studies of Pune (India) babies and white UK babies (Yajnik et al., 2002, Yajnik et al., 2003) described these differences in terms of a specific thin-fat phenotype of South Asians. These are discussed in more detail later in this chapter.

The detailed birth measurements collected for this study (birthweight, head, MUA and abdominal circumferences and skinfolds) will contribute to this area by providing a comprehensive assessment of birth size, rather than just weight, to examine the mechanisms underlying differences in size between Pakistani and White British babies in Bradford.

2.3 What factors may influence ethnic variations in birth size?

In this section factors that may influence birth size differences between South Asian and white western populations are discussed. The relevant research question is:

Do socioeconomic position and maternal pregnancy characteristics (including age, parity, BMI, maternal glucose tolerance, hypertensive disorders of pregnancy, smoking, alcohol and antenatal attendance) explain or mask any identified ethnic differences in birth size and adiposity?

Understanding ethnic differences in birth size is not straightforward as the potential causes of restricted growth are considerable, complex and not fully understood. As noted above, most research in this area has assessed birthweight only and therefore the following is mostly a summary of the evidence for factors known to be associated with variation in birthweight. Evidence regarding which of these are likely to explain or mask differences between South Asian and white babies in the UK, the focus of this thesis, is also discussed.

2.3.1 Social and economic factors

In high income countries major disparities in birthweight have been evident across different social groups (Bambang et al., 2000). Lower social groups have lower birthweights (Spencer et al., 1999) and although mean birthweight has increased over the last century the social economic gradient in birthweight has remained unchanged (Spencer and Logan, 2002). In the UK, Pakistani and Bangladeshi communities are on average very poor (Nazroo, 2001). As a consequence social economic position may contribute to ethnic variations in birth size and ethnicity may be a marker for social disadvantage in birthweight differences

(Nazroo, 2001). Indeed, data from the Millenium Cohort Study (MCS) suggest that socioeconomic factors accounted for 23% of the 305g difference in mean birthweight between Pakistani and White British babies (Kelly et al., 2008). Any effect of socioeconomic position on birthweight is likely to be mediated by more proximal characteristics such as smoking. In fact, a systematic review concluded that maternal smoking was the strongest explanation for the association of socioeconomic position with variation in birthweight (Kramer and Seguin, 2000). Since smoking is uncommon in women of South Asian origin this is probably an unlikely explanation for birthweight differences between South Asian and European origin infants but is discussed in more detail below.

Poor antenatal care attendance has been associated with lower socioeconomic position and has been found to increase the risk of low birthweight (Blondel and Marshall, 1998, Humphrey and Keating, 2004) although in very different populations to those reported in this thesis. In the UK, Firdous & Bhopal (Firdous and Bhopal, 1989) found that South Asians generally were less well informed about antenatal services and used them less despite equal access being available, although no more recent evidence was identified to suggest that this is still the case. They also identified low levels of literacy and English was commonly a second language, both factors that can hinder uptake of health services firstly in terms of direct communication with health workers, but also in terms of a poor understanding of health services and how they operate (Abba, 2001).

2.3.2 Maternal behaviours

A number of maternal health-related behaviours have been associated with birthweight. Key amongst these is maternal smoking in pregnancy which is strongly and consistently associated with lower birthweight across a range of studies (Messecar, 2001, Jackson et al., 2007, Pringle et al., 2005) resulting in a reduction in birthweight of around 200g (Pringle et al., 2005). However, historically smoking is uncommon in South Asian women in the UK and therefore unlikely to be a major cause of lower birthweight in South Asian compared to other populations. Within the MCS, the prevalence of smoking in pregnancy was reported to be 4% in Pakistanis and Bangladeshis compared to 37% among White British women

(Hawkins et al., 2008). However rates of smoking in South Asian women appear to rise with length of residency in the UK (Hawkins et al., 2008, Health Survey for England 2004, 2006) which could mean that birthweight in South Asian populations remains low (compared to European populations) across older generations of migrants, but that this represents a shift in underlying mechanisms from ones related to genetics or lifestyles from the country of origin to one that reflects an increase in smoking in more recent generations. This increase is captured by Health Survey for England (HSE) 2004 data that found 3% of Pakistani first generation women aged between 16 and 49 smoked compared with 8% of second generation women (Leon and Moser, 2010). Using the estimated birthweight deficit of 200g, (Leon and Moser, 2010) applied the Health Survey for England smoking prevalence rates to calculate the potential effect of smoking on any generational difference in birthweight. They found that if the HSE figures applied in pregnancy (some women stop smoking in pregnancy therefore this calculation could be over-estimating any effect) babies of second generation Pakistani mothers would weigh around 10g less than first generation. Such a minor difference is unlikely to influence or mask any generational changes in birthweight among Pakistanis. In contrast to South Asian women, rates of smoking among South Asian men are similar to those of the general UK population, 26% of Pakistani men smoke in the UK compared to 27% among the male population as a whole. The one exception is UK Bangladeshi men, 44% of whom smoke (DH, 2002) but in contrast to the established association between maternal smoking and low birthweight, paternal smoking exerts little if any influence on offspring birthweight (Davey-Smith, 2008).

Alcohol consumption has been commonly under-reported making it difficult to evaluate the true associations that it has with health outcomes, and this may be particularly true within South Asian communities. There is inconsistent evidence regarding whether low levels of alcohol consumption in pregnancy is harmful to normal growth and development, with these inconsistencies likely to reflect difficulties in accurately measuring intake during pregnancy. In a birth cohort from the Netherlands, infants of women who consumed more than 1 unit per day had infants with a lower birthweight (Jaddoe et al., 2007) but given the difficulty of measuring alcohol consumption in pregnancy accurately, and of fully controlling for potential confounding factors, it is difficult to know just what the magnitude of the association (not to mention independent causal impact) of alcohol is on birth size. Alcohol consumption is uncommon in South Asian women, the MCS found that 0.1% of Pakistani mothers reported drinking alcohol during pregnancy compared with 11.1% of white mothers (Kelly et al., 2008). Thus, if alcohol consumption is related to a lower birthweight, it may mask an even greater difference in birthweight between South Asian and White British populations.

Poor maternal nutrition at conception and throughout pregnancy has been associated with low birthweight (Prada and Tsang, 1996, Cann et al., 1987) but overall diet only appears to influence birth size in extreme circumstances and even then only results in minimal change. For example, the infants of pregnant women exposed to the Dutch famine of 1944-1945 had only small reductions in birthweight (compared to infants born just before the famine and those whose mothers were pregnant after the famine) and only in those whose mothers were exposed to the famine in late pregnancy (Stein et al., 2004). The Pune Maternal Nutrition Study (Yajnik, 2004, Rao et al., 2001) examined the relationship between birth size and nutrition during pregnancy in Pune, rural India. The subjects were known to be small, thin and undernourished but their intake of energy during pregnancy was not found to be associated with birth size. However, intake of nutrient rich foods such as green vegetables and milk was associated with birth size. Greater intake was associated with, on average greater birthweight although the mean difference was small and the association strongest among lighter and thinner mothers (Yajnik, 2004). Whilst there are differences in nutrient intake between different ethnic groups in the UK (Rees et al., 2005), none are likely to be severely compromised nutritionally. Among UK South Asians calcium, iron and vitamin D deficiencies have been reported (Thomas, 2002, Vyas et al., 2003) but on the strength of current evidence these are unlikely to result in important differences in birthweight once other potential confounding factors have been taken into account. Furthermore, differences in fetal size between South Asian and White European populations have been identified as early as 18 weeks gestation when rural Indians were smaller on sonography than white Europeans (Kinare et al., 2010). This suggests that ethnic differences in size may already be set early in pregnancy and that any effect of nutrition in utero, especially during second and third trimesters, is probably minimal. Since current evidence does not suggest that maternal dietary intake during pregnancy has a major effect on birth size or ethnic differences in this, diet has not been examined in this thesis as a potentially important cause of birth size differences between South Asian and white populations.

2.3.3 Other maternal and pregnancy characteristics

A number of non-behavioural maternal factors are relevant to birthweight. First, short maternal stature has been associated with an increased risk of having a small for gestational age (SFGA) baby and this association is reported to persist over at least 2 generations i.e. birthweight is lower in infants whose grandmothers were of shorter stature (Klebanoff et al., 1997). Leary et al (2006b) identified maternal height as a strong predictor of neonatal length and suggested that geographical differences in birth size can in part be explained by differences in maternal size. In the UK, South Asian women are slightly shorter than White British women (Kelly et al., 2008) but they also tend to have a higher BMI (Health Survey for England, 2004), although this is likely to be influenced by socioeconomic position, and higher BMI is associated with an increased birthweight (Frederick et al., 2008, HAPO Study Cooperative Research Group, 2010). Thus, South Asian women tend to be slightly shorter, which could explain smaller birthweight but on average, have a higher BMI which is associated with a higher birthweight.

Second, the prevalence of small for gestational age (birthweight below the 10^{th} percentile for gestational age and gender) is lowest in mothers aged 26-30 with similar increasing prevalence at younger and older ages outside this range (Lawlor et al., in press), with some evidence that young maternal age (<18 years) increases the risk of low birthweight (McCleod and Kielty, 1988). A large within sister analysis suggested that at younger ages this association is largely explained by shared familial characteristics such as socioeconomic position, whereas at older ages such characteristics may in fact mask larger associations (Lawlor et al., in press).

Third, increasing parity has also been associated with higher birthweights (Wilcox et al., 1996, McCleod and Kielty, 1988) although birthweight reportedly drops markedly with high parity (4 or more). As stated previously, few studies have reported birth size outcomes other than birthweight, however Joshi et al (Joshi et al., 2005) described the effect of parity on triceps and subscapular skinfold thickness (as measures of adiposity). Their study of 770 Indian mothers and babies found increasing parity was associated with increased birthweight and skinfold thickness, although women were grouped into primiparous women, second para women and third or more therefore it was unclear whether weight and skinfold thickness reduced with para 4 or more as described by McCleod & Kiely (1988). Early studies in the UK suggested that there were differences in maternal age and parity between Asian mothers and white mothers (Lindley et al., 2004) (Asian women tending to start their families at younger ages than white women and to have more children) and this may still be the case in first generation South Asian women. However, differences in parity have declined in second generation UK born South Asians (Harding et al., 2004, Dhawan, 1995).

Fourth, maternal glucose intolerance and diabetes have been associated with greater birthweight, fetal adiposity and risk of macrosomia (Ovanovic and Pettitt, 2001, Catalano et al., 2003). This association is continuous across the whole distribution of maternal glycaemia in pregnancy (HAPO Study Co-operative Research Group, 2008). South Asian populations have a higher risk of gestational diabetes compared to other ethnic groups (Nanda et al., 2011). Thus, given the robust associations of greater maternal glycaemia in pregnancy with greater birth size and infant adiposity, one would expect that South Asian babies would have higher birthweights and greater adiposity than white babies. It is possible that the difference in mean birthweight in South Asian and white babies is underestimated in studies that do not take account of maternal glycaemia in pregnancy, but that the difference in fat mass (and the thin-fat insulin resistant phenotype) are at least in part explained by ethnic differences in maternal glycaemia. This thesis is the first study, that I am aware of, that will be able to examine these possibilities.

Fifth, both low and high gestational blood pressure, have been associated with low birthweight (Steer et al., 2004, Wollmann, 2009). In particular pre-eclampsia has been importantly associated with intrauterine growth restriction (Ness and Sibai, 2006, Geelhoed et al., 2010) and a recent detailed analysis in a UK cohort found that ethnicity was an independent (of socioeconomic position and a range of other maternal risk factors) predictor of hypertensive disorders of pregnancy. Specifically, women described as Black, Pakistani and Indian were more likely to experience late pre-eclampsia (Poon et al., 2010).

Last, gestational age at delivery has been associated with birthweight and there is some evidence that gestational length varies by ethnic group (Kelly et al., 2008, Patel et al., 2004) although findings are inconsistent. Patel et al (2004) found a higher proportion of pre-term deliveries in Asians compared to White Europeans (6.5% and 5.1% respectively). However, data from the Millenium Cohort Study suggest that when South Asian populations are categorised according to country of origin, the proportion of pre-term births varies between these different groups, with the proportion in Indian women (9.5%) being higher, and that in Pakistani women lower (5.7%) than the proportion in white women (6.7%) (Kelly et al., 2008). Including pre-term births in estimates of mean gestational length masks potential differences in term gestation and it has been suggested that what constitutes 'term' may vary by ethnic group with South Asian infants in particular reaching maturity at an earlier gestation than white populations (Balchin et al., 2007). As noted in the introduction, in order to focus on low birthweight specifically, the analyses in this thesis include only infants born at 37 weeks gestation or more although any ethnic differences in mean gestation beyond 37 weeks will be reported.

2.3.4 Neonatal factors

The only notable neonatal influence is gender which is known to influence birthweight. Boys have been reported to have a higher mean birthweight than girls and a lower rate of low birthweight (Halileh et al., 2008) and this gender difference has been seen in most ethnic groups in the UK including South Asians (Margetts et al., 2002). By contrast, girls have been found to have higher skinfold thickness measurements at birth, possibly reflecting greater adiposity (Luque et al., 2009, Rodriguez et al., 2005).

2.3.5 Genetics

Birthweight has been described as a highly heritable phenotype, but in fact family studies over the last 6-7 decades have reported heritability rates between 0-70% for birthweight (Gjessing and Lie, 2008). The genetic contribution to birth size is complex as maternal genetic variation, via the intrauterine environment, may influence birth size. For example, women with genetic variants that predispose them to higher glucose levels or a greater propensity to smoke, may, via the influence of glycaemia and smoking during pregnancy, influence their offspring birthweight.

Freathy et al (2010) identified two fetal genetic variants that influence birthweight, one of which is associated with an increased risk of diabetes in later life. They suggested that individuals that inherit two risk copies of this gene have a 25% higher risk of diabetes than individuals who inherit two non-risk copies. This suggests that the recognised association between low birthweight and diabetes in later life may have a genetic component. However, Freathy et al (2010) reviewed 19 studies where all study samples were of European ancestry, and whilst genetic differences between populations are thought to be modest (Witherspoon et al., 2007), it cannot be assumed that these findings would be repeated across other population groups. Investigation of similar associations among South Asians is needed but is beyond the scope of this thesis.

In migrant populations, acculturation may have some bearing on inherited genetic traits. It is notable that some migrant South Asian communities remain very close knit and integration with the indigenous population is minimal. This can create a relatively homogenous group in genetic terms (Steijn et al., 2009) which may contribute to the persistence of fetal growth patterns.

In this thesis I have examined the following as factors that might explain or even result in an underestimation of differences in birth size between UK born babies of Pakistani or UK origin:

- Social economic circumstances
- Smoking
- Alcohol
- Maternal age
- Parity
- Maternal size (height, BMI)
- Maternal diabetes
- Maternal hypertensive disorders
- Sex
- Gestation

These are chosen on the basis of available evidence that they are associated with birth size and that these distributions are likely to vary between babies of South Asian and UK origin. To my knowledge no previous study has been able to explore the impact of all these characteristics simultaneously with ethnic differences in birth size. The direction of associations with birthweight and ethnicity and hence the likely effect they would be predicted to have on differences in birthweight between White British and South Asian populations is summarised in Table 2. Of relevance to this thesis, this summary focuses largely on the situation in UK South Asian and white populations.

Table 2 Summary of factors that may influence ethnic variations in birthsize

Factor	Summary of association with birth weight?	Summary of how the characteristic differs between South Asian and White populations	Comment
1.Socioeconomic	Mean birthweight lower and rate of low birthweight higher in infants of women from lower socioeconomic groups	In the UK, in general, South Asian populations tend to be in lower socioeconomic groups	Socioeconomic position may confound differences in birthweight between South Asian populations – i.e. difference may be exaggerated if socioeconomic position is not fully accounted for in the analysis
2.Smoking	Consistently associated with lower mean birthweight and higher rates of low birthweight in a large number of studies. Suggested that smoking mediates much of the association of socioeconomic position with low birthweight	Early generations of South Asian women did not smoke. Some evidence that more recent generations are more likely to smoke, but prevalence is still lower than that of white women	The higher prevalence of smoking in white women would be expected to result in their having lower birthweight infants. Thus, smoking might mask an even larer difference in birthweight between South Asian and white populations than is reported if this is not taken fully into account
3. Alcohol	Greater alcohol intake in pregnancy may be associated with lower mean birthweight but the nature (e.g. continuous across the whole spectrum of consumption or threshold at higher levels only) and magnitude of associations is difficult to determine because of measurement error and likely confounding	Alcohol consumption in South Asian women is unusual	If alcohol association is related to lower birthweight, then as with smoking (see above), this may mask an even larger difference in birthweight between South Asian and white populations if it is not fully taken into account

Factor	Summary of association with birth weight?	Summary of how the characteristic differs between South Asian and White populations	Comment
4. Maternal age	Young and old maternal age is associated with an increased risk of low birthweight (risk is lowest where mothers are age 26-30). In young mothers largely explained by familial characteristics (e.g. socioeconomic position), in older mothers such factors likely to mask larger associations	South Asian women tend to start families at a younger age and continue to an older age than white women	If differences in maternal age between South Asian and white mothers persist could contribute to the observed difference
5.Parity	In general mean birthweight increases with increasing parity in all ethnic groups up to parity 4 (from 4 or more it tends to decrease)	South Asian women are likely to have higher parity than white women	Any effect would depend on the parity/birth order of a particular baby in a given cohort study. If all parities are included then will be influenced by how many parity 4 or more are included (particularly in the South Asian women). Parity could exaggerate or mask the birthweight difference
6. Maternal size	Taller women tend to have babies with longer birth length and women with higher early/pre-pregnancy BMI tend to have babies with higher birthweight	On average South Asian women in the UK tend to be shorter and to have higher mean BMI than do white women (though the difference is also influenced by socioeconomic position differences between the two ethnic groups)	Greater BMI/adiposity in South Asian women would be expected to result in greater birthweight (and possibly more adipose) infants and this may mask the observed difference in South Asian and white birthweights. Shorter stature could result in smaller birthweight and explain some of the difference

Factor	Summary of association with birth weight?	Summary of how the characteristic differs between South Asian and White populations	Comment
7. Maternal glycaemia	Higher maternal glucose in pregnancy associated with greater birthweight and fetal/infant adiposity and risk of macrosomia	South Asian women more at risk of gestational hyperglycaemia and diabetes	Could mask the observed difference in birthweight but explain a difference in adiposity (South Asian babies have higher adiposity at a given birthweight than white babies) and the thin-fat insulin resistant phenotype
8. Maternal hypertensive disorders of pregnancy	Pre-eclampsia is associated with lower birthweight (independent of gestational age)	Some evidence that late onset pre-eclampsia may be more common in South Asian women than white women	Could contribute to the observed difference in birthweight between South Asian and white women
9. Attendance for antenatal care	Some evidence that poorer attendance for antenatal care is associated with lower birthweight	Some evidence that women of South Asian origin less likely to take up all antenatal care than white women (though this may vary by socioeconomic position)	Could contribute to an observed difference

The 'observed difference' referred to in the comment column of the above table is largely the observation that birthweight in South Asian populations is lower than in white populations; where adiposity at birth is referred to, the assumption is that this might be larger (once birthweight is accounted for) in South Asian populations than in white populations in line with the thin-fat insulin resistant phenotype

2.4 Generational differences

In this section, generational differences in birthweight in South Asian migrants are examined. This discussion focuses specifically on birthweight as no relevant published studies were found that reported additional measures of size (i.e. head circumference, skinfold measurements). All studies of South Asian populations were included as only two studies specific to Pakistanis were identified (Leon and Moser, 2010, Harding et al., 2004). Evidence from UK studies and other high income countries is included and is relevant to the following research question:

Are the magnitudes of any differences in birth size between Pakistani and white origin infants different depending upon whether the parents, grandparents and great-grandparents of the Pakistani origin infants were born in Pakistan or the UK?

As discussed earlier in this chapter, babies born in high income countries to mothers of South Asian origin are generally lighter than babies born to the indigenous population. This might be expected in first generation mothers who are likely to have been exposed to poverty in their earlier lives, but how these differences change over generations is unclear. This is important as if birthweights of subsequent generations begin to move closer to the indigenous white population, it would suggest that host country environmental characteristics, such as better housing, nutrition and antenatal care, explain the differences. By contrast, if birthweights remain similar over generations it would suggest that differences are genetically determined or are affected by epigenetic or persisting behaviour characteristics with effects lasting for several generations. Knowing and understanding more about this process may be important to reducing health inequalities. Understanding these mechanisms should include ethnic differences in body composition (see later section on the thin-fat insulin resistant phenotype and fat-preserving tendency). Simply aiming to identify interventions to increase birthweights of South Asian populations, in order to reduce health inequalities between ethnic groups, may be too simplistic. Indeed Muthaya (Muthaya et al., 2006) suggested that increasing birthweight could be associated with disproportionately greater adiposity in South Asian babies which may then be potentially damaging to long term health. Again this is explored in more detail later in this chapter within the thin-fat insulin resistant phenotype discussion.

Classifying pregnant women and their newborn babies by generational status is not straightforward and there is no clear, universally recognised definition of 'first' 'second' or 'third' generation. Generally, previous studies have defined generation based on the subject's place of birth, i.e. if the mother is born in the UK they categorised as 'second' generation and if born outside the UK 'first' generation (Dhawan, 1995, Draper et al., 1995, Margetts et al., 2002, Harding et al., 2004). The Millenium Cohort Study took this one step further by reporting whether the mother's mother and father were UK or non-UK born. The mother was classified as an immigrant if they and their parents were born outside the UK, first generation if they were born in the UK but at least one parent was non-UK born, and second generation if they and both parents were UK born (Hawkins et al., 2008). This is manageable for the mother's status but without paternal data will arguably be insufficient to accurately describe the generational status of the infant, particularly in terms of a potential 'third' generation. Clearly routine or registration data will only permit a crude assessment of born within or outside the UK. To establish precise categories and definitions of generation, intricate ancestry information incorporating both maternal and paternal lines is necessary but no studies with such detail were identified for this review.

Most generational studies of birth size in South Asian migrants have been UK studies and are discussed below. Only one non-UK study was found. Steijn et al (2009) reported birthweights in fourth and fifth generation South Asian immigrants living in Surinam, a former Dutch colony in South America, and compared them with earlier data from Pune, India. It is not clear how generation is defined from the report and moreover this was not strictly a study across generations of the same community as birthweights of fourth and fifth generation migrants were compared with birthweights of babies born in their country of origin. In fact, the main aim of the study was to identify whether the fat thin phenotype identified in Indian babies (discussed later in this chapter) persisted in migrant communities and as such also involved comparison with white UK born infants. The mean birthweight of the Surinam fourth/fifth generation babies was higher (3159g) than the Indian (2666g) babies but lower than the white UK birthweights (3494g). The Indian data were drawn from an earlier study (Yajnik[1] et al., 2003). Without birthweights from earlier Surinam generations or more recent Indian data, it is not possible to directly compare the Indian and Surinam birth weights or suggest any important change across generations. In addition, the mean birthweight for Surinam as a whole was 2990g (WHO 1992 – more recent data unavailable) which was similar to the mean birth weight of 2790g in India (WHO Global Survey on Maternal & Perinatal Health www.who.int/reproductivehealth/topics/best_practices/globalsurvey accessed on 21.1.2010) and therefore raises the question of whether the Surinam environment is any more advantageous in terms of birthweight than that in India. The fact that the mean birthweight for the South Asian migrants in Surinam was higher than both the mean birthweight for India and for native Surinamese, could indicate that this was a select group of migrants that may not represent South Asian migrants elsewhere.

2.4.1 UK generational studies of South Asian birth weights

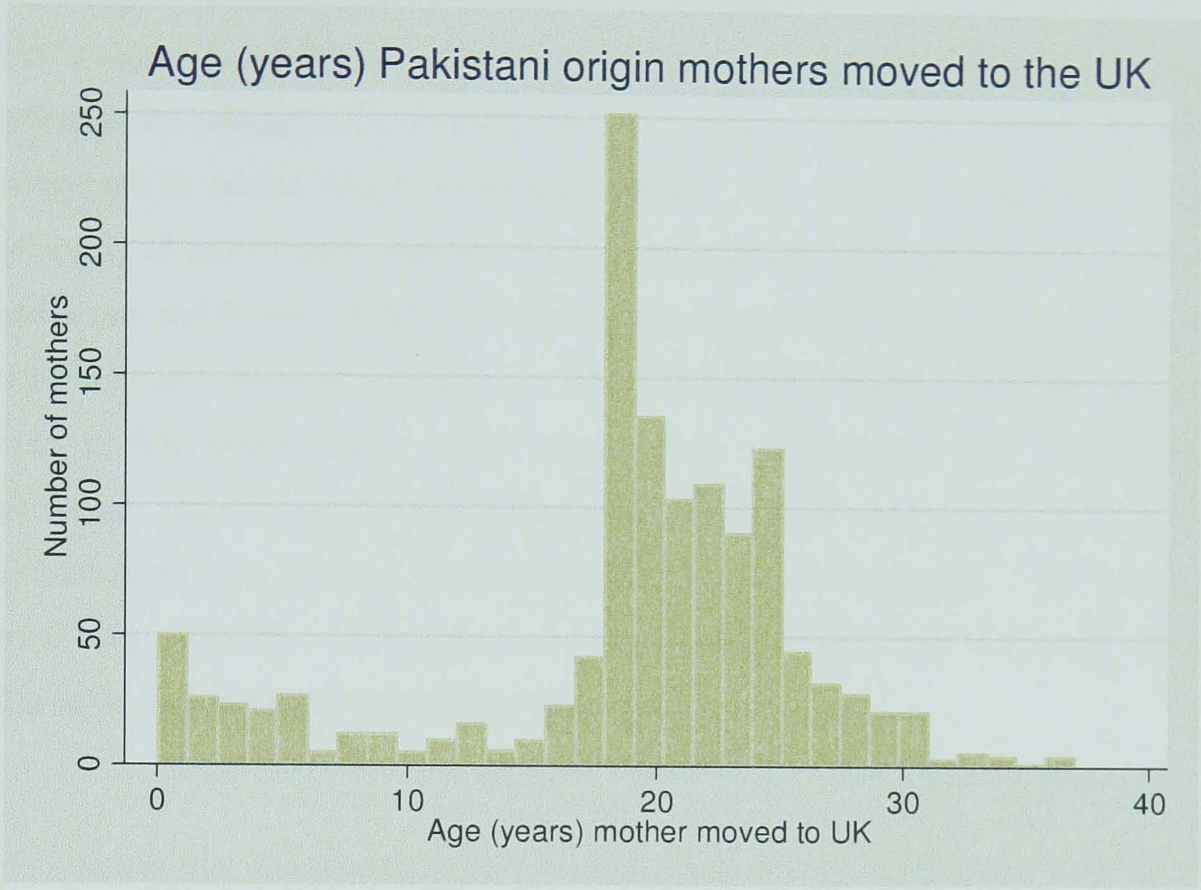
Table 3 summarises the methods and findings of UK based generational studies of birthweight in South Asian compared to white babies. Five studies were found that have compared differences in birthweight between first and second generation (none were found that include third generation) South Asian women in the UK. Four reported no increase in birthweights (Draper et al., 1995, Margetts et al., 2002, Harding et al., 2004, Leon and Moser, 2010), in fact three reported mean birthweight as slightly higher in babies of first generation than second generation mothers (Draper et al., 1995, Harding et al., 2004, Leon and Moser, 2010) although the difference was slight and only statistically significant (at conventional 5% levels) in one (Leon and Moser, 2010). One study, the smallest with a sample of 331, found higher mean birthweights in second compared to first generation offspring (Dhawan, 1995). All five studies were retrospective reviews of routine birth notification or clinical / case note data, the largest (Leon and Moser, 2010) used routine birth registration records linked to ONS data for England and Wales, three used local populations (Dhawan, 1995, Draper et al., 1995, Margetts et al., 2002) and the fifth was based on a 1% sample of the national population (Harding et al.. 2004). All but the Dhawan study (1995) had large sample sizes (all > 2,300). Below I discuss the key issues of these studies in more detail.

Overall the five generational studies identified did not suggest that birthweight was increasing over successive generations of UK South Asian migrants. Only the smallest study (Dhawan, 1995) reported a significant increase in birthweight between first and second generation South Asians, an adjusted mean difference of 280g in the birth weights of second generation compared to first generation mothers. Across all five studies there are a number of factors that potentially affect the interpretation of results.

First, all five studies included some adjustment for potential confounding factors, although this was limited, dependent on the data source and varied by study (detailed in Table 3). Only one study (Margetts et al., 2002) restricted analysis to term births (37 weeks gestation and over), however Dhawan (1995), Draper (1995) and Leon and Moser (2010) all included adjustment for gestational age in their analyses. Harding et al (2004) used census and birth registration data which does not include gestational age and as a result were unable to account for gestational age resulting in a data set of both pre-term and term births. As discussed previously, there is some evidence of ethnic variations in gestational length (Patel et al., 2004). A higher proportion of preterm births in South Asians could result in a lower mean birthweight.

Second, in all five studies generational status was based on maternal place of birth which excluded any possible paternal influence. The precise paternal contribution to birthweight is unclear but paternal characteristics, notably height and birthweight, have been found to influence offspring birthweight (Knight et al., 2005). The idea that second generation South Asian women can benefit from a more affluent UK environment must also apply to a second generation father. This may be via a biological mechanism (better childhood health and development) or through improved education, language and the ability to access services. Either way excluding paternal birth place from generational classification may well limit how best to interpret comparisons across generations. A further complication of classifying generation is that patterns of migration suggest a significant number of South Asians migrate to the UK in childhood. Early data from the BiB cohort (Figure 2) suggested that around 11% of mothers who stated they were born in Pakistan, moved to the UK before they reached school age (age 5 or under). Hence their place of birth may be recorded as South Asia but it is plausible that much of their childhood and development took place in the UK. It is impossible to judge how important this may be in any of the studies under discussion here but potentially it could dilute any differences between the two generations and serves to highlight the lack of detail in routine data sources. Similarly, the second generation group in all five studies potentially included women who may in fact be third generation as categorisation is based on maternal place of birth and does not include the place of birth of the baby's grandmother. This becomes relevant if improvements in birthweight take more than one generation to emerge, which is likely. If increases in birthweight by generation are found, as in the Dhawan (1995) study, including third generation women in this group could overestimate the increase in second generation birthweights. Or conversely, where no differences are found as in the other studies, increases in birth weights of babies born to third generation mothers may be masked by a greater number of offspring of second generation mothers. Again, this is a limitation of clinical / registration data and unavoidable in all five studies. The title of the Draper (1995) study suggests that data for a third generation are reported. However no data are presented for third generation mothers and it seems likely that the 'third generation' label refers to babies (i.e. babies of second generation mothers), which is confusing as the 'first' and 'second generation' labels used in the report are applied to mothers.

Figure 2 BiB data for the age at which Pakistani born mothers moved to the UK



An important factor in all five studies was their definition of ethnicity. Defining ethnicity is complex but important. The term not only incorporates race but also culture, language, religion and health beliefs (Chaturvedi, 2001). Three of the five studies (Dhawan, 1995, Draper et al., 1995, Margetts et al., 2002) categorised all women broadly as 'South Asian' but there can be important heterogeneity between South Asian communities. For example, in the UK Indians are reported to be more advantaged in socioeconomic terms and better educated than Pakistanis and Bangladeshis (Bhopal et al., 2002, Pickett et al., 2009). Indeed Leon and Moser (2010) reported clear social and demographic differences across ethnic groups. It is therefore not surprising that differences in mean birthweight are apparent when analyses are specific to country of origin rather than a general region of origin (Leon and Moser, 2010, Harding et al., 2004). In one study (Draper et al., 1995) additional analyses were undertaken for Muslim mothers (around 1/3 of the overall sample), which potentially can result in a more homogenous group (Bhopal et al., 1991). Birthweights of babies born to second generation Muslim mothers were on average 76g lighter than babies born to first generation mothers, almost double the difference reported for the initial groups of all Asian women as a whole. No adjustment for potential confounders was undertaken for the Muslim birthweights and there was no breakdown by gestational age therefore the mean birthweights included those of premature infants and potential confounding effects. however the principle of categories based on religion could result in more accurate groupings in mixed South Asian populations. The higher birthweights among offspring of more recent migrants (first generation) reported by Draper et al (1995) and Leon and Moser (2010) are interesting and could reflect negative changes in behaviour as a result of living in the UK, for example smoking, although smoking rates in UK South Asian women remain low. Conversely, they could reflect persistent lifestyle and cultural behaviours that remain very similar in first and second generation mothers of close-knit South Asian communities. On the other hand they could be a consequence of being unable to fully deal with confounding due to the limitations of registration data.

In all five studies the main outcome measure was birthweight and no UK studies were found that include an analysis of other measures of birth size, e.g. head circumference, abdominal circumference or skinfold assessments over generations. On the basis of current evidence an increase in birthweights across generations of UK South Asians has not been clearly identified.

The lack of evidence to support a clear increase in birthweight, or certainly a consistent increase, suggests that either existing reports / methodologies have failed to identify an increase or that the lack of increase is real. A time trend analysis of South Asian birthweights over a 13 year period in Leicester, UK found that whilst South Asian birthweights had increased by the same proportion as White British birth weights, the gap between white and South Asian birthweights remained unchanged. Therefore, whilst overall all birthweights in all ethnic groups increased slightly, the difference between South Asian and white weights was stable (Chowdhury et al., 2000). Whilst it is not possible to draw direct conclusions from this study in terms of generation as it is impossible to define the generation of the South Asian mothers, this failure to 'catch up' suggests that South Asian birthweights are either not increasing, again suggesting a genetic, epigenetic or cultural influence, or that a longer time period (greater generations) is required before the inequalities in birthweight between South Asian and indigenous UK populations is realised. Indeed, (Kuzawa, 2004) suggested that changes in fetal growth are gradual and may take 3 or 4 generations to respond to environmental changes.

Research in my thesis will add to this area by clearly defining generation using information on mothers and fathers and maternal and paternal grandparents and by examining intergenerational differences in birthweight, head, arm and abdominal circumference and skinfold thickness at birth.

Table 3 UK generational studies of South Asian birth weight

Study	Type	Population	How is ethnicity defined?	How is generation defined?	Outcome	Main findings	Confounding factors included in analysis	Comments
Dhawan 1995	Retrospective case note review	Asian women who gave birth between Jan & Dec 1989 in Bolton, UK (all births included at any gestation) n=331 (220 1st generation, 111 2nd generation)	Not clearly stated-but assumed to be self-reported recording in case notes	Based on maternal line. Used case note record of place of birth, 1st generation born in Asia, 2nd generation born in UK	Mean birth weight	At all gestations 2nd generation mean birth weights were higher than 1st generation. Overall mean birthweight for 2nd generation was 3196g, 2946g for 1st generation. Difference of 280g remained after adjustment for potential confounders	Maternal age Maternal height Maternal weight Marital status Parity Gest at delivery Social class Smoking status	South Asian (SA) women grouped together, not by country. Generation based on maternal line only. 2nd generation may include 3rd generation. Not all data presented particularly from regression analysis. Small numbers in some comparisons. P-values, no CIs reported.

Study	Type	Population	How is ethnicity defined?	How is generation defined?	Outcome	Main findings	Confounding factors included in analysis	Comments
Draper et al 1995 (Correspondence)	Cross-sectional review of birth notification data	Asian women who gave birth between 1991 & 1993 in Leicestershire, UK (all births included at any gestation) n=4562 (3784 1st generation, 778 2nd generation) Also sub-sample of just Muslim women compared by generation (n=1649)	Obtained from birth notification data: self-reported but may be completed by a health professional	Based on maternal line. Used mother's place of birth as recorded on birth notification	Mean birth-weight	For most comparisons mean birthweight was higher in babies of 1st generation mothers. For births between 37 and 40 weeks: mean birthweight in 1st generation group = 3061g, in 2nd generation = 3037g (ns). Significant difference found in mean birthweight (unadjusted) of 1st & 2nd generation Muslim sub-sample (3060g & 2984g respectively)	Maternal age Parity Marital status Gest at delivery	SA women grouped together, not by country. Generation based on maternal line only. 2nd generation may include 3rd generation. Small numbers in some comparisons Maternal height & weight not included as potential confounders. No adjustment in Muslim sub-group. P-values, no CI's reported

Study	Type	Population	How is ethnicity defined?	How is generation defined?	Outcome	Main findings	Confounding factors included in analysis	Comments
Margetts et al 2002	Retrospective cohort study	Mothers of SA origin who gave birth in Southampton between 1957 & 1996 (>37 weeks) -included women from East Africa & Fiji) n=2395 Generational analysis on sub-sample of mothers born in UK (2nd generation) n=283 & mothers born in Indian sub-continent (1st generation) n=1435	Identified by SA names of clinical birth records	Based on maternal line. Used mother's place of birth as recorded in clinical birth record	All information from birth records compared either by country of origin or as 1 SA group by generation (sub-group). Mean birthweight presented by country of origin & by 1st or 2nd generation SA. % low birth weight reported by generation	In overall analysis mean birthweight higher in Pakistani born SAs than UK born SAs. Sub-group analysis by generation reported mean birthweight in 1st generation = 3133g, in 2nd generation = 3046g (unadjusted). After adjustment for confounders difference not significant. % of low birthweight babies in 1st generation = 7.5% & 11.7% in second generation babies. No trend to increasing birthweights over 40 years in either SA born or UK born SAs	Maternal height Maternal weight Maternal age Parity Gest at delivery Gender	Mean birthweight reported by country of origin but all countries grouped together for generational comparison. Generation based on maternal line. 2nd generation may also include 3rd generation. Only study to analyse term births only. Census data used to confirm representativeness of study sample. CI's presented for means but p-value for statistical comparison between generations

Study	Type	Population	How is ethnicity defined?	How is generation defined?	Outcome	Main findings	Confounding factors included in analysis	Comments
Harding et al 2004	Retrospective cohort study	Mothers giving birth in the UK between 1983 & 2000 who were present at the 1991 census. Following some exclusions and missing data 57,674 births were included in analysis	Based on reported ethnicity in 1991 census	Maternal place of birth obtained from 1991 census	Mean birthweight	No significant differences between mean birthweight of 1st & 2nd generation SAs in all country groups except Bangladeshis where girls born to 2nd generation mothers had a significantly lower mean birth weight than girls born to 1st generation Bangladeshis	Maternal age Birth order Socioeconomic factors Gender	Analyses by country of origin rather than combined SA group. Census reporting of ethnicity likely to be more accurate than clinical records or name identification. Generation based on maternal line only. 2nd generation may include 3rd generation. No controlling for gestational age, therefore all gestations (pre-term & term) included in analyses. No adjustment for maternal height, weight, smoking but social-economic circumstances, maternal age, gender & birth order considered.

Study	Type	Population	How is ethnicity defined?	How is generation defined?	Outcome	Main findings	Confounding factors included in analysis	Comments
Leon & Moser 2010	Cross-sectional review of birth notification data linked to national ONS data	Live singleton births in the UK between 2005 & 2006 of White British, Bangladeshi, Indian or Pakistani origin where the mother was either born in England & Wales or in the country of her ethnicity. Births to South Asian mothers born elsewhere were excluded. Births that could not be linked to ONS data were also excluded (n=858,529)	ONS data for ethnicity was used, this is self-reported by the mother but in practice may be recorded by the health professional	Based on maternal line. Used mother's place of birth as recorded on birth notification	Mean birth weight	Infants born to UK born South Asian mothers had a slightly lower mean birth weight than those born to South Asian born mothers. For Pakistani origin infants, mean birthweight was 3148g in those with Pakistan born mothers compared to 3097g in those with UK born mothers, a difference remains following adjustment for gestational age, gender and maternal age	Gestational age Gender Maternal age Parity (only available for births in marriage therefore only considered in a sub-sample of around half the overall sample n=464,310)	Large sample size, remains large even when restricted to births born in marriage. Analyses by country of origin rather than combined SA group. Generation based on maternal line only. 2nd generation may include 3rd generation. No adjustment for maternal height, weight, smoking, social-economic circumstances, & birth order. Ethnicity may not always be self-reported if assumed and recorded by a health professional

2.5 Thin / fat insulin resistant phenotype

This section discusses the evidence relating to the thin / fat insulin resistant phenotype in South Asians. The specific research question that this relates to is:

Are Pakistani babies more centrally obese, as indicated by sub-scapular skinfold thickness, and do they have a greater proportion of fat mass, as indicated by subscapular and triceps skinfold thickness and cord blood leptin analysis at a given birth weight, than White British babies?

2.5.1 The thin / fat insulin resistant phenotype in South Asians

For the same percent body fat, South Asian adults have a BMI around 3-4 units lower than their white counterparts (WHO Expert Consultation, 2004). Indeed, for a given BMI South Asian adults, particularly those who have migrated to South Asian urban areas or to Europe and the USA, have greater central adiposity, low muscle mass, increased insulin resistance and higher rates of diabetes and cardiovascular disease than white Europeans (McKeigue et al., 1993, Deurenberg-Yap et al., 2002, Chan et al., 2009). This has led to the term 'thin-fat insulin resistant phenotype' to describe South Asian populations. Whether this phenotype is present in childhood or at birth is less clear, but if it is then low birthweight may, in South Asian populations, be associated with greater adiposity (including central adiposity) for a given weight and greater insulin resistance. This phenotype, if present at birth, may persist in adulthood and be related to the greater prevalence of type 2 diabetes and cardiovascular disease in South Asian adults. Thus, it is important to establish whether this phenotype exists at birth because if it does then it might signify that attempts to reduce birthweight inequalities might, if they result in greater adiposity in South Asians, actually result in greater health inequalities in later life. A UK population based study of children aged 8-11 years found that south Asian children had lower ponderal indices than white children but the same waist circumference and waist:hip ratio on average, suggesting that at the same body mass index south Asian children had greater central adiposity than white children (Whincup et al., 2002). Further insulin concentrations and insulin resistance were higher among

South Asian children (fasting insulin % difference 53%) although their exact association with adiposity was unclear. More recently, the Child Heart and Health Study (CHASE) reported similar findings among UK children aged 9-10 (Whincup et al., 2010, Nightingale et al., 2010). South Asian children had higher insulin concentrations (% difference 30.0% 95% CI 23.4, 36.9) and greater adiposity (sum of skinfolds % difference 5.1 95% CI 1.1, 9.4) although adiposity did not explain the differences in insulin levels. At any given fat mass, South Asian children had a lower BMI than their white counterparts. These results suggested that similar patterns of central adiposity and insulin resistance to those seen in South Asian adults, were present in childhood.

Yajnik et al (Yajnik et al., 2002) reported a study that compared anthropometric measurements at birth in 157 urban Indian babies (born to parents living in Pune, India) and 67 UK babies born to white parents living in London. For all anthropometric measurements the Indian babies were smaller than the white babies. However, the magnitude of the differences was much smaller for triceps and subscapular skinfold thickness than for the other measurements. With adjustment for birthweight there was no difference in subscapular skinfold thickness indicating that the Indian babies tended to have more central adiposity for a given weight than white babies (Table 4). These findings were replicated in a similar study (Yajnik et al., 2003) of rural Indian babies born in villages near to Pune (n=631), compared to White British babies born in Southampton, UK (n=338), again summarised in Table 4.

These studies of birth size differences relate to South Asian infants born and living in South Asia but there are established South Asian communities living elsewhere in the world particularly Europe and the US and changes in environment, may affect adaptive changes associated with the thin-fat insulin resistant phenotype. Only one study was identified that examined the fat-thin phenotype in South Asian migrants. Steijn et al (2009) compared birth anthropometry of Indian babies born in Surinam to fourth and fifth generation migrants (n=39) with existing data from 631 Indian and 338 White British infants recruited to the Pune study discussed previously

(Yajnik et al., 2003). The Surinam babies were lighter (mean birthweight 3159g) than the White British babies (mean birthweight 3494g) but heavier than the Pune infants (mean birthweight 2666g). Subscapular skinfold thickness was similar in White British and Surinam infants and also Pune infants (once adjusted for birthweight) suggesting that the thin-fat phenotype may be preserved in the Surinam infants despite reported increases in mean birthweight. This may not be entirely justified by the data. The Surinam sample included just 39 infants and these may not be representative of the Indian migrant community living in Surinam or of South Asian migrant populations elsewhere. The Surinam infants in this study were born to mothers of high social economic status unlike those in the Pune study and also were likely to be more affluent than the Surinam general population, indeed as noted above they appeared to have higher mean birthweight than the general Surinam population. This may not be the case for South Asian migrant communities elsewhere who experience poorer social and economic lifestyles than the general population of their host country. The results of this study may not be conclusive but, they draw attention to a potential problem for WHO and other health policy aimed at increasing birthweight in populations in all low and middle income countries and in migrant populations to higher income countries. If mean birthweight increases (as is the case in the Surinam infants) but a fat-preserving tendency is maintained, the effect may be simply to increase adiposity which in turn may worsen long term health. This was recognised by Muthaya et al (2006) who compared Indian birthweights with existing data (again taken from the Pune study, 2003). Higher birthweights were found to be associated with higher skinfold thickness measurements, suggesting greater adiposity in line with increasing mean birthweight. Therefore efforts to increase birthweight need careful consideration, at least until the influences on fetal growth and adiposity are better understood. As things stand, it is unclear whether the thin-fat phenotype persists in South Asian migrant populations, particularly those living in high income countries. The research in my thesis will directly assess this gap in knowledge.

Table 4 Studies of the thin-fat insulin resistant phenotype in South Asian infants and children

Study	Type	Population	Main outcomes	Main findings	Exclusions
Yajnik et al 2002 *Adiposity & hyperinsulinemia in Indians are present at birth*	Observational study	157 Indian babies (urban) 67 White British babies (London UK)	Birthweight; crown-heel length; head, arm, abdominal circumference; subscapular & triceps skinfold thickness(SSF & TSF); cord blood glucose, albumin, lipoprotein, cholesterol, triglycerides, insulin & leptin	Indian babies were lighter (median weight 2805g vs 3475g) & smaller for all other measurements but the difference was least for median SSF (4.1mm compared to 4.6mm), when similar birthweights were compared SSF was greater in Indians (median 4.4mm vs 4.1mm)	Births <37 weeks; multiple births; maternal hypertension; maternal diabetes
Yajnik et al 2003 *Neonatal anthropometry: the thin-fat Indian baby. The Pune Maternal Nutrition Study*	Observational study	631 Indian babies (rural) 338 White British babies (Southampton UK)	Birthweight; crown-heel length; ponderal index; head, arm, abdominal circumference; subscapular & triceps skinfold thickness(SSF & TSF)	Indian babies were lighter (mean 2666g vs 3494g) & smaller for all other measurements but the differences were least for SSF (4.2mm vs 4.6mm) & crown-heel length (47.7cm vs 49.8cm), when similar birthweights were compared SSF was greater in Indians (median 4.6mm vs 4.1mm)	Births <37 weeks; multiple births; maternal hypertension; maternal diabetes

Study	Type	Population	Main outcomes	Main findings	Exclusions
Whincup et al 2002 *Early evidence of ethnic differences in cardiovascular risk: cross sectional comparison of British SA and white children*	Cross sectional study	UK children age 8 to 11 years, 227 South Asian & 1287 White British	Height; weight; ponderal index; waist circumference; hip circumference; waist:hip ratio; blood pressure; heart rate; lipids, glucose & insulin concentrations	South Asians were lighter, slightly shorter and had a lower mean ponderal index (mean difference -0.43kg/m^3 95% CI -0.13, -0.73), mean waist circumference & waist:hip ratios were similar but mean insulin concentrations were higher among South Asians (% difference after glucose load and adjustment for age, sex, town, height & ponderal index = 42.7% 95% CI 12.8, 80.3)	Children of mixed race were excluded from the analysis
Whincup et al 2010 *Early emergence of ethnic differences in Type 2 diabetes precursors in the UK: CHASE Study*	Cross sectional study	UK children age 9 to 11 years, 1306 South Asian & 1153 White British	Height; weight; ponderal index; waist circumference; subscapular, triceps, suprailiac, biceps skinfold thickness; fat mass index; blood pressure; lipids, glucose & insulin concentrations	On average South Asian children had a lower mean ponderal index (% difference -1.8 95%CI -3.1, -0.4) & waist circumference (% difference-1.5 95%CI -2.6, -0.3)but higher mean sum of skinfolds (% difference 5.1 95% CI 1.1, 9.4), fat mass index (% difference 7.3 95% CI 2.8, 12.0), HbA1c (% difference 2.1 95% CI 1.6, 2.7), fasting glucose (% difference 0.8 95% CI 0.2, 1.5) and fasting insulin (% difference 30.0 95% CI 23.4, 36.9)	Type 1 diabetes

Study	Type	Population	Main outcomes	Main findings	Exclusions
Nightingale et al 2010 *Patterns of body size and adiposity among UK children of South Asian, black African-Caribbean and White European origin: Child Heart and Health Study in England* *(CHASE Study)*	Cross sectional study	UK children age 9-10 years, 1523 South Asians, 1345 White Europeans	Weight; height; waist circumference; subscapular, triceps, suprailiac, biceps skinfold thickness; fat mass percentage; BMI	South Asians had a higher adjusted mean sum of skinfolds (43.12 95% CI 41.97, 44.32 vs 41.25 95% CI 40.11, 42.41), higher adjusted mean fat mass percentage (29.22 95% CI 28.66, 29.78 vs 27.46 95%CI 26.90, 28.02) and lower adjusted mean BMI (17.96 95% CI 17.79, 18.14 vs 18.36 95%18.18, 18.55). At any given fat mass, BMI was lower in South Asians	Non-stated

2.6 Leptin as a biomarker of adiposity

Any investigation of the thin-fat insulin resistant phenotype requires a measure of fat mass that goes beyond birthweight or ponderal index which do not distinguish between lean and fat mass: at birth this is difficult. Assessments of neonatal body composition using either air displacement plethysmography (Gianni et al., 2009) or magnetic resonance imaging (MRI) (Modi et al., 2009) are expensive and thus, are generally used on relatively small sample sizes. Neonatal anthropometry (head, mid-upper arm and abdominal circumferences and skinfold thickness measures) whilst less precise, can provide useful estimates of patterns of adiposity, is not prohibitively expensive and can be assessed in large epidemiological studies. However, anthropometric measurements are characteristically less reliable and potential gains from a large sample size may be limited by less reliability. Reliability assessments are clearly important (as discussed in Chapter 4 later in this thesis) but examination of this phenotype and how it varies by ethnicity can be strengthened further by measurement of the hormone leptin.

Leptin is secreted by adipocytes and is known to play an important role in energy homeostasis (Zhang et al., 1994, Matsuda et al., 1997). It has been recognised as a biomarker of fat mass in adults (Cossidine et al., 1996, Mente et al., 2010), children (Hassink et al., 1996) and infants (Shekhawat et al., 1998, Schubring et al., 1999). Although mainly secreted by adipocytes, it is also found in other tissues, notably the placenta. Indeed, sharp decreases in leptin levels in the period following delivery suggest that in addition to fetal leptin, the placenta could be an important source of leptin in utero (Valuniene et al., 2007). Further, this may partially explain reported differences in cord leptin values by mode of delivery. It has been suggested that concentrations are significantly higher following vaginal delivery compared to elective caesarean delivery (Yoshimitsu et al., 2000), although this is not a consistent finding across all studies (Saylan et al., 2010, Marchini et al., 1998) and thus requires further investigation. There are also known differences in leptin levels by gender. Males have lower levels than females at any age, even after adjustment for differences in fat mass, and it has been speculated that these may be due to the effect of sex hormones on leptin production (Kuzawa et al., 2007) or be genetically derived (Matsuda et al., 1997).

As cord leptin is a marker of fat mass it is not surprising that a number of studies report a strong correlation with birthweight i.e. in general heavier babies are likely to be more adipose and thus have higher cord leptin concentrations (Karakosta et al., 2010, Cetin et al., 2000, Schubring et al., 1999). In South Asian populations, despite being smaller and lighter at birth, cord leptin is reportedly higher when compared to White British populations (Yajnik et al., 2002). It is suggested that this reflects greater adiposity among South Asian infants compared to White British infants (discussed earlier in this chapter) and although in general cord leptin concentrations are likely to be higher among heavier infants due their greater adiposity, higher cord leptin concentrations are also seen among smaller and lighter infants where they are shown to have a relatively high percent body fat (for example South Asian infants). Yajnik (2002) described higher leptin levels in term Indian babies (median leptin 10.4 ng/ml IQR 5.3-15.1) than White British infants of comparable birthweights (median leptin 4.6 ng/ml IQR 3.0-.6). This study (described previously in this chapter) compared anthropometric measurements between Indian and White British babies and found Indian babies to be more centrally obese at a given weight than White British infants. The additional reporting of cord blood leptin as a biomarker of adiposity, adds weight to the identified ethnic differences in body fat estimates between the two groups.

Cord blood leptin is therefore a useful biomarker of neonatal adiposity and is used in this thesis in a sub-sample (n=1388) to estimate percent body fat and examine differences in fat mass between White British and Pakistani babies.

2.7 Chapter summary and questions addressed in this thesis

In this review I have examined the literature related to the research questions of this thesis. This has included ethnic differences in birth size, factors that are known to influence birth size, changes in birth size across generations of South Asian migrants and literature related to the South Asian thin-fat insulin resistant phenotype.

I have noted key gaps in the current literature and how the research in my thesis addresses these. Specifically, I will be able to examine: (i) ethnic differences in birth size that go beyond birthweight by comparing differences in head, mid-arm and abdominal circumference as well as in skinfold thicknesses; (ii) examine a considerably wider range of characteristics that might explain or mask the observed ethnic differences in birth size than any previous study has been able to explore and thus increase understanding of the mechanisms underlying these differences; (iii) examine how birth size differences change with generation of South Asian migrants taking into account both maternal and paternal lines and (iv) compare indicators of the thin-fat insulin resistant phenotype between South Asian babies born in the UK in the same geographical area as white babies born in the UK.

The results of this review provide the foundation for this thesis and the subsequent chapters. The following chapter describes the methods used to answer my research questions.

Chapter 3
Methods

Overview

The aim and hypotheses of this study are outlined in Chapter 1. This chapter includes a description of the BiB project and the methodology used to answer my research questions.

3.1 Study population

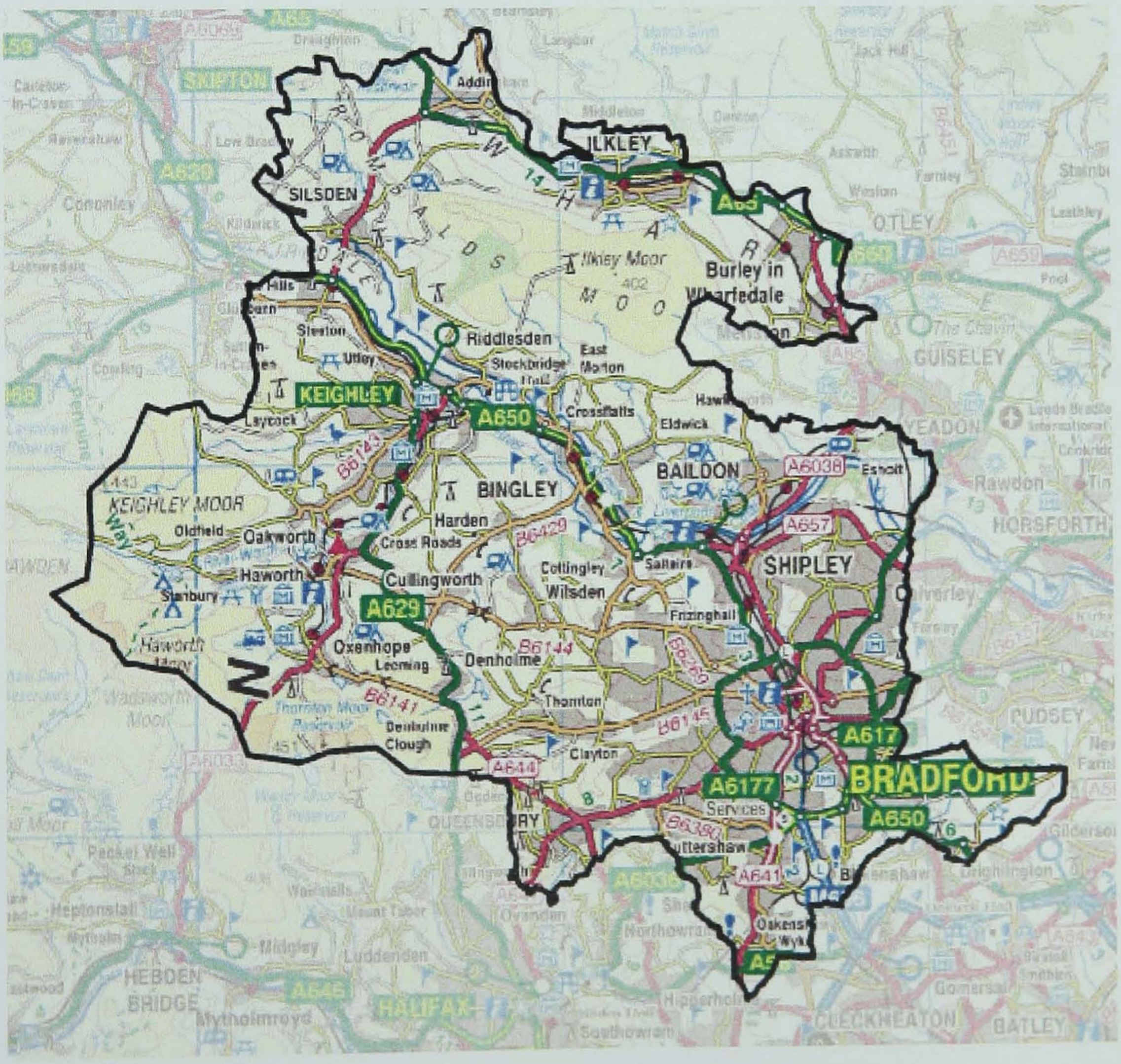
This study uses data from mothers, fathers and babies recruited to the Born in Bradford (BiB) project.

3.1.1 The population of Bradford

Bradford (shown in Figure 3) is a northern industrial city close to the Pennines and dales of Yorkshire. The district includes the smaller towns of Ilkley, Bingley, Shipley and Keighley (Figure 3). The city is the eighth most deprived health community in the UK. Deprivation, life expectancy, early deaths and infant deaths are significantly worse than the England average (Association of Public Health Observatories, 2008). Indeed babies born in Bradford are 1.7 times more likely to die in their first year of life than babies born in England and Wales as a whole (Bradford District Infant Mortality Commission, 2006). Health problems are wide-ranging and many are associated with deprivation and an ethnically diverse population.

Bradford has a population of 483,600 (Bradford District Metropolitan Council, 2008) and a long history of diversity. During the 1800's Irish migrants came to work in Bradford's expanding textile industry and by 1851 made up 10% of the population. The industry grew and attracted German wool merchants and workers from across Western Europe. After the Second World War and the resulting population shifts across Europe, Jewish, central and Eastern European immigrants arrived in the city. In the 1950's Asian and Afro-Caribbean immigrants came to Bradford and as a result of changes to immigration rules were encouraged to bring their families (Bradford District Metropolitan Council, 2008). By 1987, 64,000 Asian and Afro-Caribbean immigrants had made Bradford their home. Today ethnic minority communities account for 18% of the population and this is expected to increase to 26% by 2011 (Bradford District Metropolitan Council, 2008). Most are Pakistani (14.5%) and originate from the Mirpur region of Pakistan. The Pakistani community in Bradford has been a relatively stable group and there are now births to first, second and third generation Pakistani women.

Figure 3 Bradford District (Taken from Bradford District Infant Mortality Commission Report 2006)

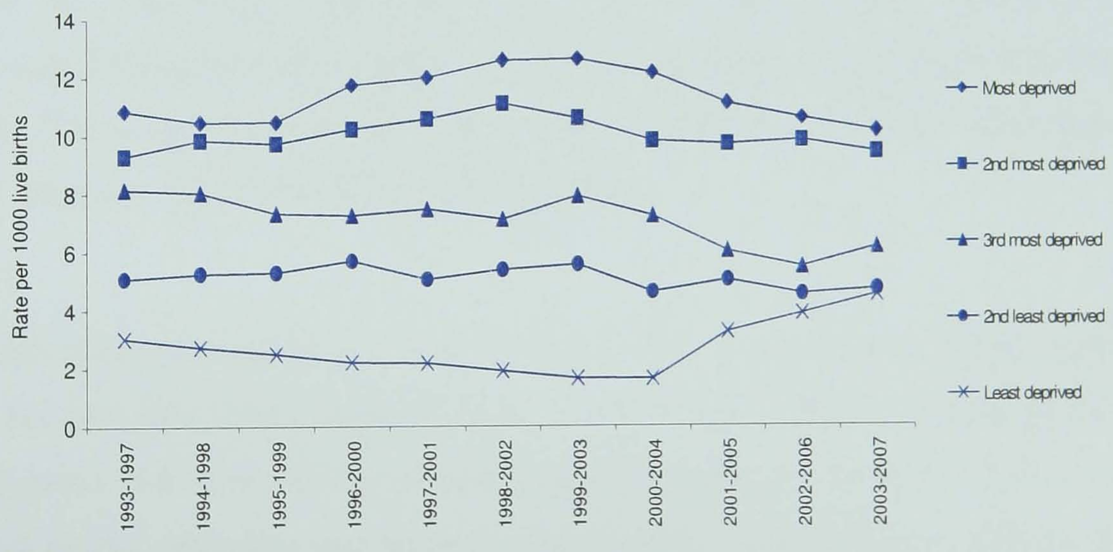


Whilst the Pakistani community in Bradford has been well established for several decades, there remain a number of differences between Pakistanis and the indigenous white population. First, the Pakistani community is on average younger than the white population. Around 39% of white women in Bradford are aged between 15 and 44 compared to 51% of Pakistani women (Bradford District Infant Mortality Commission, 2006). Second, Pakistanis are more likely to live in poorer areas of the city and suffer greater deprivation than the white population. An overview of the changing geography of South Asians in Bradford (Phillips, 2001) reported that over 80% of Muslims (mostly Pakistanis, Kashmiris and Bangladeshis) were living in 'struggling' inner city areas in 2000. In 2008 the proportion of Pakistani children in the city eligible for free school meals, a marker of deprivation, was 29.8% compared with 16.9% of white children eligible (Association of Public Health Observatories, 2008). Third, the birth rate among Pakistanis is higher. Almost 50% of the 5,500 babies born in the city each year have parents of Pakistani origin and it is striking that Pakistani babies are more likely to be born small than white babies even when comparable levels of deprivation are reported (Bradford District Infant Mortality Commission, 2006). This is likely to contribute to a consistent pattern of increased risk of infant and possibly later life health problems. Fourth, rates of childhood morbidity and mortality are higher among Pakistani babies and the same is true for disability rates. The infant mortality rate (IMR) for Bradford was 8.0 / 1,000 in 2008 compared to the national rate of 5.1. The IMR for South Asians living in Bradford was 12.3 / 1,000 (2008). There was some variation in rates between individual South Asian groups as detailed in Figure 4. The highest levels of deprivation in the city were also associated with increased infant mortality with some evidence that this has increased over the last decade (Figure 5).

Figure 4 Infant mortality by ethnic group within Bradford

Source:BradfordObservatory(www.observatory.bradford.nhs.uk/.../Infant%20Mortality/Infant%20Mortality%20Update%20Oct%2008.pptx)

Figure 5 Infant mortality by deprivation quintile within Bradford 1993-2007



Source: ONS Annual District Births and Deaths files

3.1.2 The Born in Bradford Project

BiB is a large birth cohort study that aims to investigate environmental, psychological and genetic factors that impact upon health and development during both childhood and adulthood. The full study methodology is available at http://www.borninbradford.nhs.uk. The study concept was born out of a desire to tackle the burden of poor health in the city and a need to understand more clearly the complex interplay between ethnicity, deprivation and health.

These issues create many challenges for Bradford and tackling them requires a better understanding of the origins of poor health. Hence the BiB project which began in March 2007 and aims to improve our understanding of health and disease in Bradford. The project is a longitudinal birth cohort study that involves research collaboration between Bradford Teaching Hospitals, Bradford & Airedale PCT, University of Leeds and the University of Bradford. Additional research partners include the University of Bristol, University of Loughborough, University of Edinburgh, London School of Hygiene and Tropical Medicine and Imperial College London. The project has received support from a number of funders including MRC, NIHR, Diabetes UK and the Department of Health.

All women booked to give birth in Bradford were asked to participate in BiB and where possible their partners were also invited to take part. Recruitment began in September 2007 and ended in December 2010. Baseline data were collected from mothers during pregnancy and included social, ethnic, economic, demographic and lifestyle information. Babies in the BiB project will be followed throughout their childhood and into adulthood. For this thesis, infants of parents of Pakistani and White British origin were used. Their ethnic classification was based on self reported information and is described later in this chapter.

The full BiB study protocol has been previously published (Raynor, 2008). The methodology relevant to this study is described below.

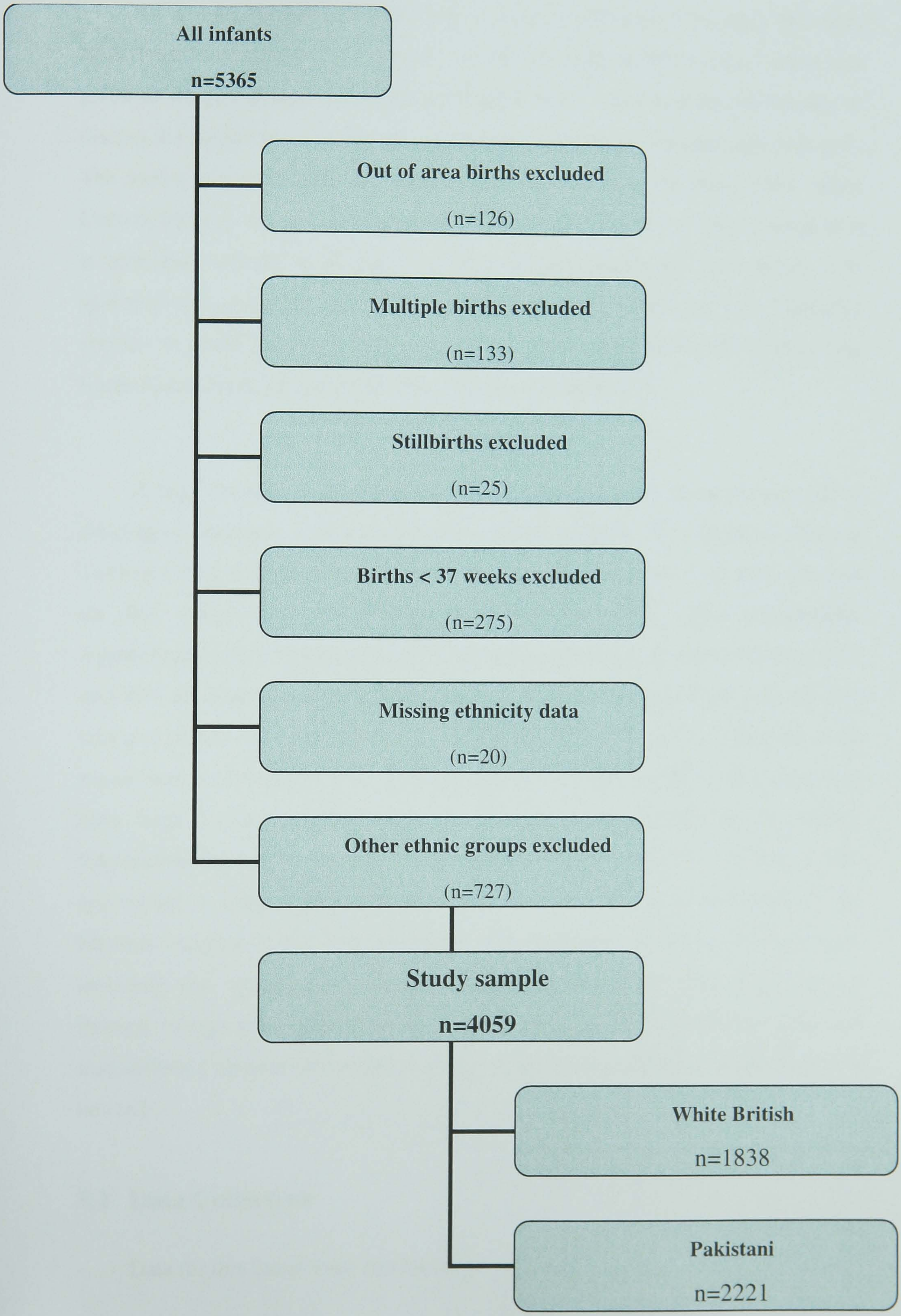
3.1.3 Exclusions

For the BiB project as a whole the only exclusion criterion was if a mother planned to move away from Bradford before the birth. However, for this thesis the following additional exclusions were applied:

- Babies born at less than 37 weeks gestation
- Stillbirths and babies with major anomalies
- Multiple births
- Births that occurred outside Bradford
- Babies with incomplete data e.g. no mother's questionnaire
- Babies born to parents of ethnic origin other than Pakistani or White British

This thesis used data from infants and mothers recruited between September 2007 and December 2009 to BiB. The data set was extracted on 10.1.2010 and comprised 5365 mother-offspring pairs. After exclusions for the main analyses I included 4059 (1838 White British origin infants and 2221 Pakistani origin) participants (figure 6). Througout this thesis the term 'White British' includes those who originate either from the UK or Ireland. No formal power calculation was performed a priori, rather all complete data collected and available at the time of analyses was included in this thesis.

Figure 6 Study sample selection



3.1.4 Recruitment

All women booked and intending to deliver at Bradford Teaching Hospitals NHS Trust were eligible for inclusion in BiB. The Patient Information Leaflet was given to women at their first antenatal appointment. They had the opportunity to discuss the project at this stage and also during subsequent antenatal appointments. The leaflet was translated into Urdu as most Pakistanis in Bradford speak either Urdu or Mirpuri. Mirpuri has no written script but the leaflet was transliterated, that is translated verbally to Mirpuri and then written phonetically precisely as it is spoken to ensure that all interpreters translate it in exactly the same way. Maternity services in Bradford and the BiB project have an established team of translators for South Asian languages including Urdu, Mirpuri and Bengali.

A high number of pregnant women in Bradford have an increased risk of developing diabetes. As a result all pregnant women are offered a Glucose Tolerance Test (GTT) at around 26-28 weeks gestation. Women were invited to join the BiB study when they visited the hospital for their GTT appointment. Approximately 80% of women booked for delivery in Bradford attend for their GTT and 87% of women who were approached at their GTT appointment consented to take part in BiB. Overall, there were 22,813 deliveries in Bradford during the study recruitment period and 12, 995 (57%) partcipated in BiB (a number of deliveries will have been booked in other areas or will have occurred before 26 weeks). Recruitment figures are not recorded by ethnicity. Those who did not attend were approached at other antenatal clinics and later stages during their antenatal care. Mothers included in the study provided written consent for the use of their data, including that specifically collected for the BiB study and other data obtained through linkage with medical records. They also provided consent for additional data collected on their babies and routinely collected clinical data on their babies to be used.

3.2 Data Collection

Data for this thesis were obtained from:

- Mother's study questionnaire (completed for BiB)
- Anthropometric baby measurements (routine and BiB measurements)
- Routinely collected clinical data
- Biomedical samples (maternal and cord blood collected routinely and for BiB)

3.2.1 Semi-structured interview questionnaire

During the GTT appointment, women who consented to take part in BiB were interviewed by a trained BiB project worker. A baseline questionnaire (Appendix B) was completed as part of a semi-structured interview. The questionnaire included questions relating to social and economic circumstances, smoking, alcohol, diet, education and employment and ethnicity and migration history.

A series of questions were used to establish the social and economic circumstances of participating families. These included questions regarding education, employment and occupation, income, housing and receipt of benefits. This information was used to estimate socioeconomic position. Income assessment was based on the baby's parents combined income. Income brackets were condensed into 4 categories representing very low, low, middle and high incomes. Participants were classified as receiving means tested benefits if they were in receipt of any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit.

In addition women were asked for details of their and their partner's education including the age at which they left full time education, their highest educational qualification and which country they received most of their education. Detailed information regarding smoking, alcohol and drug use was obtained via the questionnaire which included details of exposure to other peoples cigarette smoke either at work or home and about other tobacco products for example Paan. Alcohol information included intake prior to pregnancy and during early and later stages of pregnancy.

For this thesis, information that defined ethnic group was obtained from data collected in the mother's questionnaire. Ethnic categorisation was based on self-defined ethnicity. Classifying ethnicity is 'at best an approximation' (Kaplan and Bennett, 2003), the term is not fixed (in that individuals may describe their ethnicity differently over time) and can represent different concepts depending on how it is defined. For example, ethnicity based on nationality or place of birth will not always capture differences in culture, lifestyle or heritage (Rafnsson and Bhopal, 2009) which are likely to be most important to epidemiological study. Self-defined ethnicity is said to reflect identity and self-perception (Rafnsson and Bhopal, 2009) and has been described as the 'optimal' method of defining ethnicity (Kaplan and Bennett, 2003). Details of the baby's parents' and grandparents' place of birth were used to categorise generational status as outlined in Table 7. During the questionnaire interview, trained project workers recorded the mother's height using the Leicester Height Measure (SECA Ltd., Birmingham, UK) and weight using SECA digital scales (SECA Ltd., Birmingham, UK) with outdoor clothing and shoes removed. BMI was derived by trained project workers for the entire BiB cohort using these measurements.

3.2.2 Neonatal anthropometric measurements

Following delivery and prior to hospital discharge, neonatal anthropometric measurements were obtained. Birthweight is routinely recorded by the midwife at delivery using SECA digital scales and these routine records were used for this thesis. Head, mid-upper arm (MUA) and abdominal circumference measurements are not routinely taken but were added to the routine neonatal examination which is performed within the first 24 hours by a paediatrician. Paediatricians were trained by a Consultant Neonatologist according to written protocols (Appendix C). Measurements were recorded using Lasso-o tape measures specially manufactured for the BiB study to accommodate small MUA circumferences. Reliability assessments were performed as described later in this chapter and in the following chapter. Subscapular and triceps skinfold thickness were measured by trained project workers again according to written protocols (Appendix C) using Harpendon calipers. Project workers attempted to obtain all skinfold measurements within the first 24 hours. Rarely some measurements were obtained after this time but were always within 72 hours of delivery. Three project workers left during the study period and were replaced by new team members. Training was delivered at regular intervals throughout the study to all project workers and reliability assessments were performed twice during the study period. All neonatal measurements were entered into the EClipse routine data maternity system. I participated in all aspects of data collection, developed protocols for neonatal measurements, trained project workers and undertook the reliability assessments (reported in Chapter 4).

3.2.3 Routinely collected maternity information

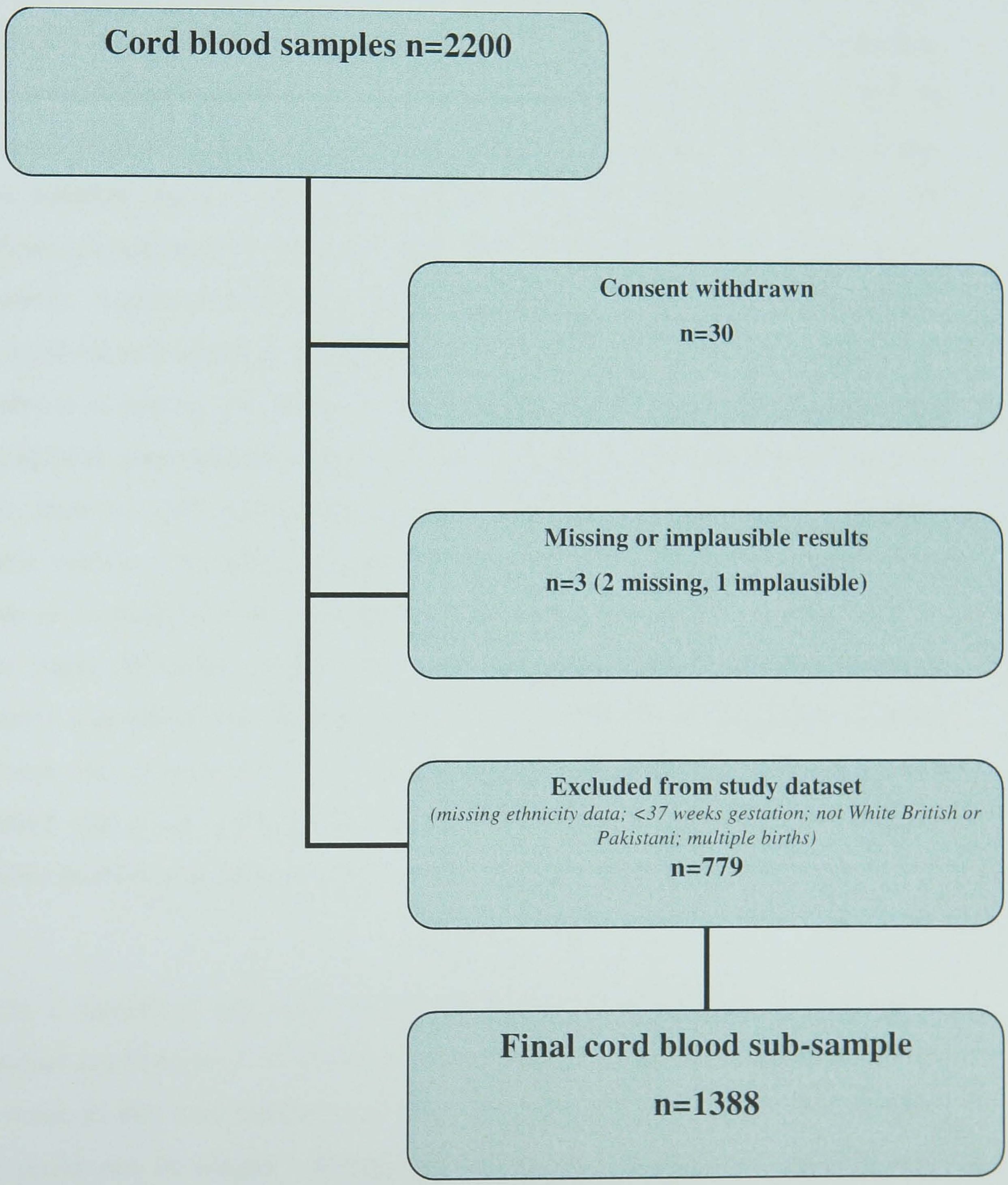
Bradford has an electronic maternity care records system, EClipse, which was accessed to obtain routine clinical data for participating mothers and babies and to validate information collected by the questionnaire. This included medical and obstetric information (maternal age, parity, maternal diabetes and hypertensive disorders of pregnancy) and perinatal data (gestation at delivery, baby's gender and birthweight). For this thesis maternal diabetes was categorised as existing diabetes or gestational diabetes based on clinical diagnosis. At Bradford Teaching Hospital NHS Trust (BTHNHST) gestational diabetes is diagnosed following a glucose tolerance using standard WHO thresholds for impaired glucose tolerance or impaired fasting glucose (fasting plasma glucose ≥6.0mmol/l and/or post challenge glucose ≥7.8mmol/l). Hypertension in pregnancy was classified as mild to moderate (≥140 systolic and 90 diastolic on 2 or more occasions) or severe (≥150 systolic and 105 diastolic on 2 or more occasions). Gestational age at delivery is calculated by the attending midwife and entered into the Eclipse data system. This information was used to exclude births before 37 weeks gestation. At BTHNHST the expected date of delivery (EDD) is based on the date of the mother's last menstrual period, this is confirmed by a dating ultrasound scan at around 12 weeks gestation. If the ultrasound dates are within 7 days of the menstrual dates the menstrual date is used, if the difference is greater than 7 days the ultrasound date is used (Guidelines for Obstetric Ultrasound BTHNHST 2005).

3.2.4 Biomedical samples – Maternal Glucose Tolerance Test (GTT), cord blood analysis

All pregnant women in Bradford are invited for a GTT, which is conducted at approximately 28 weeks of gestation. Women arrive at a morning appointment having fasted overnight. A fasting blood sample is taken and sent to the hospital laboratory for processing and glucose assessment. The woman receives a 75g glucose load in 250-300ml water. This is given as Polycal. The volume of Polycal is 113ml (equivalent to 75g anhydrous glucose) made up to a total volume of 250-300ml with water. A repeat blood sample is taken at 120 minutes after consumption of the glucose load, with samples again sent to the hospital biochemistry laboratory for processing and completion of assays. Approximately 94% of women who agreed to participate in the study completed a glucose tolerance test. A diagnosis of gestational diabetes mellitus (GDM) was based on current WHO thresholds of fasting plasma glucose ≥6.0mmol/l and/or a 2 hour post challenge glucose ≥7.8mmol/l. The assay results were not available at the time of my analysis therefore a clinical diagnosis of diabetes was used for this thesis (extracted from the eClipse electronic records system).

A consecutive sub-sample of cord blood samples was obtained (n=2200) between 1.10.2008 and 31.10.2009 for leptin analysis. These samples were obtained on the Delivery Suite for all infants enrolled in BiB and inevitably some were either not in the data set for this thesis, missing or implausible results or consent had been withdrawn after the sample had been obtained (Figure 7). This left a final sub-sample of 1388, of which 613 were of White British origin and 775 of Pakistani origin. Samples were collected at delivery using the vacutainer system by the attending midwife and kept refrigerated at 4°C in EDTA tubes until collected by laboratory staff at 8am the next working day. Samples were then processed according to the Standard Operating Procedure (Appendix D) and forwarded by courier to Glasgow in batches of 1,000 for analysis. The Biochemistry Department of Glasgow Royal Infirmary is a Centers for Disease Control and Prevention (Atlanta) reference laboratory and accredited by Clinical Pathology Accreditation U.K. Leptin was measured by a highly sensitive in house ELISA with better sensitivity at lower levels than commercial assays. All samples were labelled with a unique barcode which was used to match aliquots to participants. The time from sample collection to processing and sample collection to analysis was recorded for each sample.

Figure 7 Summary of selection of cord blood sub-sample



3.3 Data Management

3.3.1 Data cleaning

3.3.1.1 Outcome varaiables

The data used in this thesis were sorted, cleaned and coded according to the standard BiB data cleaning protocol. This incorporated validity checks including validation of study identification numbers, identification of duplicate records and investigation of invalid responses and also consistency checks for example, comparing fields where possible (such as date of birth and age) and checking consistency of questionnaire responses (for example checking that responses to similar qustions are consistent). I undertook further cleaning and coding as required for my analyses. This involved identifying potential implausible values and re-coding a number of variables to an appropriate format for my analyses. Initially this involved examining the graphical presentations of each outcome variable, including histograms and scatter plots of each measurement against a different measurement to identify possible outliers. No fixed criteria for the identification of outliers (e.g. falling outside +/- 2 standard deviations from the mean) were applied as it was felt that values could fall outside these limits and remain clinically plausible. Rather I undertook a graphical assessment and in addition, examined the credibility of both minimum and maximum values for each variable. For example, an outlier was identified within the maternal height data (1.20 metres) which was small but plausible therefore the value was not removed from the data set.

On a number of occasions errors in data entry became clear. For example, abdominal circumference measurements were entered as MUA circumference and vice versa, in this case records were corrected accordingly. Where errors in data entry could not be simply rationalised, the clinical records were checked and appropriate changes to the data set were undertaken (n=4). Any implausible recordings that could not be explained or amended through this process were classified as missing for the purpose of the analysis (n= 8). Numbers and proportions of missing data are reported for each outcome and explanatory variable in Chapter 5.

3.3.1.2 Explanatory variables and covariables

A number of variables were re-coded to create manageable and appropriate categories for my analyses. For example, information regarding smoking in pregnancy was collected via several questions, as a result information from each question was re-coded to create one new variable that captured whether mothers had never smoked or smoked at any time during their pregnancy. Likewise, a number of variables were combined to estimate socioeconomic position for multivariable modelling including maternal education, income, receipt of benefits and housing tenure.

3.4 Outcome variables / explanatory variables / covariables

All outcome variables and potential explanatory variables included in this thesis are described earlier in this chapter and are listed in Table 5.

Table 5 Outcome, explanatory and co-variables

Outcome variables (y)	Explanatory variables (x)	Potential mediating/masking covariates / factors
Birthweight (g)	White	Smoking during pregnancy – mother (Y/N)
Subscapular skinfold thickness (mm)	Pakistani: (I) As one group and (2) by generation	Alcohol during pregnancy – mother (Y/N)
Triceps skinfold thickness (mm)	1^{st} 2^{nd} 3^{rd}	Mother's age at delivery
Head circumference (cm)		Maternal diabetes (Y/N)
Abdominal circumference (cm)		Hypertensive disorders of pregnancy (Y/N)
MUA circumference (cm)		Mother's height
Cord blood leptin (ng/ml)		BMI at booking
		Parity (birth order)
		Gestational age at delivery
		Baby's gender
		Economic/deprivation status: • Housing tenure • Maternal education level • Paternal education level • Maternal occupation • Paternal occupation • Receipt of benefits • Income
		Attendance for antenatal care (Y/N) (as measured by attendance for dating USS and GTT)

3.5 Statistical methods

3.5.1 Representativeness of sample

To ensure that the study sample are representative of Bradford's population, data gathered for the sample used in this study were compared to anonymised data for the Bradford district as a whole for 2009 obtained from NHS Bradford and Airedale. Cohort members were compared to all babies within the Bradford district on key outcomes (ethnicity; maternal age; birthweight). In addition, the sample used in this thesis was compared to the BiB sample as a whole on mean birthweight, ethnicity and maternal age. Results of these comparisons are presented in Chapter 5.

3.5.2 Reliability of anthropometric measurements

Measurement reliability is a direct indicator of quality of data (WHO, 2006). A number of procedures were included in this study to ensure that accurate recordings were obtained. Paediatricians and project workers received intensive training throughout the study. Measurements were taken and recorded according to strict guidelines, equipment was regularly calibrated to maintain accuracy and a number of reliability tests were performed. Various techniques are available to formally test reliability. The most common methods are:

- Technical Error of Measurement (TEM)
- Relative TEM
- Reliability (R)

The TEM measures the standard deviation between repeated measurements (Goto and Mascie-Taylor, 2007) using the same units of measurement and is calculated using the following formula:

$$\sqrt{((\sum d^2)/2n)} \qquad \text{Equation 1}$$

Where d=the deviation between first and second measurements and n=the total number of infants measured by the same measurer

The relative TEM is a measure of the coefficient of variation and provides an estimate of the size of the error relative to the size of the measurement (Goto and Mascie-Taylor, 2007). It is calculated using the following formula:

$(TEM/(\sum a/n)) \times 100$ Equation 2

Where a=the average of the first and second measurement and n=the total number of infants measured by the same measurer

R estimates the proportion of variance not due to error (WHO, 2006). For example, R of 90% means that 90% of the total variance is not due to error and 10% is attributable to error (WHO, 2006). It was calculated using the following formula:

$R = 1 - ((TEM^2/(sd)^2)$ Equation 3

Where sd=the standard deviation of all the measurements taken

The technical error of measurement (TEM), relative TEM and coefficient of reliability were calculated for both intra and inter reliability of circumference measurements and skinfold measurements. Bland Altman plots were used to investigate agreement between the measurer and the observer. The results are discussed in the following chapter. The results of reliability assessments are presented in detail in Chapter 4.

3.5.2.1 Birthweight

Routinely collected birthweight measurements were used in this study. Birth weight was recorded by the attending midwife immediately following delivery using SECA electronic scales, as is standard clinical practice in Bradford. The birthweight was then entered by the midwife into the EClipse data system. This becomes the formal birthweight recording for the child. A number of studies have examined the accuracy of routinely collected birthweight measurements and report high levels of accuracy (Stenhouse et al., 2004, Johnson et al., 1997). Furthermore Wilcox (Wilcox, 2001) suggests that routinely collected birthweight is sufficiently reliable for use in research. As such the quality of routinely collected birthweight data was judged adequate for this thesis.

3.5.2.2 Neonatal head, MUA and abdominal circumference

Neonatal head, MUA and abdominal circumference measurements were performed by a paediatrician during the routine first examination as previously described. Both intra and inter-observer reliability assessments were undertaken using convenience samples. Intra-observer reliability was assessed once during the study in the first ten months of data collection. The paediatricians were accompanied by an independent observer over a one week period and were asked to perform each measurement twice, once at the start of the examination and once at the end.

Inter-observer reliability data were collected throughout the data collection period. Obtaining duplicate paediatrician measurements was problematic and it was necessary to continue the assessments throughout the data collection period in order to achieve a sufficient sample. The measurements taken by the paediatrician were repeated blind by myself within 3 hours of the first examination on approximately one morning per month between September 2007 and July 2009. A total of 24 paediatricians and 8 specially trained midwives collected measurements during the data collection period often whilst providing emergency cover for the unit.

3.5.2.3 Skinfold measurements

Skinfold measurements have characteristically low precision (WHO, 2006) and are likely to be less reliable than other anthropometric measures. As reported earlier in this chapter, skinfold measurements for this study were recorded by trained project workers. A total of 9 project workers collected skinfold measurements during the study and both intra and inter observer reliability assessments were undertaken. Intra-observer reliability was assessed using a convenience sample once during the data collection period.

Inter-observer assessments were performed during the first year of data collection on a sample of 50 infants. I accompanied the project workers one morning per week over a six month period in the first year of the project and performed a repeat measurement blind to their initial recording. Because of staff changes and ongoing training I repeated this exercise in the second year of data collection over a period of 6 months again on a sample of 40. Again limitations and results are described in the following chapter.

3.5.3 Descriptive statistics

For every variable (Table 5) used in this thesis, distributions are presented for the whole cohort and separately by ethnic group. For continuous variables mean and standard deviation (SD), median and interquartile range (IQR) and histograms are used. For categorical variables number (%) are used. This includes the mean birth weight for Pakistani babies and the mean for White British babies. In addition the proportion of low birthweight babies in both groups is presented. Low birth weight is defined as a birthweight less than 2500g. These descriptive statistics are presented in Chapter 5.

3.5.3.1 Confounding and mediation

Confounding is important in observational epidemiology. It is defined as one or more characteristics that are associated with the risk factor of interest and influence the outcome, but are not on the causal pathway between risk factor and outcome, and that explains some or all of the observed association between the risk factor and outcome. For example, if investigating whether exercise causes a reduced risk of coronary heart disease by looking at the association of exercise with heart disease incidence in a prospective cohort study and those who exercise more at baseline are found to be less likely to have a heart attack over the follow-up period, one possibility is that exercise does indeed protect from heart attacks. However, it is also possible that those who exercise more are also less likely to smoke, and that it is their lack of smoking, rather than their exercise that protects them from having a heart attack (see Figure 8). Smoking, in this example, confounds the association between exercise and heart disease. Thus, a confounder can lead one to assume that a risk factor is causally affecting an outcome when it is not. By contrast, a mediator is part of what causes the disease and gives information about the mechanism by which the risk factor affects the outcome (Figure 9). Hernan et al. (2002) have pointed out that when examining ethnic inequalities, confounding is rarely a problem. This is because to confound a characteristic has to occur before the risk factor and influence it, and few other characteristics influence ethnicity directly. For example, with respect to this thesis, maternal smoking in pregnancy is a strong causal risk factor for low birthweight and smoking differs markedly between women of Pakistani origin (very unlikely to smoke) and White British women (smoking prevalence of between 20 and 40% depending on age and socioeconomic position (Hawkins et al., 2008)). However, smoking does not cause or influence ethnicity and so could not really be considered a confounder. On the other hand it is also hard to see how it could be a mediator since the direction of association of ethnicity with birthweight is of lower birthweight amongst Pakistani compared with White British. Therefore, for smoking to mediate the association (i.e. be on the causal pathway between Pakistani origin and low birthweight) Pakistani women would have to smoke more than White British women and this is not the case. Other characteristics may mediate some of the associations I have examined in this thesis for example, gestational and type 2 diabetes are associated with higher birthweight and greater adiposity at birth (as discussed in Chapter 2) and both are more common among Pakistani origin mothers. Thus, diabetes might mediate any association of Pakistani origin with greater adiposity. The one possible exception to the issue of confounding is socioeconomic position where it is often argued that ethnic inequalities in health may simply reflect socioeconomic inequalities (see Chapter 2). However, applying the same logic as above (i.e. that to confound a characteristic has to occur before the risk factor and be able to influence it) Kawachi and colleagues (2005) have argued that socioeconomic position cannot precede ethnicity or race and therefore cannot confound its association with outcomes. They do however note the importance of understanding how both together affect outcomes.

Given that the notion of confounding with ethnic inequalities can be problematic, I have not referred to confounding in my analyses. I was however interested in whether some characteristics might mediate any association of ethnicity with birth size. I was also interested in whether some characteristics (e.g. smoking) that differ between Pakistani and White British women, might mask an even greater difference (i.e. the difference would be even greater were smoking prevalence the same in both groups). Therefore, for clarity, where I anticipated that a characteristic may have been on the causal pathway between Pakistani origin mother and lower birthweight (or fatter) infant I have referred to this situation as a mediator and likewise, where I have anticipated that a characteristic might mask an even larger difference I have referred to it as a masking characteristic.

Figure 8 Illustration of confounding

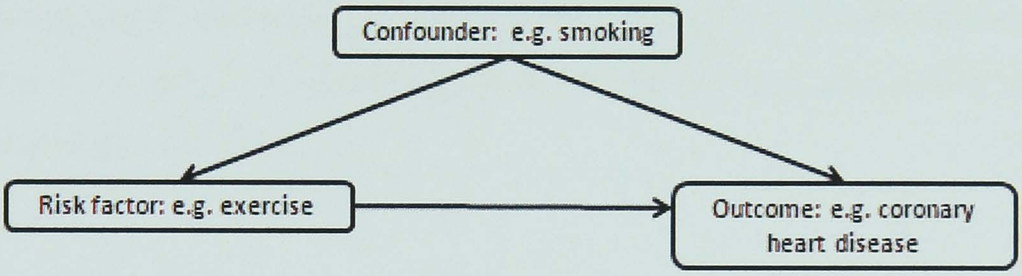
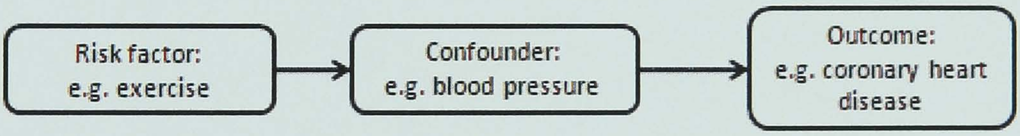


Figure 9 Illustration of mediation



3.5.4 Statistical analyses

All analyses were performed using STATA (version 10) and included:

1. Definition of ethnicity and classification of generational status based on place of birth of parents and grandparents (see below)
2. Comparison of birth size and cord leptin across categories of ethnicity (White British and Pakistani) and Pakistani generation using linear regression to estimate mean differences (95% CI), described below

3. Comparisons of covariables with birth size outcomes and across ethnic and generation categories using cross tabulations and regression analyses, described in more detail below.

3.5.4.1 Generational status

Previous studies have primarily classified generation based on maternal place of birth (first generation born outside the UK and second generation born within the UK) with the exception of the Millenium Cohort Study that classified non-UK born mothers as immigrants and also incorporated birth place of maternal grandparents. Existing studies all based generation on the maternal line and did not or were unable due to the nature of the data used, to report the age at which non-UK born mothers moved to the UK (Table 6).

Table 6 Classification of generational status (UK studies)

Study	**Generation classification**	***Comments***
Leon & Moser (2010) **ONS national data**	Mother classified as: • **First generation** – Mother born in her country of origin (eg India, Pakistan, Bangladesh) • **Second generation** – Mother UK born	*'Second generation' may also include third or higher generation*
Hawkins et al (2008) **Millenium Cohort Study**	Mother classified as: • **Immigrant** – mother and both maternal parents born outside the UK • **First generation** – Mother born in the UK but at least one maternal parent born outside the UK • **Second generation** – Mother and both maternal parents born in the UK	*'First generation' will include mothers who were born in the UK and whose mother was also UK born*
Harding (2004) **National longitudinal study data**	Mother classified as: • **UK born** • **Migrant** (born outside the UK)	
Margetts (2002) **Local birth record data**	Mother classified as: • **First generation** – Mother UK born • **Second generation** – Mother born outside the UK	*'Second generation' may also include third or higher generation*
Draper (1995) **Local birth notification data**	Mother classified as: • **First generation** – Mother UK born • **Second generation** – Mother born outside the UK	*'Second generation' may also include third or higher generation*
Dhawan (1995) **Local birth record data**	Mother classified as: • **First generation** – Mother UK born • **Second generation** – Mother born outside the UK	*'Second generation' may also include third or higher generation*

Paternal line not included in previous studies & all have not/were unable to include age moved to the UK

Pakistani babies were categorised according to their generational status using information on both parents and all grandparents. Initially Pakistani cohort members (babies) were classified according to their mother's, father's, maternal and paternal grandparent's place of birth. This included all babies with any parent or grandparent born in Pakistan, Bangladesh or India. This created 66 categories (Table 7). To develop a manageable data set and avoid difficulties with small numbers in some cells, categories were combined according to the number in each cell and the similarity in migration history. This reduced the number of categories to 17. Within the 17 groups, 90% fell into one of four categories:

1. Both parents UK born & all grandparents South Asian born
2. Both parents South Asian born & all grandparents South Asian born
3. Mum UK born, dad and all grandparents South Asian born
4. Dad UK born, mum & all grandparents South Asian born

The remaining 10% fell across the remaining 13 groups however this resulted in very small numbers hence these were combined into one 'other' group. The analyses therefore include 7 groups (Table 8). First the two main ethnic groups, White British and Pakistani, and then the five Pakistani subgroups by generation (N.B. the five generation groups are sub-groups of the one Pakistani ethnic group). Despite the small number of UK born grandparents, the above groups have allowed a robust exploration of generation i.e. groups 1 & 2 above enabled a pure comparison of parental generation and groups 3 & 4 above have allowed a comparison of place of birth between mothers and fathers. As all grandparents were South Asian born (with the excpetion of the 'other' group) and to simplify interpretation of the generation groups, they were labelled according to whether parents/grandparents were South Asian born i.e. neither; dad only; mum only; both and other (Table 8).

Mother	Father	Grandmother (maternal)	Grandfather (maternal)	Grandmother (paternal)	Grandfather (paternal)	Mean birthweight (g)	Count
UK	South Asian	Other	Other	South Asian	South Asian	2520	1
UK	Other	South Asian	South Asian	South Asian	South Asian	3670	2
UK	Other	South Asian	South Asian	Other	Other	3536.67	3
UK	Don't know	UK	South Asian	South Asian	South Asian	2660	1
UK	Don't know	South Asian	South Asian	South Asian	South Asian	3340	1
UK	Don't know	South Asian	South Asian	Don't know	Don't know	2755	2
South Asian	UK	South Asian	South Asian	UK	UK	2860	1
South Asian	UK	South Asian	South Asian	UK	South Asian	3027.89	19
South Asian	UK	South Asian	South Asian	South Asian	UK	3425.71	7
South Asian	UK	South Asian	South Asian	South Asian	South Asian	3177.87	523
South Asian	UK	South Asian	South Asian	South Asian	Other	4140	1
South Asian	UK	South Asian	South Asian	South Asian	Don't know	2810	2
South Asian	UK	South Asian	South Asian	Other	South Asian	3520	1
South Asian	UK	South Asian	South Asian	Don't know	South Asian	2940	1
South Asian	UK	South Asian	South Asian	Don't know	Don't know	2860	1
South Asian	South Asian	UK	South Asian	South Asian	South Asian	3136	5
South Asian	South Asian	South Asian	UK	South Asian	South Asian	3055	4
South Asian	South Asian	South Asian	South Asian	South Asian	UK	3240	2
South Asian	South Asian	South Asian	South Asian	South Asian	South Asian	3206.29	675
South Asian	South Asian	South Asian	South Asian	South Asian	Don't know	3350	1
South Asian	South Asian	South Asian	South Asian	Don't know	Don't know	2840	1
South Asian	South Asian	South Asian	South Asian		South Asian	3840	1
South Asian	South Asian	South Asian	Other	South Asian	South Asian	3195	2
South Asian	South Asian	Other	South Asian	South Asian	South Asian	3740	1
South Asian	Other	South Asian	South Asian	South Asian	South Asian	3236	5
South Asian	Other	South Asian	South Asian	Other	Other	3207	5
South Asian	Other	South Asian	South Asian	Don't know	Don't know	3840	1
South Asian	Don't know	South Asian	South Asian	South Asian	South Asian	2660	1
Other	UK	South Asian	South Asian	South Asian	South Asian	3677.5	4
Other	South Asian	South Asian	South Asian	South Asian	South Asian	3208.67	15
Other	South Asian	Other	South Asian	South Asian	South Asian	3100	2
Other	South Asian		South Asian	South Asian	South Asian	3100	1
Other	Other	Other	Other	Other	Other	3120	2

Table 7 The 66 categories of parents' and grandparents' place of birth (4 main groups highlighted)

Mother	Father	Grandmother	Grandfather	Grandmother	Grandfather	Mean	Count
UK	UK	UK	UK	South Asian	South Asian	3060	5
UK	UK	UK	South Asian	UK	South Asian	2480	1
UK	UK	UK	South Asian	South Asian	South Asian	3110	5
UK	UK	UK	South Asian	Don't know	Don't know	3000	1
UK	UK	South Asian	UK	UK	UK	2900	1
UK	UK	South Asian	UK	UK	South Asian	2820	1
UK	UK	South Asian	UK	South Asian	UK	3140	1
UK	UK	South Asian	UK	South Asian	South Asian	3403.33	6
UK	UK	South Asian	UK	Don't know	Don't know	2880	1
UK	UK	South Asian	South Asian	UK	UK	2815	4
UK	UK	South Asian	South Asian	UK	South Asian	3183.33	6
UK	UK	South Asian	South Asian	UK	Don't know	3350	1
UK	UK	South Asian	South Asian	South Asian	UK	2760	3
UK	UK	South Asian	South Asian	South Asian	South Asian	3181.19	232
UK	UK	South Asian	South Asian	South Asian	Other	2880	1
UK	UK	South Asian	South Asian	South Asian	Don't know	3300	1
UK	UK	South Asian	South Asian	Other	South Asian	2990	2
UK	UK	South Asian	South Asian	Other	Other	3080	1
UK	UK	South Asian	South Asian	Don't know	Don't know	2780	2
UK	UK	South Asian	Other	South Asian	South Asian	3103.33	3
UK	UK	Other	South Asian	South Asian	South Asian	3220	2
UK	UK	Other	Other	South Asian	South Asian	4300	1
UK	South Asian	UK	UK	South Asian	South Asian	3005	4
UK	South Asian	UK	South Asian	South Asian	South Asian	3253.23	31
UK	South Asian	UK	South Asian	Don't know	Don't know	2640	1
UK	South Asian	South Asian	UK	South Asian	South Asian	3190	14
UK	South Asian	South Asian	UK	Don't know	Don't know	3960	1
UK	South Asian	South Asian	South Asian	UK	South Asian	3730	1
UK	South Asian	South Asian	South Asian	South Asian	UK	3097.5	2
UK	South Asian	South Asian	South Asian	South Asian	South Asian	3205.73	584
UK	South Asian	South Asian	South Asian	Don't know	Don't know	2880	2
UK	South Asian	South Asian	Other	South Asian	South Asian	3130	4
UK	South Asian	Other	South Asian	South Asian	South Asian	3030	2

Table 8 Analysis groups by ethnicity and generation

	Mean birthweight (g)	Number
White British	**3421**	**1838**
Pakistani (all groups)	**3194**	**2222**
Pakistani sub-groups by generation:		
Neither (both parents UK born & all grandparents SA born)	3181	232
Dad only (mum UK born, dad & all grandparents SA born)	3206	584
Mum only (dad UK born, mum & all grandparents SA born)	3178	523
Both (both parents SA born & all grandparents SA born)	3206	675
Other (all remaining 13 groups including all those with 'other' or 'don't know)	3163	207

3.5.4.2 Comparison of birth size, cord leptin and all co-variables across categories of ethnicity and generation

Means (sd) are reported for each outcome variable in each category of ethnicity and generation. The proportion of low birthweight babies by group is also reported. Mean differences (95% CI) are presented to describe the association of ethnicity and generational status with each outcome variable. For all these analyses White British babies are used as the reference group, thus all Pakistani infants are compared to white infants and then each generation group is compared to the white group. I also compared mean birthweight between the different generation groups (using the neither group as the reference group). White British babies are defined as babies with both parents and maternal and paternal grandparents born in the UK or Eire. I undertook multiple regression analyses in which adjustment was made for a number of factors known to be associated with birth size (as listed in Table 5) to estimate adjusted mean differences (95% CI). All birth size measurements followed approximately normal distributions with the exception of cord leptin data which were log transformed to satisfy assumptions of normality, therefore leptin estimates presented are ratios of geometric means (95% CI). Linear models assume normality, that the relationship between variables is linear, constant variance and independence. The assumptions are tested by calculating residuals (the difference between the observed and fitted values). The distribution of residuals was examined to test the assumption of normality, residuals were plotted against predictor variables to test linearity and residuals were plotted against fitted values to test the assumption of homogeneity of variance.

Variation inflation statistics were used to check for multicollinearity. Multicollinearity can lead to unstable estimates and large standard errors which can result in significant variables appearing insignificant. Variation inflation factors (VIF) were computed for each independent variable in all final models and were all <10.

Mean z-score differences relative to White British infants were calculated to compare differences across different measurements with different ranges or units of measurement. In addition, sensitivity analyses to examine the potential effect of lower reliability of one measurer and the effect of migration to the UK at age 5 or under on comparisons of birth size and adiposity were undertaken.

3.5.4.3 Comparisons of covariables with birth size outcomes

Adjusted mean differences (95% CI) were estimated using multiple linear regression models to show the effect of each individual explanatory / mediator variable on each birth size outcome by ethnic and generation group. In addition, covariables were compared across ethnic and generation categories using cross tabulations.

3.6 Ethics

The BiB protocol for recruitment and collection of baseline data and biological samples was approved by Bradford Research Ethics Committee (**06/Q1202/48**; August 2006). This thesis is included in that approval. Information about the study and the consent process was available in a number of languages and translators were used when necessary. All BiB participants were asked to sign a consent form which included consent for a cord blood sample at delivery. All samples were stored and transported in accordance with the Human Tissue Act 2004.

3.7 Research governance and confidentiality

Research governance approval for BiB was granted by Bradford Teaching Hospitals NHS Foundation Trust and Bradford & Airedale PCT. Data collection and handling complied with the Data Protection Act 1998. Data for this thesis was managed using unique study identifiers only and I did not have access to files containing personal identifiers.

3.8 Summary

The methods of this study have been described in this chapter. In the following chapter, an assessment of the reliability of the measurements used in this study is presented. Descriptive results are presented in Chapter 5 followed by the results of the regression analyses in Chapter 6.

Chapter 4
Measurement reliability

Being able to assess neonatal and infant size reliably is important for research and clinical practice. This chapter examines the reliability of both routine clinical measurements of neonates and also of more complex measurements undertaken in the same population for the Born in Bradford study and this thesis.

4.1 Neonatal anthropometric measurements

Neonatal anthropometry has been essential to understanding fetal growth and forms a basis for both subsequent growth monitoring and predictions of short and long term health forecasts. Birthweight, whilst the standard measure of growth and often the most readily available, reflects a number of components including bone, muscle, fat and fluids (Shields et al., 2006). The importance of these components individually, particularly fat mass, has grown following advances in the developmental origins of adult disease concept. Neonatal fat represents just 12-14% of the total birthweight of a term baby but is thought to explain 50% of the variance in birthweight (Catalano et al., 1992). Hence there is increasing interest in additional measurements of size that might provide more precise estimates of fat versus lean mass, fat distribution and head circumference (as a possible proxy indicator of neurological development).

Assessments of neonatal body composition using either air displacement plethysmography (Gianni et al., 2009) or magnetic resonance imaging (MRI) (Modi et al., 2009) are expensive and thus, to date, have only been used on relatively small sample sizes. Skinfold thicknesses are considered to be a more direct way of measuring fat than is weight or weight for length and ratios of central (subscapular) to peripheral (e.g. triceps) skinfolds are frequently used to indicate central distribution of fat. These are not prohibitively expensive and can be assessed in large epidemiological studies (Luque et al., 2009). However skinfold thickness measurements are characteristically less reliable than other anthropometric measurements and the potential benefit of this direct measure might be mitigated by their lack of reliability. Only one previous study has examined the reliability of neonatally assessed skinfold thicknesses (Johnson et al., 1997) and no studies were found that have examined the reliability of routinely measured neonatal circumferences and neonatal skinfolds assessed for research purposes within the same study population.

4.2 Reliability of measurements

Measurement reliability is an indicator of data quality (WHO, 2006)) and an important consideration when interpreting research findings. All measurements are taken with some error (Himes, 2009) but quantifying such error allows a judgment to be made regarding how useful the measurement is. Reliability is the ability to obtain the same measurement under the same conditions (Johnson et al., 1997). Inter-observer reliability relates to different examiners obtaining equivalent measurements under the same circumstances. Intra-observer reliability is concerned with one examiner being able to record the same result under the same circumstances.

Essentially it is important to know that the same (or very similar) result would be obtained were the same baby to be measured at a slightly different time or by a different health professional. If reliability is poor then it may result in incorrect assumptions about changes in measurements during infancy and inappropriate clinical monitoring.

For this thesis birthweight, head, MUA and abdominal circumference and triceps and subscapular skinfold thickness were used to assess birth size and adiposity. Birth length is not included in current UK guidelines for newborn physical examination (National Screening Committee, 2008) and was not part of the routine newborn examination at Bradford Hospitals, as such birth length data were not available for infants in the Born in Bradford study. The reliability of birthweight was not assessed since this is less prone to human error and relies upon the scales being used in hospitals and how frequently they are calibrated. Furthermore, birthweight is assessed immediately at birth on the delivery suite where it would have been impossible to introduce reliability assessments for this study without potentially interfering with clinical management but reassuringly, previous studies report good reliability for routinely collected birthweight (Stenhouse et al., 2004, Johnson et al., 1997). Reliability of routine neonatal clinical measurements of circumferences (head, MUA and abdominal circumference) and of research collected skinfold measurements (subscapular and triceps) was tested.

4.3 Methods

TEM, relative TEM and reliability were reported for all measurements (excluding birthweight) to examine intra and inter- observer reliability (described in Chapter 3). Neonatal anthropometric measurements for this thesis were either abstracted from routinely collected clinical measurements undertaken as part of the routine first baby examination (head, MUA and abdominal circumference) or were additional measurements conducted on study participants (subscapular and triceps skinfold thickness measurements). Tests of the reliability of neonatal anthropometric measurements collected both as part of the routine clinical assessment and added for this study were undertaken at intervals between September 2007 and September 2009.

4.3.1 Routine clinical measurements of circumferences

In Bradford head, MUA and abdominal circumference are collected by a paediatrician or specially trained midwife, as part of the routine hospital neonatal examination within the first 24 hours following delivery. These measurements are obtained for all babies born in Bradford regardless of whether they are enrolled in the BiB Study. Paediatricians and midwives are trained in measurement technique by a Consultant Paediatrician according to written guidelines as part of their induction to the neonatal unit. Measurements are taken using Lasso-o tapes specially manufactured by Harlow Printing Ltd (South Shields, UK) to accommodate small arm circumferences. A new tape measure is used for each baby. Data are entered into the hospital's electronic records system (eClipse).

4.3.2 Research collected neonatal skinfold measurements

Subscapular and triceps skinfold measurements were collected specifically for the BiB project and only recorded for babies enrolled in the study. Measurements were obtained using Harpenden Calipers (Holtain Ltd) by specially trained BiB study administrators according to a written protocol. Equipment was re-calibrated every 12 months. Most skinfold measurements were obtained within the first 24 hours following delivery. Rarely some measurements were recorded after this time but were always within 72 hours of delivery and prior to discharge. Training was delivered at regular intervals and periodic monitoring (monthly) continued throughout the data collection period. Skinfold measurements were entered into the EClipse electronic records system.

4.3.3 Reliability assessments

4.3.3.1 Routine clinical measurements of neonatal circumferences

Both intra and inter-observer reliability assessments were undertaken using convenience samples. Intra-observer reliability was assessed once during the data collection period on a sample of 29 infants. Three paediatricians were accompanied by an independent observer (a medical student working with the BiB team) over a one week period and measured 23, 4 and 2 infants twice respectively for each paediatrician. They were asked to perform each measurement twice, once at the start of the whole neonatal examination and once at the end. On average this would give a 5 minute difference in time between the two measurements. The written record of the first measurement was removed once this was completed so that it was not available for the clinician to see as they performed the second measurement.

Inter-observer reliability data were collected throughout the data collection period. The measurements taken by the paediatrician or midwife were repeated by myself blind to the paediatrician or midwife measurements, within 3 hours of the first examination. A total of 24 paediatricians and 8 midwives collected measurements during the data collection period and reliability data were obtained for 6 paediatricians. Replicate recordings were obtained on 10 infants, different to those included in the intra-observer testing, for each of the 6 paediatricians.

4.3.3.2 Research collected neonatal skinfold measurements

Both intra and inter reliability assessments were performed on convenience samples based on the infants measured on days when I worked with the study administrators. This was generally one day per fortnight but was flexible to ensure that I worked regularly with each individual administrator. A total of 9 study administrators collected skinfold measurements during the data collection period and both intra and inter observer reliability assessments were undertaken. Intra-observer reliability was assessed using a convenience sample once during the first year of data collection on a sample of 40 infants. Project workers recorded measurements twice usually in the presence of myself. On a small number of occasions (20% of the total) it was not possible for me to be present in which case the study administrators recorded their own repeat measurements. Repeat measurements were taken approximately five minutes after the initial recording. The number of infants measured for intra-observer calculations ranged between 4 and 10.

Inter-observer assessments were performed on a convenience sample of 90 infants throughout the two year data collection period. Ten infants, different from those included in the intra-observer testing, were measured by each administrator. The measurement was then repeated by myself within 5 minutes of the initial recording. I performed all replicate inter-observer measurements blind to the study administrator's initial recording.

4.3.4 Analysis

Statistical analyses included the calculation of the technical error of measurement (TEM), the relative TEM and the coefficient of reliability (R) for both intra and inter reliability assessment of routine clinical measurements (head, MUA and abdominal circumference) and research measurements (triceps and subscapular skinfold thickness). For interpretation, the (WHO, 2006) suggest that where an expert assessor is available, acceptable TEM cut-offs should be based on the expert's intra-observer TEM, TEM values for other observers in the study should then lie within +/- 2 times the expert's TEM. Where an expert is not available, the average of well trained observers can be used to set acceptable limits. We took this latter approach here, since for the routine circumference measurements there was no individual paediatrician or midwife who could be considered more experienced than all the others and for the research skinfold measurements, I was trained at the same time as the study administrators and so could not be considered to be more expert than them. For the routine circumference measurements each individual paediatrician/midwife TEM was compared to the average of all paediatricians/midwives assessed during the study period. For the research skinfolds each assessor was compared to the average of all assessors. The relative TEM provides an estimate of the size of the error relative to the size of the measurement, therefore smaller values suggest less error. R estimates the proportion of variance not due to error and whilst there is no defined threshold for an acceptable level of R (Ulijaszek and Kerr, 1999), a cut-off of 90% has been suggested as acceptable for growth measurements (Marks et al., 1989). R of 75% and over has also been suggested as acceptable for skinfold thickness measurements which are typically less reliable than other anthropometric measurements (WHO, 2006).

Bland Altman plots were used to investigate agreement between the paediatrician or study administrator and the observer. The difference between the paediatrician / study administrator and the observer was plotted against the mean of the two measurements. If both measurements were exactly the same the mean difference would be 0, thus the closer the mean difference is to 0 the better the agreement. The plots define 95% levels of agreement within which 95% of the data points should lie, further the data points should be distributed evenly at either side of the mean difference to eliminate the possibility of any systematic bias (Bland and Altman, 1986).

Analyses were performed using SPSS version 14.0 for Windows (SPSS Inc., Chicago, IL) and STATA 10 (StataCorp, College Station, Texas, USA).

4.3.5 Results

Results of intra and inter-reliability tests of routinely collected circumferences are presented in Table 9 and Table 10. The intra-observer TEM values were all within +/- 2-times the average for all assessors, which were 0.12cm, 0.16cm, 0.11cm for head, MUA and abdominal circumferences respectively. Inter-observer TEM ranged from 0.20 to 0.36cm for head circumference, 0.19 to 0.39cm for MUA circumference and from 0.39 to 0.77cm for abdominal circumference and all were within +/- 2-times the average for all assessors, which were 0.28cm, 0.29cm, and 0.69cm for head, MUA and abdominal circumferences, respectively. Relative TEM values were all below 3.5%. R was between 80% and 96% for the majority of routinely collected circumference measurements, though was low (64 and 65%) for two.

Table 9 Intra-observer reliability of routine clinical measurements (circumferences)

Measurer/ anthropometry	TEM (cm)	Relative TEM (%)	Reliability (%)	*Average TEM (cm)*
Head circumference				
*Clinician 1**	0.10	0.28	99	*0.12*
*Clinician 2***	0.20	0.57	99	*0.12*
*Clinician 3****	0.06	0.17	97	*0.12*
MUA circumference				
*Clinician 1**	0.33	2.98	65	*0.16*
*Clinician 2***	0.09	0.81	99	*0.16*
*Clinician 3****	0.06	0.54	97	*0.16*
Abdominal circumference				
*Clinician 1**	0.13	0.40	99	*0.11*
*Clinician 2***	0.17	0.56	99	*0.11*
*Clinician 3****	0.03	0.10	97	*0.11*

***Results based on 23 replicate measurements ** Results based on 4 replicate measurements**
*****Results based on 2 replicate measurements**
Average TEM is the average of all the measurers assessed during the study period

Table 10 Inter-observer reliability of routine clinical measurements (circumferences)

Measurer/ anthropometry	TEM (cm)	Relative TEM (%)	Reliability (%)	*Average TEM (cm)*
Head circumference				
*Clinician 1**	0.29	0.86	94	*0.28*
*Clinician 2**	0.35	1.01	96	*0.28*
*Clinician 3**	0.36	1.04	92	*0.28*
*Clinician 4**	0.20	0.60	95	*0.28*
*Clinician 5**	0.25	0.74	95	*0.28*
*Clinician 6**	0.21	0.61	95	*0.28*
MUA circumference				
*Clinician 1**	0.29	2.57	78	*0.29*
*Clinician 2**	0.39	3.39	84	*0.29*
*Clinician 3**	0.22	1.98	95	*0.29*
*Clinician 4**	0.19	1.77	95	*0.29*
*Clinician 5**	0.35	3.40	64	*0.29*
*Clinician 6**	0.28	2.61	87	*0.29*
Abdominal circumference				
*Clinician 1**	0.54	1.71	87	*0.69*
*Clinician 2**	0.58	1.75	93	*0.69*
*Clinician 3**	0.39	1.22	96	*0.69*
*Clinician 4**	0.74	2.42	81	*0.69*
*Clinician 5**	0.63	2.11	86	*0.69*
*Clinician 6**	0.77	2.48	88	*0.69*

***Results based on 10 replicate measurements for each clinician**

Average TEM is the average of all the measurers assessed during the study period

Intra and inter-observer reliability of research skinfold measurements are shown in tables 12 & 13. Intra and inter-observer TEM for subscapular skinfold thickness ranged from 0.14 to 0.25mm and 0.17 to 0.63mm respectively. The average for these for all assessors was 0.20mm for intra- and 0.42mm for inter-observer comparisons. 100% of the intra- and 100% of the inter-observer comparisons were within +/- two-times the average. Triceps skinfold thickness TEM values were 00.22 to 0.35mm for intra-observer measurements and 0.15 to 0.54mm for inter-observer measurements. The average for these for all assessors was 0.26mm for intra- and 0.35mm for inter-observer comparisons. 100% of the intra- and 100% of the inter-observer comparisons were within +/- two-times the average. The relative TEM for the intra-observer comparisons for the skinfolds were <5% for the majority and <7% for all. The inter-observer relative TEM, however, varied markedly from 3.27% to 14.23%. R was >= 70% for all but one of the study administrators for whom it was 64%.

Table 11 Intra-observer reliability of research collected measurements (skinfolds)

Measurer/ anthropometry	TEM (mm)	Relative TEM (%)	Reliability (%)	*Average TEM (mm)*
Subscapular skinfold				
*Administrator 1**	0.16	3.00	76	*0.20*
*Administrator 2****	0.19	3.81	97	*0.20*
*Administrator 3***	0.25	5.98	78	*0.20*
*Administrator 4****	0.14	2.88	98	*0.20*
*Administrator 5****	0.25	5.09	94	*0.20*
Triceps skinfold				
*Administrator 1**	0.26	4.25	94	*0.26*
*Administrator 2****	0.22	4.06	97	*0.26*
*Administrator 3***	0.26	5.29	64	*0.26*
*Administrator 4****	0.35	6.98	87	*0.26*
*Administrator 5****	0.22	4.16	94	*0.26*

***Results based on 6 replicate measurements **Results based on 4 replicate measurements ***Results based on 10 replicate measurements**

Average TEM is the average of all the measurers assessed during the study period

Table 12 Inter-observer reliability of research collected measurements (skinfolds)

Measurer/ anthropometry	TEM (mm)	Relative TEM (%)	Reliability (%)	*Average TEM (mm)*
Subscapular skinfold				
*Administrator 1**	0.38	7.07	77	*0.42*
*Administrator 2**	0.17	3.55	97	*0.42*
*Administrator 3**	0.49	9.68	79	*0.42*
*Administrator 4**	0.63	14.23	75	*0.42*
*Administrator 5**	0.42	9.01	71	*0.42*
*Administrator 6**	0.22	4.15	94	*0.42*
*Administrator 7**	0.55	11.99	53	*0.42*
*Administrator 8**	0.31	6.68	86	*0.42*
*Administrator 9**	0.61	10.64	71	*0.42*
Triceps skinfold				
*Administrator 1**	0.26	4.47	88	*0.35*
*Administrator 2**	0.15	3.27	97	*0.35*
*Administrator 3**	0.47	8.75	80	*0.35*
*Administrator 4**	0.37	7.85	89	*0.35*
*Administrator 5**	0.51	10.32	68	*0.35*
*Administrator 6**	0.25	3.93	96	*0.35*
*Administrator 7**	0.54	10.39	62	*0.35*
*Administrator 8**	0.24	4.79	83	*0.35*
*Administrator 9**	0.38	6.55	89	*0.35*

***Results based on 10 replicate measurements**

Average TEM is the average of all the measurers assessed during the study period

Tables 9-12 demonstrate two additional points. They illustrate that TEM and R assess different aspects of reliability so that the lowest levels of relative TEM do not correspond to the highest levels of R. This illustrates the value of using more than one measurement of reliability. Second, for both routine clinical measurements of circumferences and research measurements of skinfolds intra-observer reliability is better than inter-observer reliability.

Bland Altman plots (Figures 10 to 45) show that all mean differences were close to zero. Data points fell close to the line of mean difference and were spread evenly across either side of the line suggesting no systematic bias although they should be viewed with the understanding that each plot was based on just 10 data points.

Figure 10 Paediatrician 1 Head Circumference (cm)

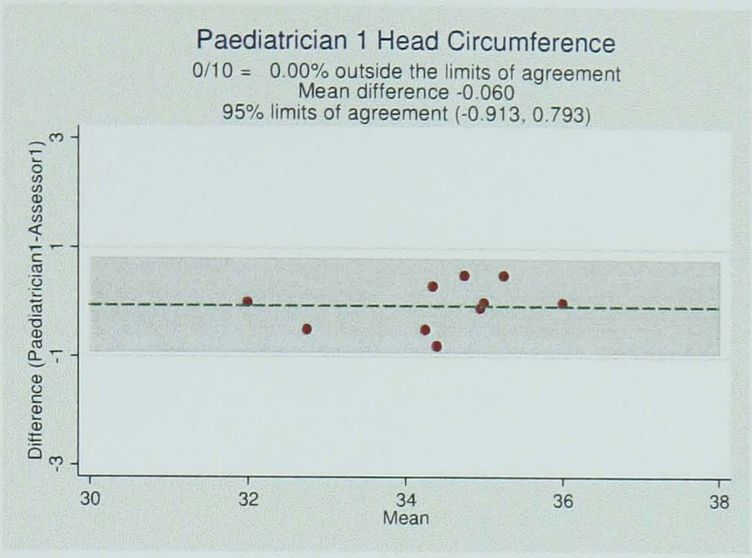


Figure 11 Paediatrician 2 Head Circumference (cm)

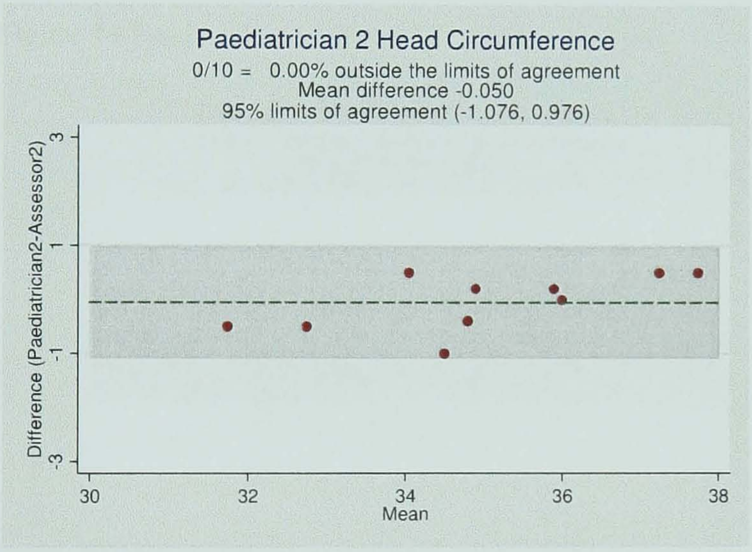


Figure 12 Paediatrician 3 Head Circumference (cm)

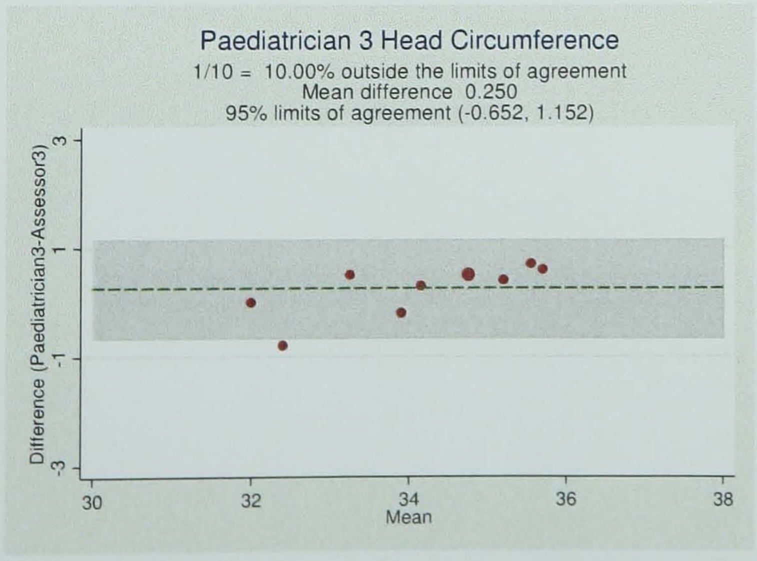


Figure 13 Paediatrician 4 Head Circumference (cm)

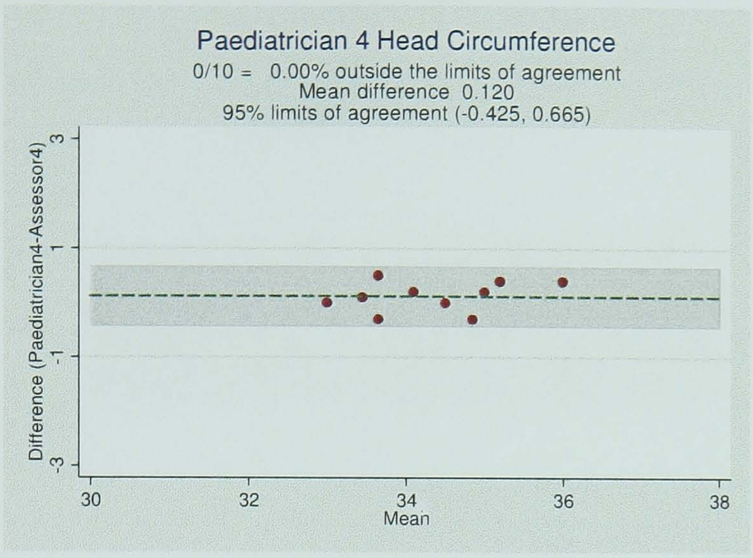


Figure 14 Paediatrician 5 Head Circumference (cm)

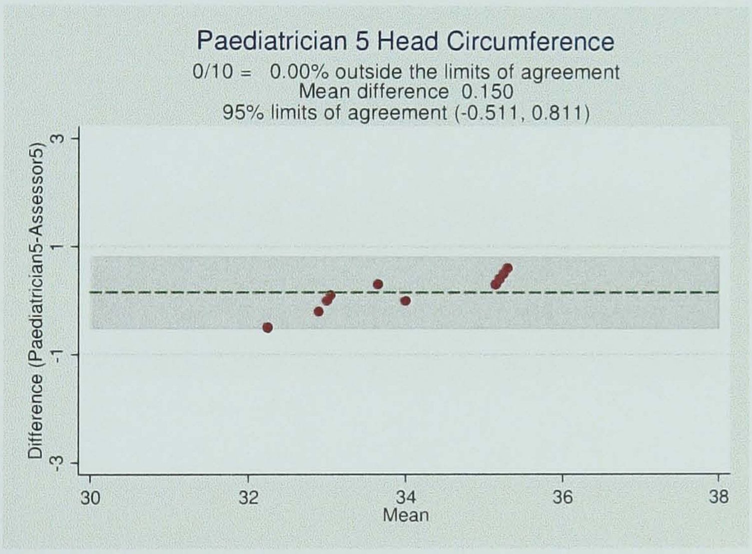


Figure 15 Paediatrician 6 Head Circumference (cm)

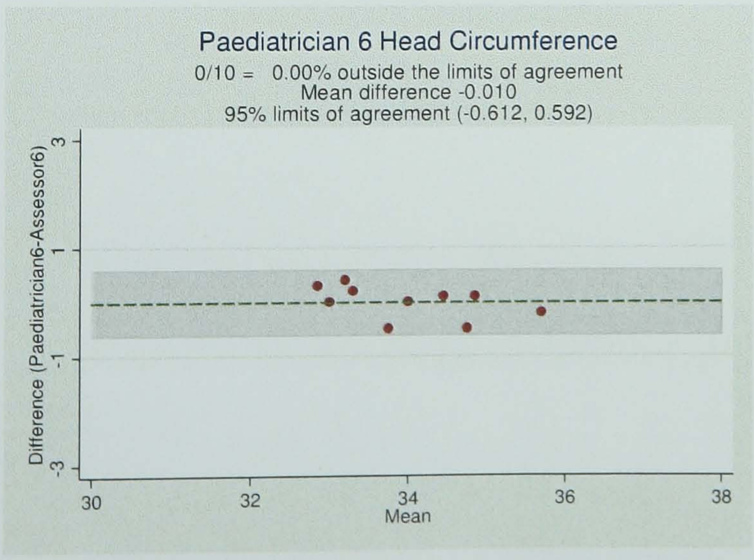


Figure 16 Paediatrician 1 Abdominal Circumference (cm)

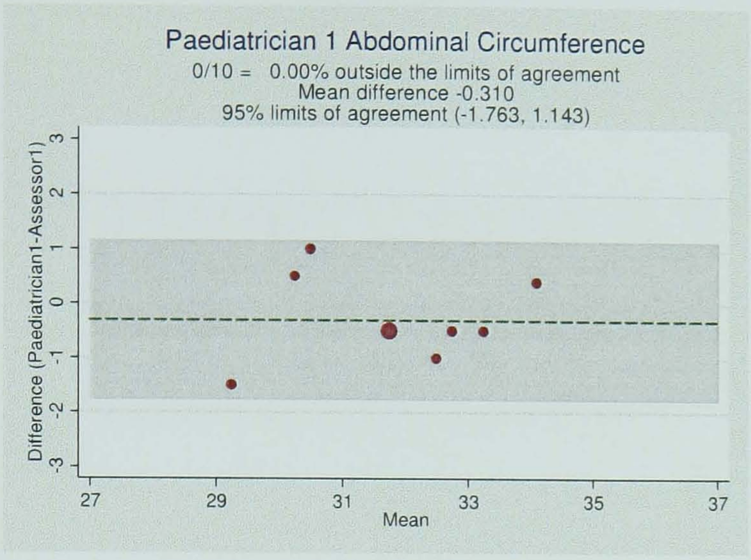


Figure 17 Paediatrician 2 Abdominal Circumference (cm)

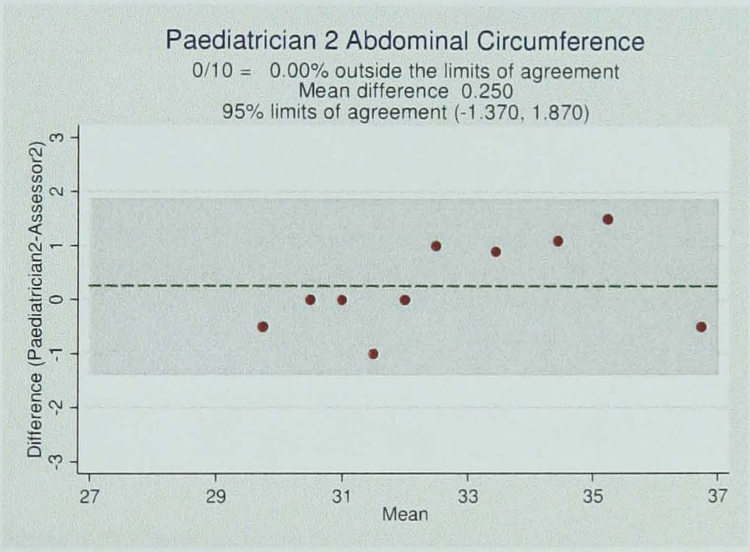


Figure 18 Paediatrician 3 Abdominal Circumference (cm)

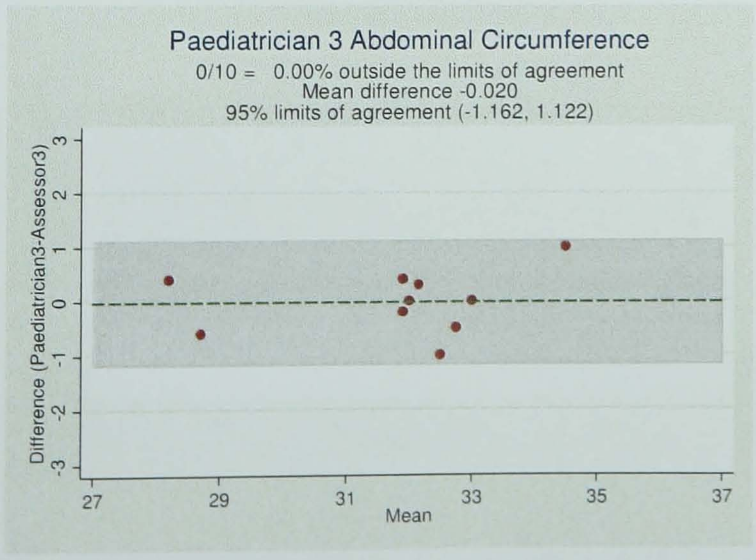


Figure 19 Paediatrician 4 Abdominal Circumference (cm)

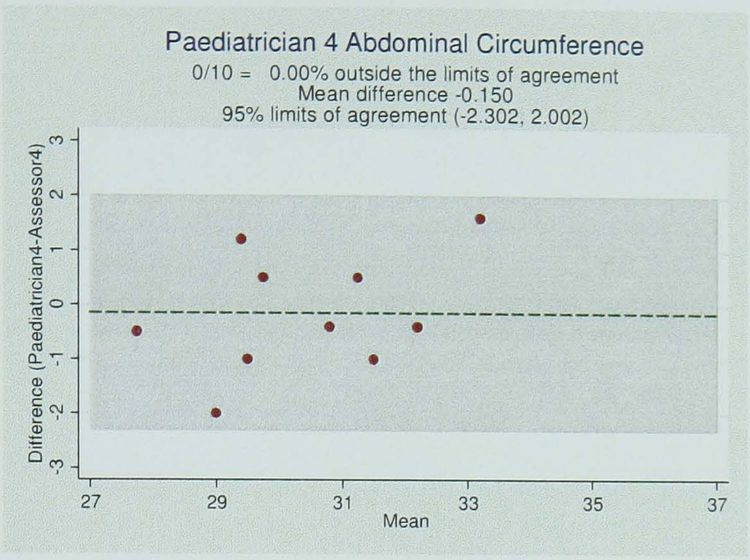


Figure 20 Paediatrician 5 Abdominal Circumference (cm)

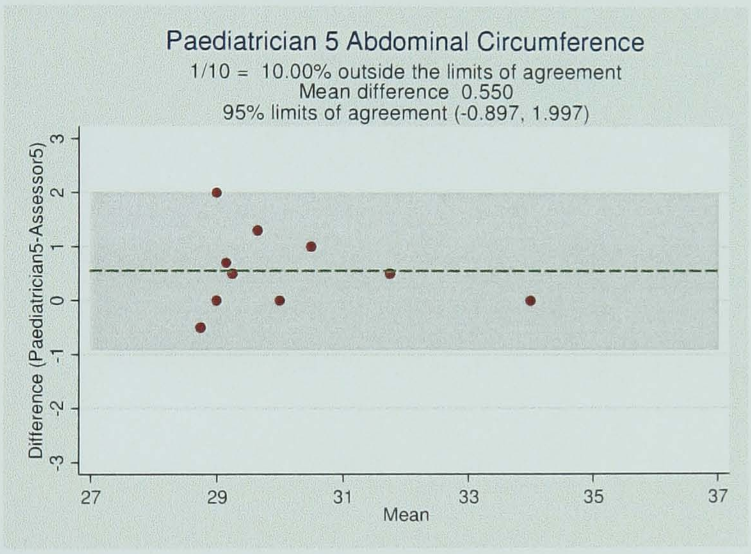


Figure 21 Paediatrician 6 Abdominal Circumference (cm)

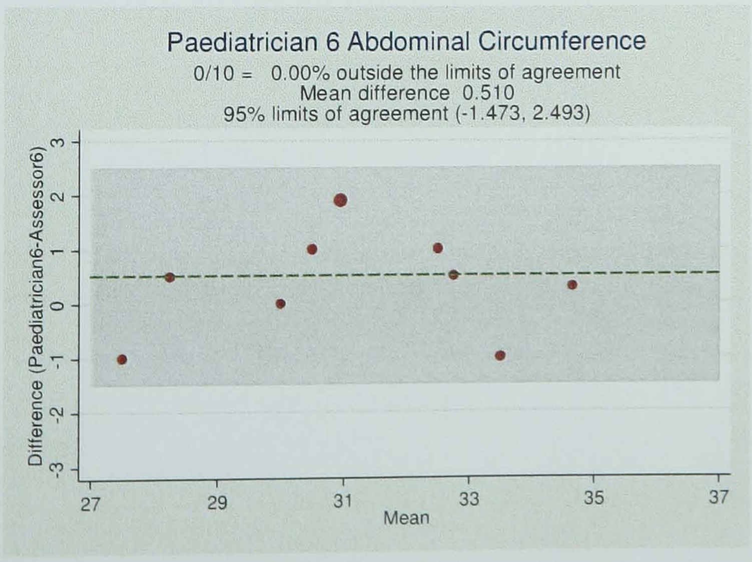


Figure 22 Paediatrician 1 MUA Circumference (cm)

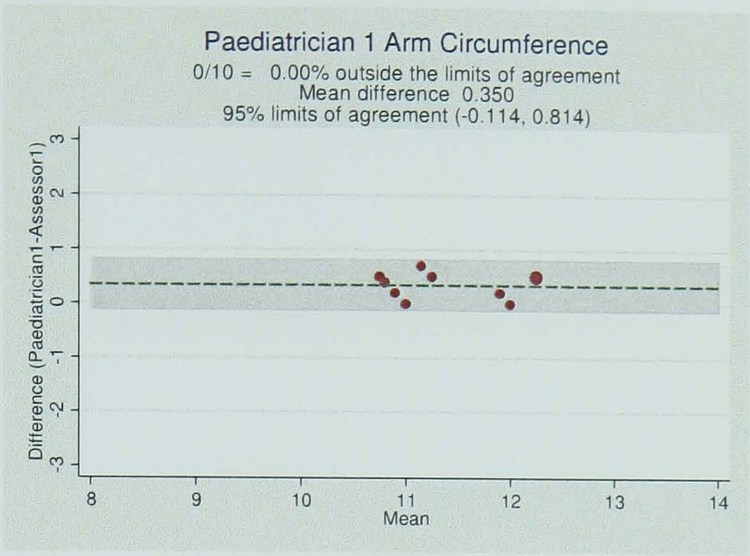


Figure 23 Paediatrician 2 MUA Circumference (cm)

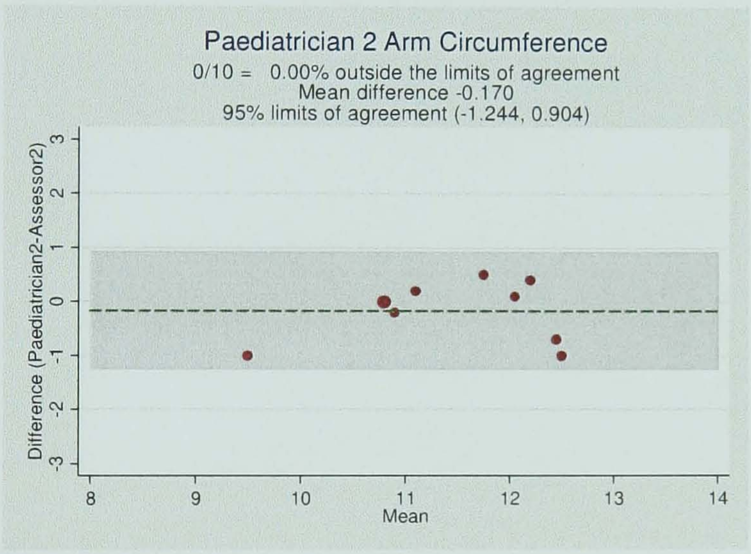


Figure 24 Paediatrician 3 MUA Circumference (cm)

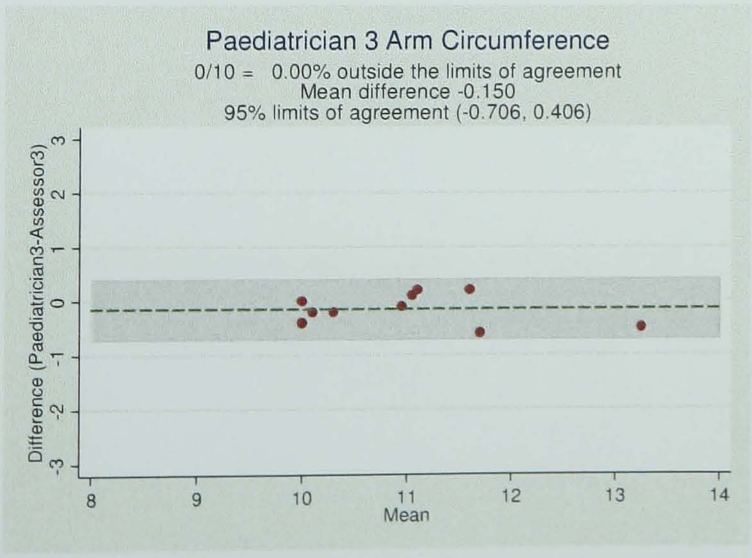


Figure 25 Paediatrician 4 MUA Circumference (cm)

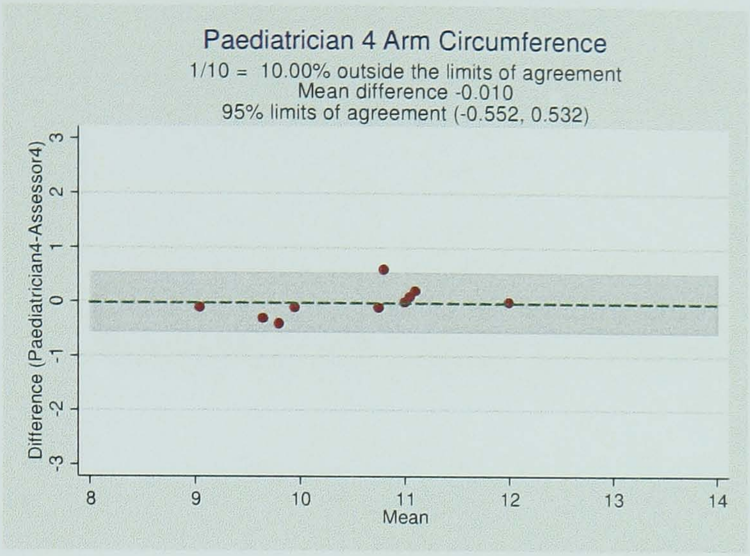


Figure 26 Paediatrician 5 MUA Circumference (cm)

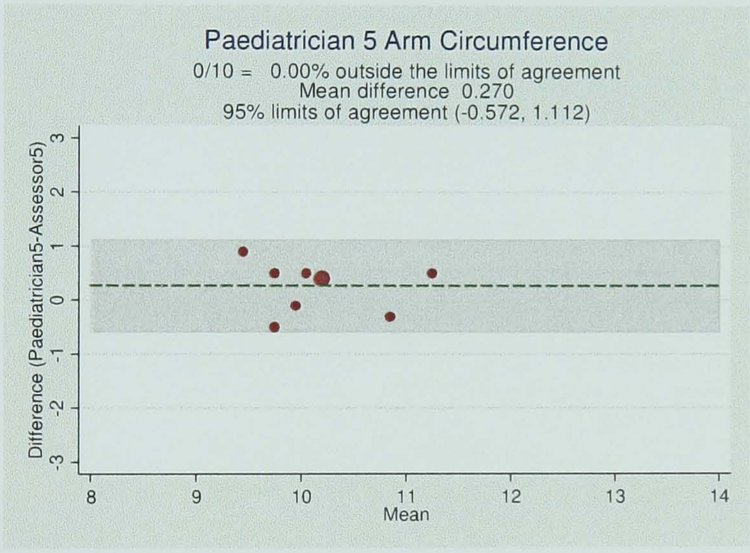


Figure 27 Paediatrician 6 MUA Circumference (cm)

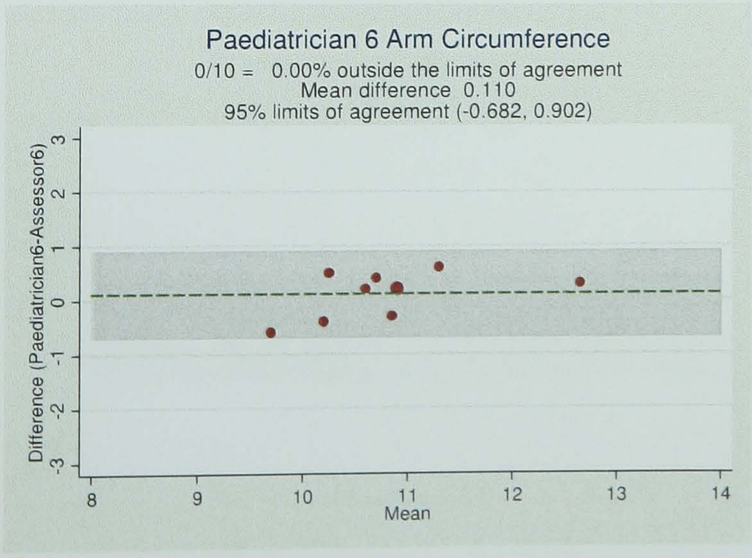


Figure 28 Administrator 1 Sub-scapular Skinfold (mm)

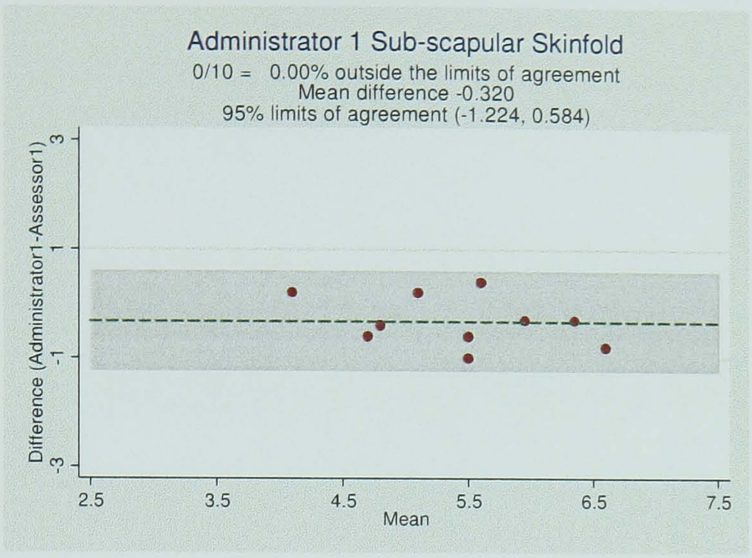


Figure 29 Administrator 2 Sub-scapular Skinfold (mm)

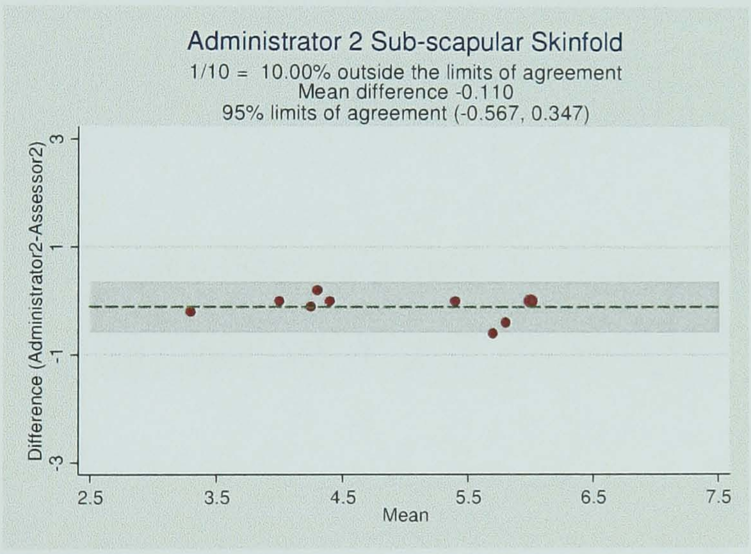


Figure 30 Administrator 3 Sub-scapular Skinfold (mm)

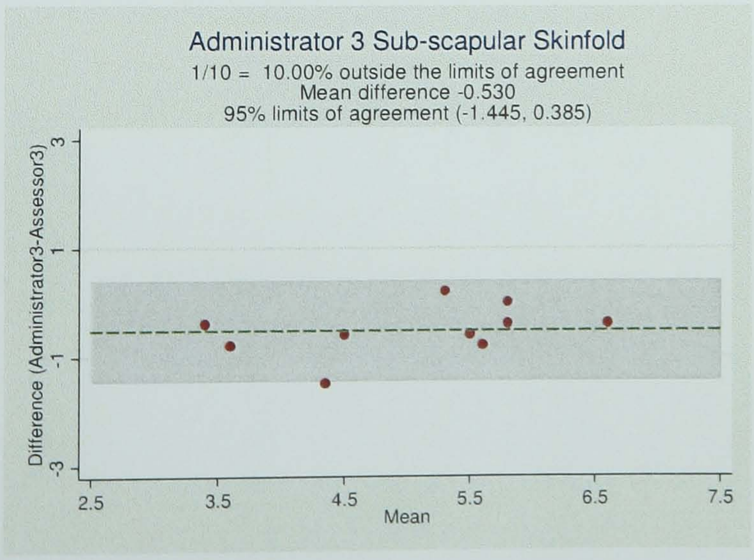


Figure 31 Administrator 4 Sub-scapular Skinfold (mm)

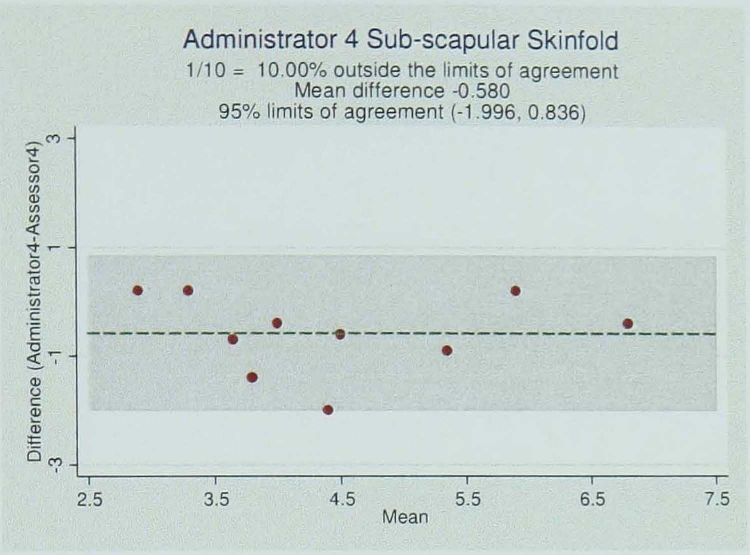


Figure 32 Administrator 5 Sub-scapular Skinfold (mm)

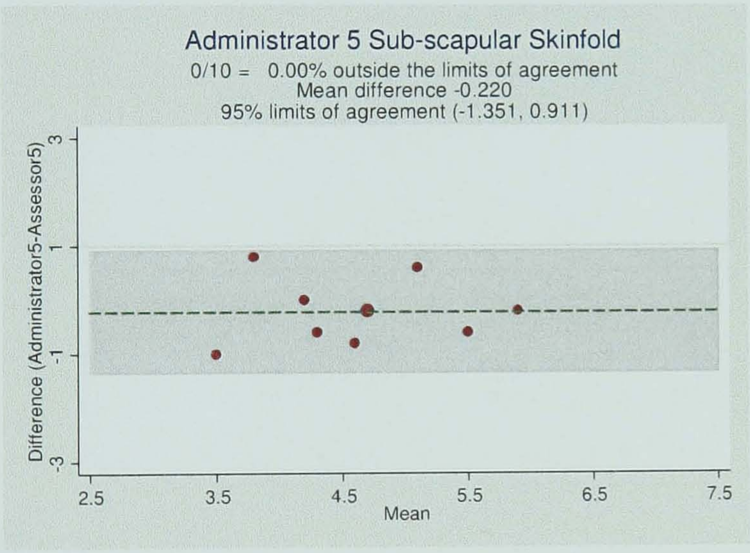


Figure 33 Administrator 6 Sub-scapular Skinfold (mm)

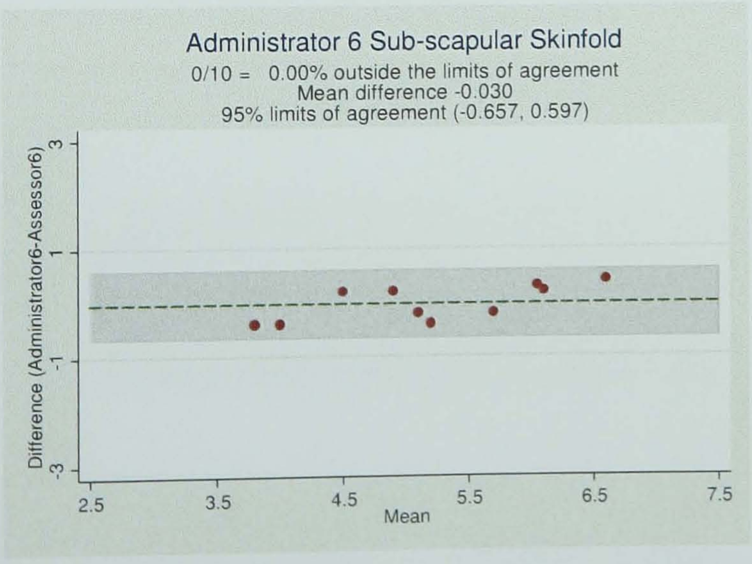


Figure 34 Administrator 7 Sub-scapular Skinfold (mm)

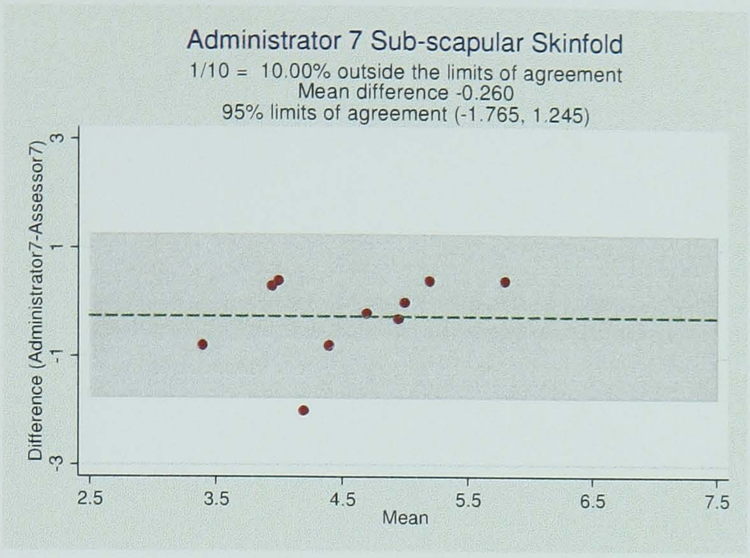


Figure 35 Administrator 8 Sub-scapular Skinfold (mm)

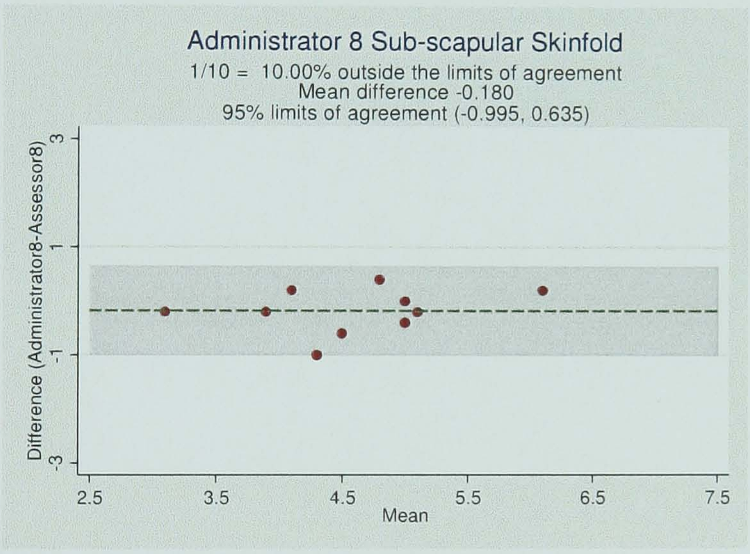


Figure 36 Administrator 9 Sub-scapular Skinfold (mm)

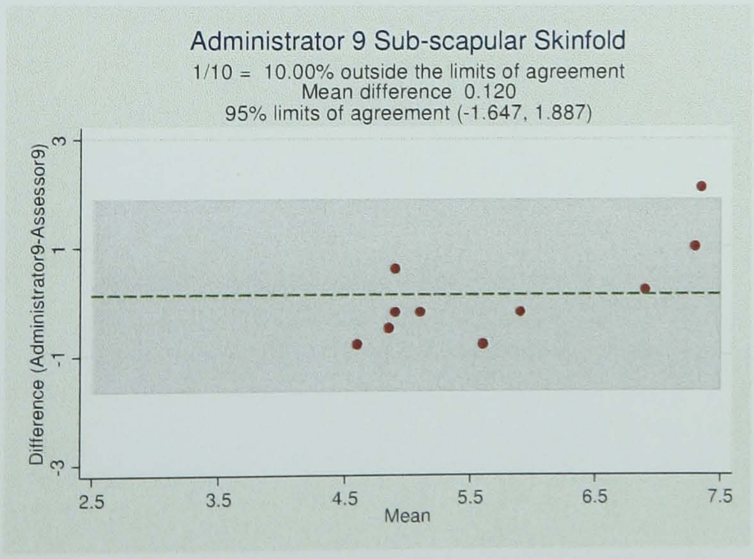


Figure 37 Administrator 1 Triceps Skinfold (mm)

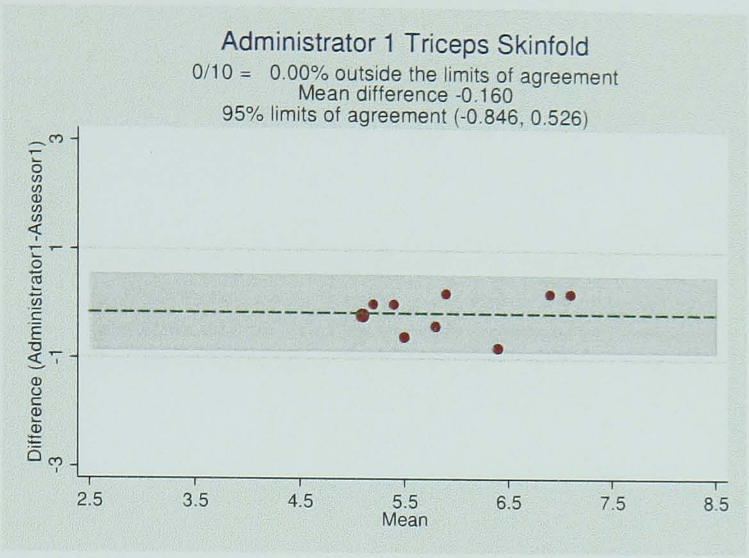


Figure 38 Administrator 2 Triceps Skinfold (mm)

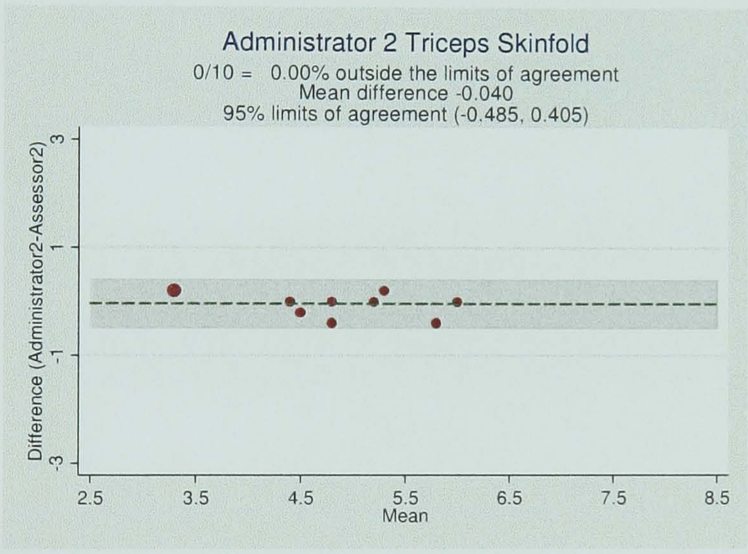


Figure 39 Administrator 3 Triceps Skinfold (mm)

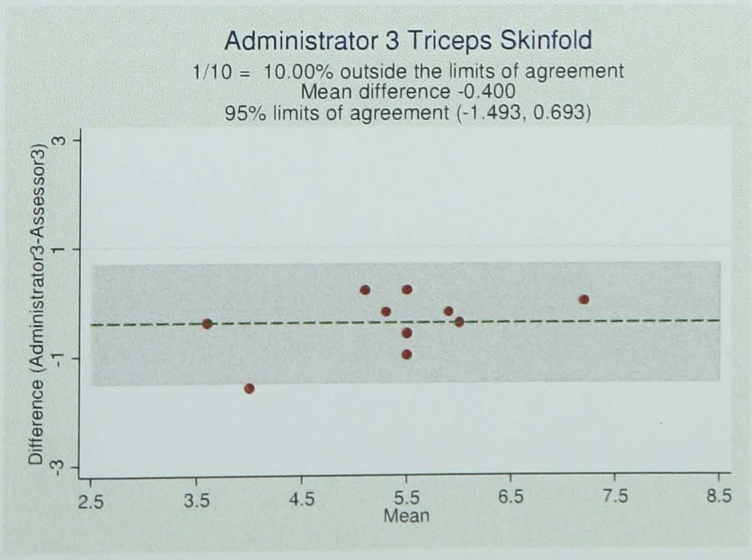


Figure 40 Administrator 4 Triceps Skinfold (mm)

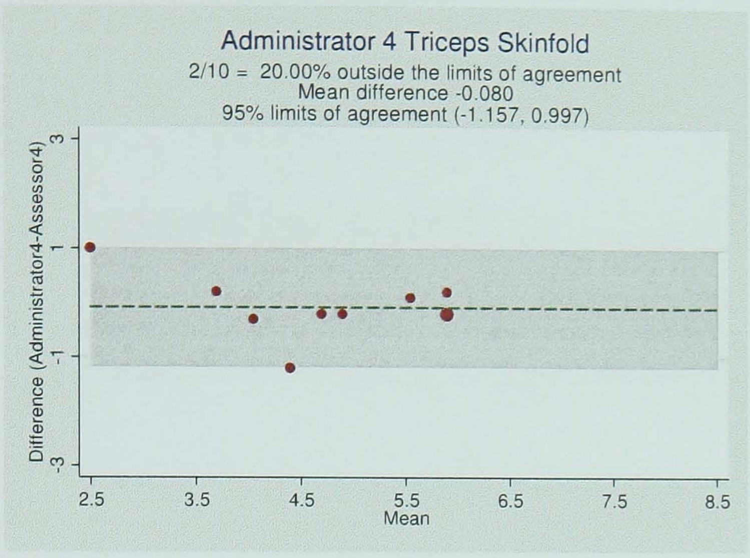


Figure 41 Administrator 5 Triceps Skinfold (mm)

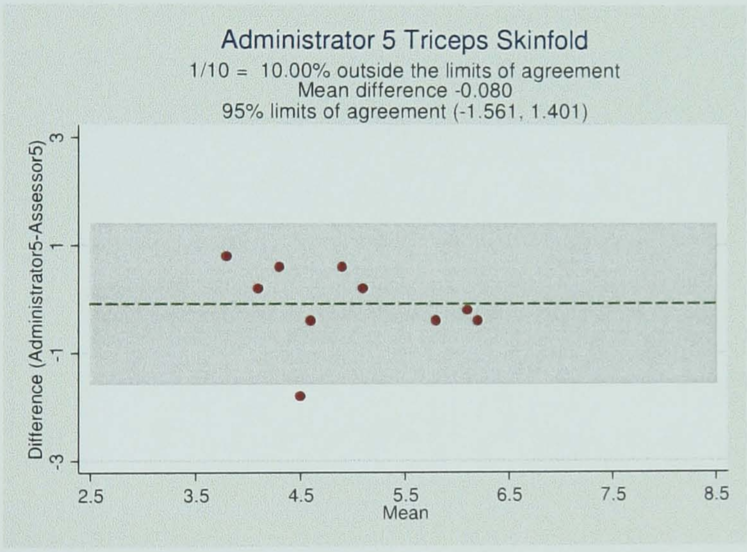


Figure 42 Administrator 6 Triceps Skinfold (mm)

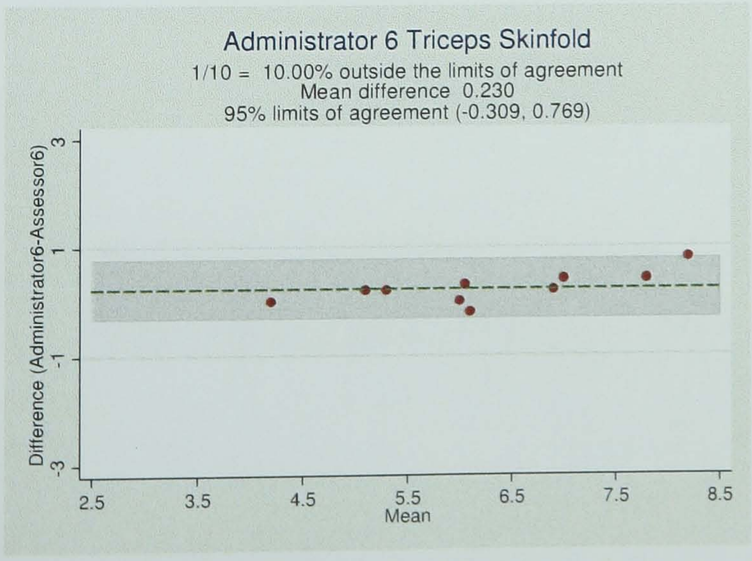


Figure 43 Administrator 7 Triceps Skinfold (mm)

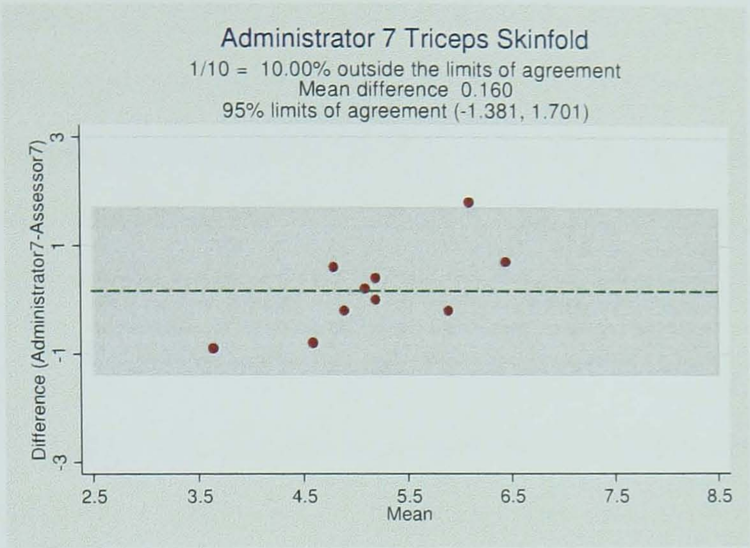


Figure 44 Administrator 8 Triceps Skinfold (mm)

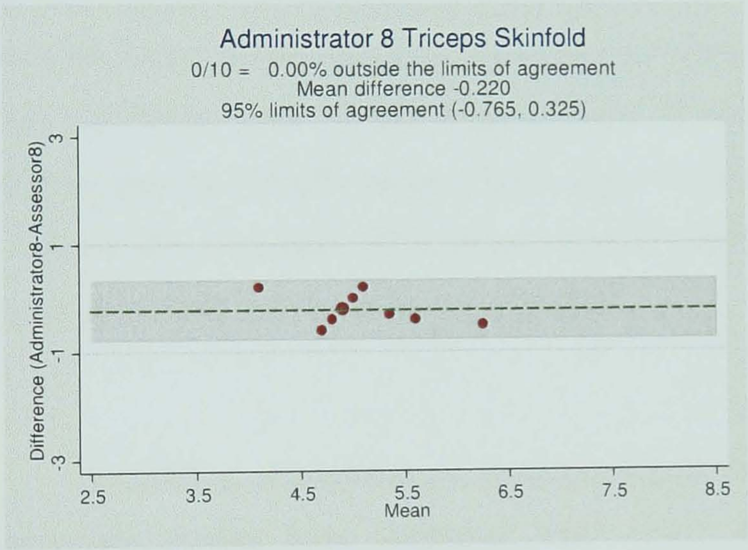
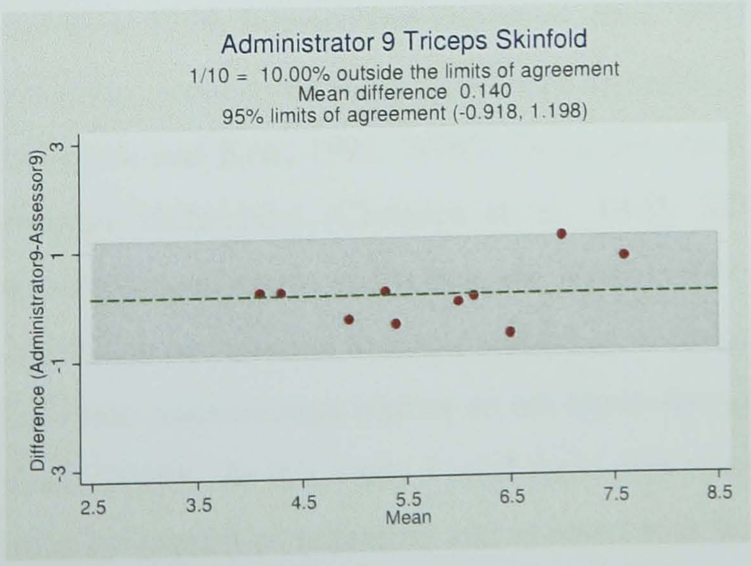


Figure 45 Administrator 9 Triceps Skinfold (mm)



4.3.6 Discussion

These results show that the routinely assessed clinical measurements of head, MUA and abdominal circumference collected for this thesis are measured reliably. Skinfold thicknesses measured specifically for this study were less reliably measured, which has implications for their use in this and other research studies but this probably reflects the fact that skinfolds are known to be characteristically less reliable than other anthropometric measurements (WHO, 2006).

For both sets of measurements intra-observer reliability was better than inter-observer reliability, highlighting the importance of minimizing the number of individuals completing measurements in any cohort. I did not assess the reliability of birth weight which is also routinely collected for all newborn babies and widely used in research and important for clinical practice. This was because the potential role of human error in this measurement, as compared to those assessed which require placing of tape measures and calipers in specific places, is considerably less. It would also have been difficult to assess its reliability without interrupting clinical management of the end of labour and birth.

Reliability assessment of neonatal measurements is not straightforward and very few studies have attempted this. First, there is no universal consensus regarding the most appropriate statistical method (Chumlea et al., 1990, Ulijaszek and Kerr, 1999, Johnson and Engstrom, 2002, WHO, 2006). For example, TEM and reliability seem to be most commonly reported (reported by Chumlea et al., 1990, Ulijaszek and Kerr, 1999, WHO, 2006) but other measures reported include mean absolute differences (Chumlea et al., 1990, Johnson and Engstrom, 2002) and intraclass coefficients (Ulijaszek and Kerr, 1999). Yajnik et al (2002) reported the coefficient of variation to assess reliability of neonatal anthropometric measurements but some measurement studies do not report formal reliability assessment (Whincup et al., 2010). In this study I used three commonly used measurements that assess different aspects of reliability and as noted with the results give different indications of which measures or which assessors are most reliable. Second, there are widespread inconsistencies in the interpretation of results, with results often interpreted by comparison to previously published studies that have used different protocols, observers, subjects and equipment (WHO, 2006). Papers frequently report that reliability is within acceptable ranges, but since this is often done on the basis of comparison to previous studies and acceptable ranges should take account of the differing characteristics of the measurements and population, such conclusions should be treated with caution (Ulijaszek and Kerr, 1999, WHO, 2006). In these analyses I have followed WHO guidance and compared each individual to the average of all of them, rather than compare to any published study. Third, the robustness of assessments of reliability of neonatal measurements is likely to be affected by small study sample numbers. Ideally, one would like to repeatedly assess the reliability of routine and research measurements on large numbers throughout the whole of the study period. In practice this is extremely difficult because of the short time period between birth and discharge for most babies and the need to prioritise clinical care over any audit or research needs.

I used three different measurements of reliability to increase the robustness of my conclusions. For the routine clinical measurements the TEM showed small standard deviations between repeated measurements, the relative TEM values were all low (< 3.54%) showing minimal error relative to the size of the overall measurement and R was high demonstrating that the vast majority of variance in each measure was not due to measurement error. For the research measurements of skinfold thickness the relative TEM were low for intra-observer comparisons (all < 7%), but were generally high and also varied markedly between assessors for inter-observer comparisons (3.27-14.23%) suggesting more error compared to the size of the measurement. R for skinfold measurements suggested a greater proportion of the variance was due to measurement error here than for the routine clinical measurements of circumferences. Nonetheless, with the exception of one assessor, R was >70% for all. In this study, R was similar to skinfold R coefficients of 75-93% reported in the WHO Multicentre Growth Reference Study (2006). Reliability for one administrator (Administrator 7) fell short of acceptable limits but interestingly this individual had been identified for re-training through ongoing monitoring prior to these results. This highlights the importance of both detailed protocols and repeated training, as well as monitoring of reliability, in research studies. The results were used to undertake sensitivity analyses to assess the impact of relatively unreliable measurements by Administrator 7 by removing participants from the analyses who had measurements by this administrator and examining whether this changed the results or key conclusions in any important way. These findings are reported in Chapter 6.

These results indicate that routinely collected circumference measurements are reliable. In a separate study of participants in the BiB study it has been demonstrated that measurements of weight, height and head circumference routinely collected by health visitors in later infancy can be accurate and reliable after training (Johnson et al., 2009). A different British cohort found that routine measurements of weight and height in infancy (from age 8 months) were accurate when compared with measurements on the same individuals conducted in research clinics with little or no training of the health visitors collecting the routine data (Howe et al., 2009). These findings – that data good enough for clinical practice is good enough for research – have important implications for future epidemiological research. Use of routine data would avoid the costly duplication of data collection by researchers, provide confidence in large population datasets for analysis and help bring together the worlds of research and practice.

4.3.6.1 Issues encountered

A number of issues were encountered during the assessment of reliability for the anthropometric measurement used in this thesis. First, the analysis included routine clinical data and research data from the same study population and whilst the measurements are not directly comparable due to differences in the characteristics of the measurements, it has allowed clinical and research data to be put side by side to examine reliability. Second, I aimed to undertake replicate measurements on a minimum of 10 infants for each measurer for all assessments as per recommendations for assessing reliability (Ulijaszek and Kerr, 1999). This was difficult to achieve for some intra-observer assessments due to clinical pressures and the importance of always allowing clinical practice to take precedence over our research. Three paediatricians participated in the intra-observer assessment on 23, 4 and 2 infants respectively. Two of the paediatricians were called to clinical incidents during these assessments resulting in the small number of infants measured. All study administrators taking measurements at the time of the intra-observer assessments were included in the assessment. Again I aimed to obtain replicate measurements on 10 infants but this was only possible for 3 administrators (due to periods of leave), 4 and 6 infants were measured for the remaining two administrators. Adequate numbers (10 infants) were obtained for all other assessments. Finally, the sample sizes for reliability tests were small and ideally I would have liked to continue testing on a larger sample. However, these measurements are still likely to be representative as they were collected over a 2-year period on various days and at various times and further, were obtained from a similar proportion of Pakistani and White British infants to that measured for the BiB study as a whole (52% and 48% respectively).

4.3.7 Summary

In summary, the main findings of this chapter are that routinely collected neonatal measurements of circumferences are reliable, assessment of neonatal skinfold thicknesses by research staff are less reliable but on the whole had reasonable reliability, whenever possible minimizing the number of staff used to assess neonatal anthropometry will improve reliability and it is always going to be important to continually train and re-train assessors, as well as monitoring reliability.

Chapter 5
Descriptive analysis

The results of the descriptive analyses for this thesis are presented in this chapter. This begins with an assessment of the representativeness of the sample and is followed by a summary of missing data and the strategy employed to manage this. Next, distributions are presented in detail for each outcome, exposure and mediating/masking variable.

5.1 Representativeness of study sample

5.1.1 The sample compared to the whole BiB cohort

To assess the representativeness of the sample used in this thesis, mean maternal age, ethnicity and mean birthweight were compared with the complete BiB cohort and the Bradford district as a whole. The mean maternal age of mothers in the sample used for this thesis was 27.3 years which is broadly similar to the mean maternal age for both the complete BiB cohort (27.8 years) and the Bradford district (28.0 years) (NHS Bradford and Airedale data). At the time of these analyses, it was only possible to compare ethnicity in terms of 'South Asian' and 'non-South Asian'. In the sample reported here, 55% were of Pakistani origin and 45% of White British origin which suggests a slight shortfall in White British mothers when compared to the BiB cohort (50% South Asian; 50% non-South Asian) and the Bradford district (47% South Asian; 53% non-South Asian) but in fact probably reflects the use of broader categories (South Asian and non-South Asian) for the comparison (i.e. non-South Asian will include other white groups eg. White Europeans, who were excluded from the sample used in this thesis). Analyses for this thesis were undertaken whilst data collection, linkage and cleaning for the BiB cohort study was ongoing. As a result it was not possible to compare mean birthweight for the sample reported here with the compete BiB cohort however, mean birthweight (for deliveries >37 weeks gestation) for this sample was comparable to mean birthweight for the Bradford district in 2009 (3297g and 3330g respectively) (NHS Bradford and Airedale data). It is anticipated that the BiB data will be available for future analyses and publications.

5.1.2 The leptin sub-sample compared to the whole sample for this thesis

A consecutive sub-sample of cord blood samples were obtained on the Delivery Suite for all infants enrolled in BiB. Some were either not in the data set for this thesis, missing or implausible results or consent had been withdrawn after the sample had been obtained (Figure 7) resulting in a final sub-sample of 1388. This was compared to the whole sample used in this thesis (n=4059) on ethnicity and mean birthweight to ensure that the sub-sample was representative of the full study population used here. In terms of ethnicity, 44% of the leptin sub-sample were White British compared to 45% of the whole sample. Mean birthweight among those with a cord leptin sample was similar to the full sample in all groups with the exception of the Pakistani 'other' generation group where the mean birthweight for those with a cord leptin sample is around 60g lower than that of the group as a whole (Table 13). This may be a chance finding or may reflect the heterogenous make-up of this group.

Table 13 Mean birthweight of cord leptin sub-sample

Ethnic group	n	%*	Mean birthweight for those with cord leptin sample (g)	SD	Mean birthweight for whole sample (g)	SD
White British (n=1838)	613	33	3456	479	3421	490
Pakistani All (n=2221)	775	35	3195	428	3194	458
Total (n=4059)	*1388*	*34*	*3310*	*481*	*3297*	*486*
Generation group	**n**	**%**	**Mean birthweight for those with cord leptin sample (g)**	**SD**	**Mean birthweight for whole sample (g)**	**SD**
Neither (n=232)	75	32	3195	428	3181	444
Dad only (n=584)	211	36	3202	413	3205	435
Mum only (n=523)	174	33	3173	470	3178	479
Both (n=675)	245	36	3227	468	3206	462
Other (n=207)	70	34	3111	475	3173	473
Total	*775*	*35*	*3194*	*451*		

*Percentage of each group that have a cord leptin sample

5.2 Missing values

Missing values are summarised below. As described previously in Chapter 3 and shown in Figure 6, the sample used in this thesis was selected on the basis of having available ethnicity data (completed mother's questionnaire) therefore self-defined ethnicity was available for all participants.

5.2.1 Outcome measurements

For outcome variables missing data was variable. Birthweight was available for all 4059 participants, however, completeness of data for all other measurements varied between 89% and 91% for circumferences and was 74 % for skinfold thickness measures (Table 14). Birthweight is recorded routinely immediately following delivery for all births and is required for birth registration, as such 100% completeness was expected. The circumference measurements (head, abdominal and MUA) were recorded by the paediatrician/midwife undertaking the newborn first examination. All neonates have a newborn examination but some specific measurements may not be completed, or may be completed but not recorded and hence there will be some missing data. Missing data for head circumference was slightly less than the two other circumference measurements possibly because head circumference has historically always been recorded at first examination and for those needing intensive or special care, whereas the other two circumference measurements were introduced by the BiB study and may have been missed by new staff or in the case of poorly infants on the neonatal unit. Skinfold thickness measurements were recorded on the postnatal wards during office hours by BiB study administrators. Missing data for these measurements generally occurred when mothers were discharged before the study administrators had an opportunity to perform the measurements. Almost all mothers in Bradford return home the day following a normal delivery which limits the opportunities for additional data collection. A small number of unrealistic outlying values were categorised as missing if they could not be validated through checking patient records as discussed in Chapter 3 (n=8).

Table 14 Number and % of participants with complete data by outcome variable

Outcome variable	Total number with complete data N(%) N=4059	White British N(%) N=1838	Pakistani N(%) N=2221
Birthweight	4059 (100)	1838 (100)	2221 (100)
Head circumference	3705 (91)	1672 (91)	2033 (91)
Abdominal circumference	3619 (89)	1629 (89)	1990 (90)
MUA circumference	3617 (89)	1634 (89)	1983 (89)
Subscapular skinfold thickness	3010 (74)	1286 (70)	1724 (78)
Triceps skinfold thickness	3021 (74)	1291 (70)	1730 (78)
Birthweight & all other measurements	2868 (71)	1227 (67)	1641 (74)

For birthweight and all circumferences the proportion of participants with missing data was similar for White British babies and South Asian babies (Table 14).

However, for data skinfold thicknesses there were somewhat more White British babies with missing data than South Asian babies. This difference could be systematic in that South Asian mothers may have on average a longer time in hospital after delivery and this may be related to birth size. To examine this further, I compared birthweight between different groups of complete data based on the outcomes listed in table 14 above. These results are shown in table 15 below.

Table 15 Mean birthweight by ethnicity and by whether there is complete data on each other outcome

Outcome variable	Mean (sd) birthweight (g)	Mean (sd) birthweight (g) White British	Mean (sd) birthweight(g) Pakistani	Mean birthweight difference (g) (95% CI)
Participants with complete data on birthweight *N=4059* *White British=1838* *Pakistani=2221*	3297 (486)	3421 (490)	3194 (458)	-228 (-257, -198)
Participants with complete data on head circumference *N=3705* *White British=1672* *Pakistani=2033*	3299 (480)	3419 (486)	3202 (453)	-217 (-248, -187)
Participants with complete data on abdominal circumference *N=3619* *White British=1629* *Pakistani=1990*	3302 (480)	3423 (486)	3204 (454)	-219 (-250, -188)
Participants with complete data on MUA circumference *N=3617* *White British=1634* *Pakistani=1983*	3302 (482)	3424 (486)	3202 (454)	-222 (-252, -191)
Participants with complete data on subscapular skinfold thickness *N=3010* *White British=1286* *Pakistani=1724*	3293 (481)	3423 (489)	3196 (453)	-227 (-261, -194)
Participants with complete data on triceps skinfold thickness *N=3021* *White British=1291* *Pakistani=1730*	3293 (482)	3423 (489)	3196 (453)	-227 (-261, -193)
Participants with complete data on birthweight & all other measurements *N=2868* *White British=1227* *Pakistani=1641*	3296 (479)	3424 (488)	3201 (450)	-227 (-261, -193)

In general the mean difference in birthweight between White British and Pakistani origin babies was greatest for the whole cohort (Table 15) but similar across all other groups with some missing data.

5.2.3 Explanatory variables

Data for explanatory variables were gathered from the eClipse maternity data system, biochemistry laboratory results, ultrasound and maternity attendance and from the maternal questionnaire. Table 16 presents the number and proportion of participants with complete data for each explanatory variable used in this thesis. With the exception of maternal BMI, data were available on between 98-100% of participants; for maternal BMI it was available on 92% . Patterns of missing data were similar across groups defined by ethnicity and generation.

Table 16 Number (%) with complete data for explanatory variables by ethnic and generation group

	White (1838)	Pakistani All groups (2221)	Pakistani Neither (232)	Pakistani Dad only (584)	Pakistani Mum only (523)	Pakistani Both (675)	Pakistani Other (207)
Maternal age	1838 (100)	2221 (100)	232 (100)	584 (100)	523 (100)	675 (100)	207 (100)
Smoking	1836 (99.9)	2214 (99.7)	232 (100)	582 (99.7)	519 (99.2)	674 (99.9)	207 (100)
Alcohol	1837 (99.9)	2214 (99.7)	232 (100)	583 (99.8)	519 (99.2)	674 (99.9)	206 (99.5)
Maternal BMI	1683 (92)	2047 (92)	211 (91)	546 (93)	486 (93)	615 (91)	189 (91)
Maternal existing or gestational diabetes	1838 (100)	2221 (100)	232 (100)	584 (100)	523 (100)	675 (100)	207 (100)
Maternal hypertension	1838 (100)	2221 (100)	232 (100)	584 (100)	523 (100)	675 (100)	207 (100)
Parity	1788 (97)	2158 (97)	224 (97)	566 (97)	507 (97)	656 (97)	205 (99)
Gestational age at delivery	1838 (100)	2221 (100)	232 9100)	584 (100)	523 (100)	675 (100)	207 (100)
Gender	1838 (100)	2221 (100)	232 (100)	584 (100)	523 (100)	675 (100)	207 (100)
Household income	1838 (100)	2219 (99.9)	232 (100)	583 (99.8)	522 (99.8)	675 (100)	207 (100)
Maternal education	1837 (99.9)	2215 (99.7)	232 (100)	584 (100)	522 (99.8)	670 (99.3)	207 (100)
Paternal education	1836 (99.9)	2210 (99.5)	232 (100)	577 (98.8)	523 (100)	673 (99.7)	205 (99)
Maternal employment	1838 (100)	2219 (99.9)	232 (100)	584 (100)	522 (99.8)	674 (99.9)	207 (100)
Housing tenure	1834 (99.8)	2216 (99.9)	232 (100)	583 (99.8)	523 (100)	673 (99.7)	205 (99)
Marital status	1836 (99.9)	2219 (99.9)	232 (100)	583 (99.8)	523 (100)	674 (99.9)	207 (100)

5.3 Distributions of outcome variables

5.3.1 Birthweight

Birthweight was recorded for all 4,059 participants in the study and was normally distributed (Figure 46). Mean birthweight for the whole sample was 3297g (sd 486) (Table 17) which is slightly below the England and Wales average of 3352g (Leon and Moser, 2010), although the national figure includes all gestations and it is likely that if this were restricted to only term infants, as in this thesis, the difference would be even larger.

Mean birthweight was higher for those of White British origin compared with Pakistani origin infants (Table 18). However, there was no strong evidence that Pakistani groups from different generations had different magnitudes of difference from the White British infants (Table 18 & Figure 47). For example, Pakistani infants born to a South Asian born mother and a UK born father (Mum only group) had a mean difference from the White British population of -243g (95% CI -316, -180) but this did not differ substantively from those with the lowest difference from the White British population (Both group), where both parents were UK born and the mean difference was -214g (85% CI -257, -173).

Figure 46 Birthweight distribution (g) for the whole sample (n=4059)

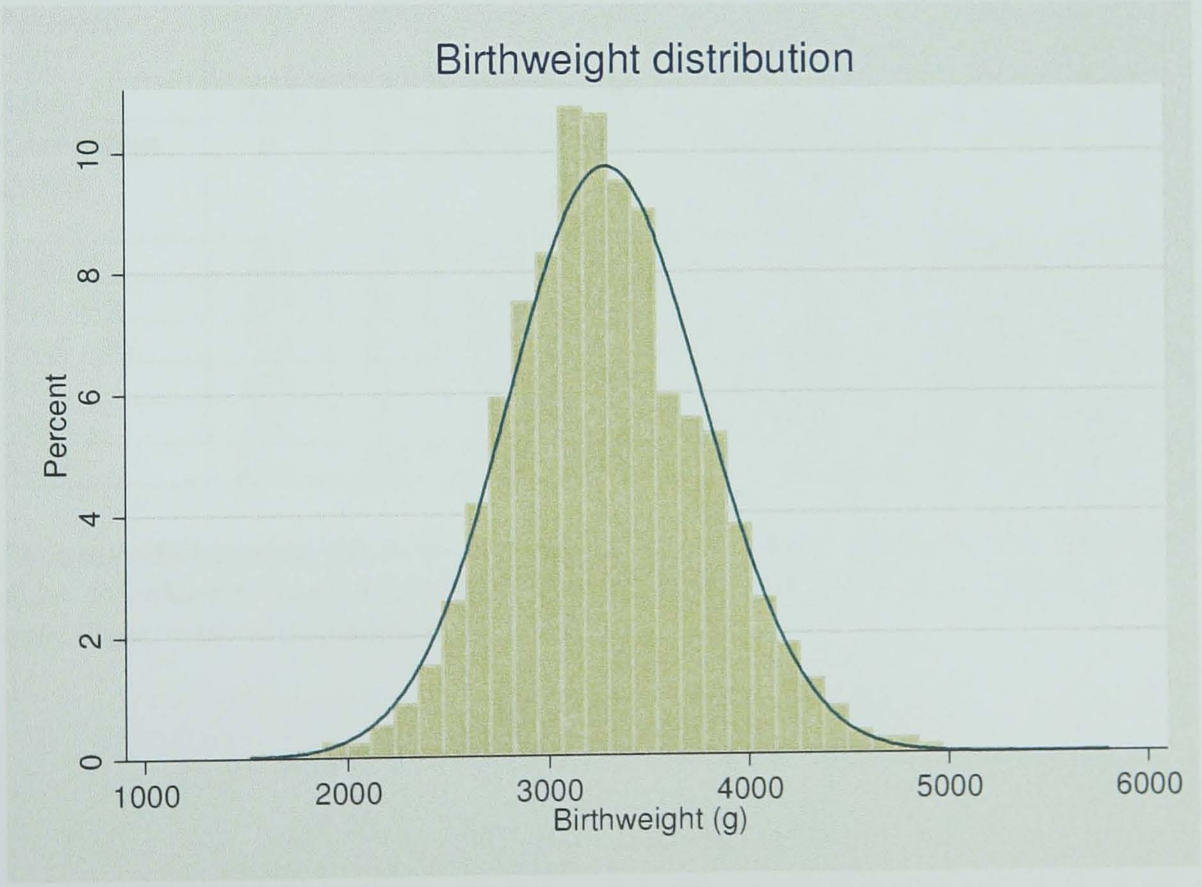


Table 17 Birthweight distribution (g)

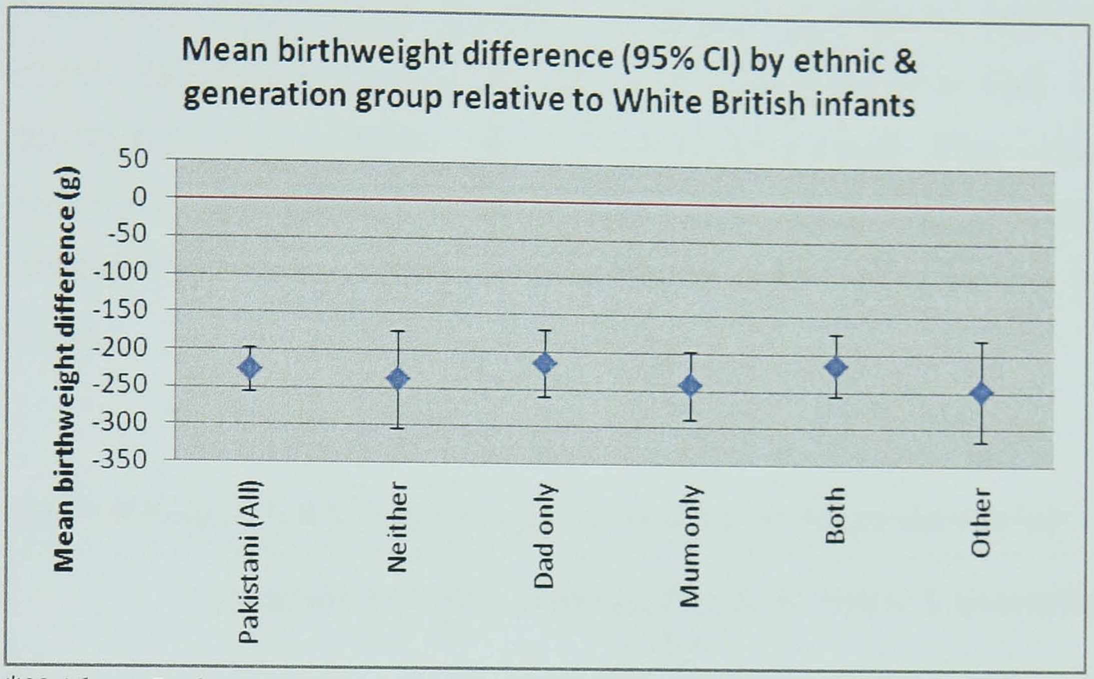
Birthweight (g)	
N	4059
Mean	3297
SD	486
Min	1520
25th centile	2980
Median	3280
75th centile	3600
Max	5800

Table 18 Birthweight by ethnic and generation group* (g)

Ethnic group	n	%	Mean	SD	Mean difference (from White British)	95% CI
White British	1838	45	3421	490		
Pakistani (All)	2221	55	3194	458	-228	(-257, -198)
Total	*4060*	*100*	*3297*	*486*		
Generation group	**n**	**%**	**Mean**	**SD**	**Mean difference** (from White British)	**95% CI**
Neither	232	10	3181	444	-240	(-305, -175)
Dad only	584	26	3205	435	-216	(-260, -172)
Mum only	523	24	3178	479	-243	(-289, -197)
Both	675	31	3206	462	-215	(-257, -173)
Other	207	9	3173	473	-248	(-316, -180)
Total	*2221*	*100*	*3194*	*458*	-228	(-257, -198)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 47 Mean birthweight difference (g) relative to White British infants by ethnic and generation groups*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

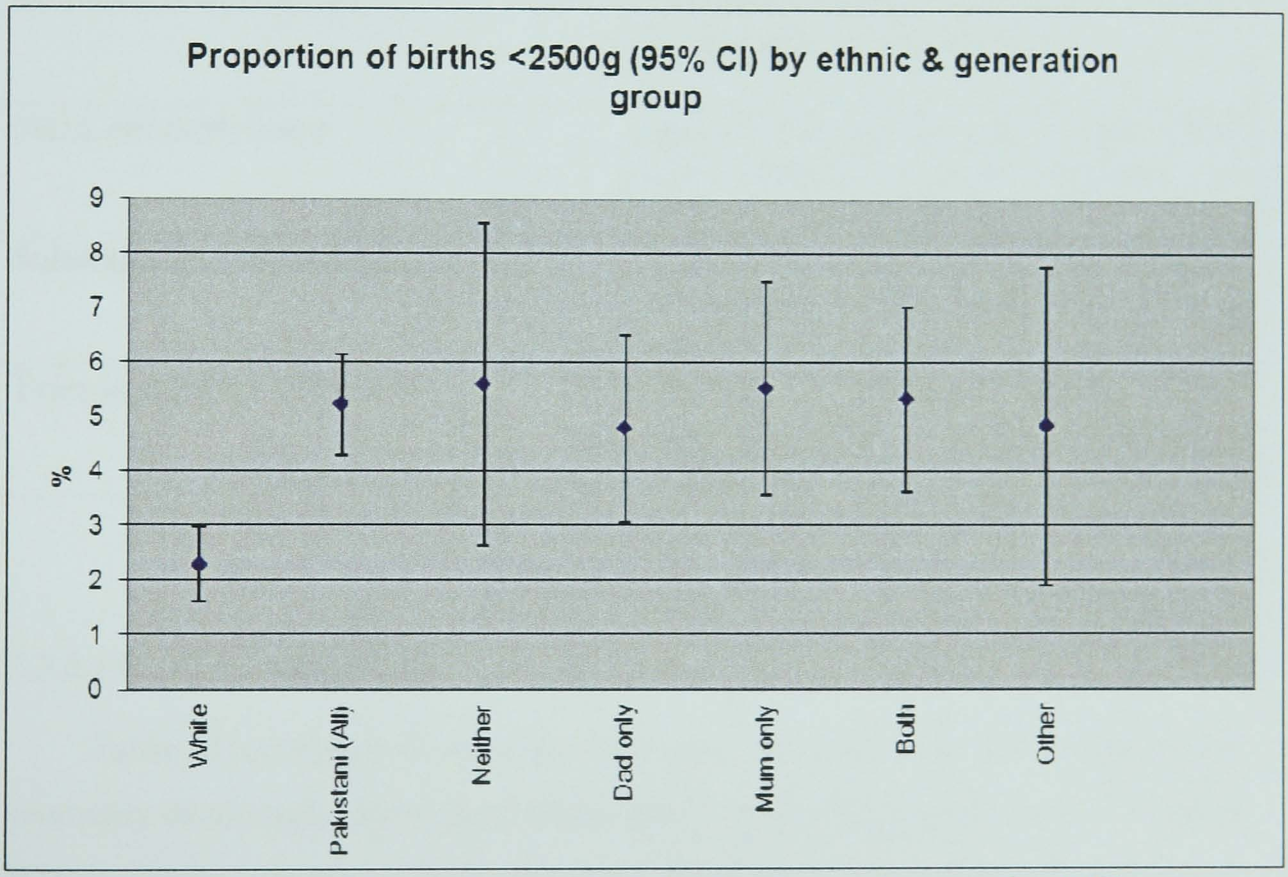
5.3.1.1 Low birthweight

Low birth weight is defined according to World Health Organisation (WHO) criteria as a weight at birth below 2500g. The proportion of infants born with a low birth weight in the whole sample was 3.9%. By ethnicity, 5.2% of Pakistani origin babies and 2.2% of White British infants had a low birthweight (Figure 46). Again, there was no strong evidence for differences by generation among Pakistani origin infants. The highest proportion of low birth weight infants (5.5%) were born to parents where the mother was South Asian born and the father UK born (Mum only group) but this was not vastly different from the lowest proportion of 4.8% who were born to a UK born mother and a South Asian born father (Dad only group).

The dataset for this thesis includes only births born at term (37 weeks gestation and over) as the research questions focus specifically on low birthweight as a result of growth restriction rather than low birthweight associated with prematurity.

Nationally birthweight data are reported collectively for all gestations (premature and term) thus comparisons between the data reported within this thesis and national/local data are limited. However, similar ethnic differences are apparent where ethnic categories are available. In England and Wales in 2008, 7.5% of all infants, irrespective of gestational age, were born with a low birth weight. In Bradford and Airedale district (2008) 8% of infants weighed <2500g at birth. When broken down by ethnicity 12.3% of South Asian infants had a low birth weight compared with 5% of infants of White British origin (NHS Bradford & Airedale 2010).

Figure 48 Proportion of term infants born <2500g by ethnic and generation group*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

5.3.2 Head, abdominal and MUA circumference measurements

Additional measurements of size, beyond birthweight, provide more precise estimates of fat versus lean mass and fat distribution (Table 19). For example, head circumference provides a possible proxy indicator of neurological development, abdominal circumference is a surrogate for visceral size and MUA circumference is used as an indicator of muscle mass. Along with skinfold thickness measurements, circumference measures can provide important information for the estimation of fat/lean mass and assessment of differences in adiposity that may be masked by comparison of birthweight alone.

Table 19 The role of different anthropometric measurements used in this thesis

Measure	Interpretation / use
Birthweight	Total fat, lean mass and water. Frequently used as an indicator of intrauterine nutrition
Head circumference	Commonly used measure of growth and size. Used as an indirect measure of brain size and development
Abdominal circumference	Surrogate marker of visceral fat. Used as an indicator of fetal nutrition
MUA circumference	Indirect measure of muscle bulk. Used with triceps skinfold thickness to calculate arm muscle area
Subscapular skinfold thickness	Measure of central subcutaneous adipose tissue. Used as a proxy measure for total body fat
Triceps skinfold thickness	Measure of peripheral adipose tissue. Used to estimate total body fat and arm muscle area

5.3.2.1 Head circumference

Table 20 and Figure 49 show the frequency distribution of head circumference (normally distributed). Mean head circumference was only slightly higher in White British infants compared with those of Pakistani origin (34.63cm and 34.17 respectively, mean difference 0.45 cm (95% CI 0.37, 0.55) as shown in figure 48 Mean difference by Pakistani generation ranged from -0.37 cm (95% CI -0.51, -0.24) in infants born to a UK born mother and a South Asian born father (Dad only group), to -0.58 cm (95% CI -0.79, -0.37) in the Other group (the Other group includes all those who fell outside the main four generation groups who reported a 'don't know' or 'other' response for any parent or grandparent).

Figure 49 Head circumference distribution (cm)

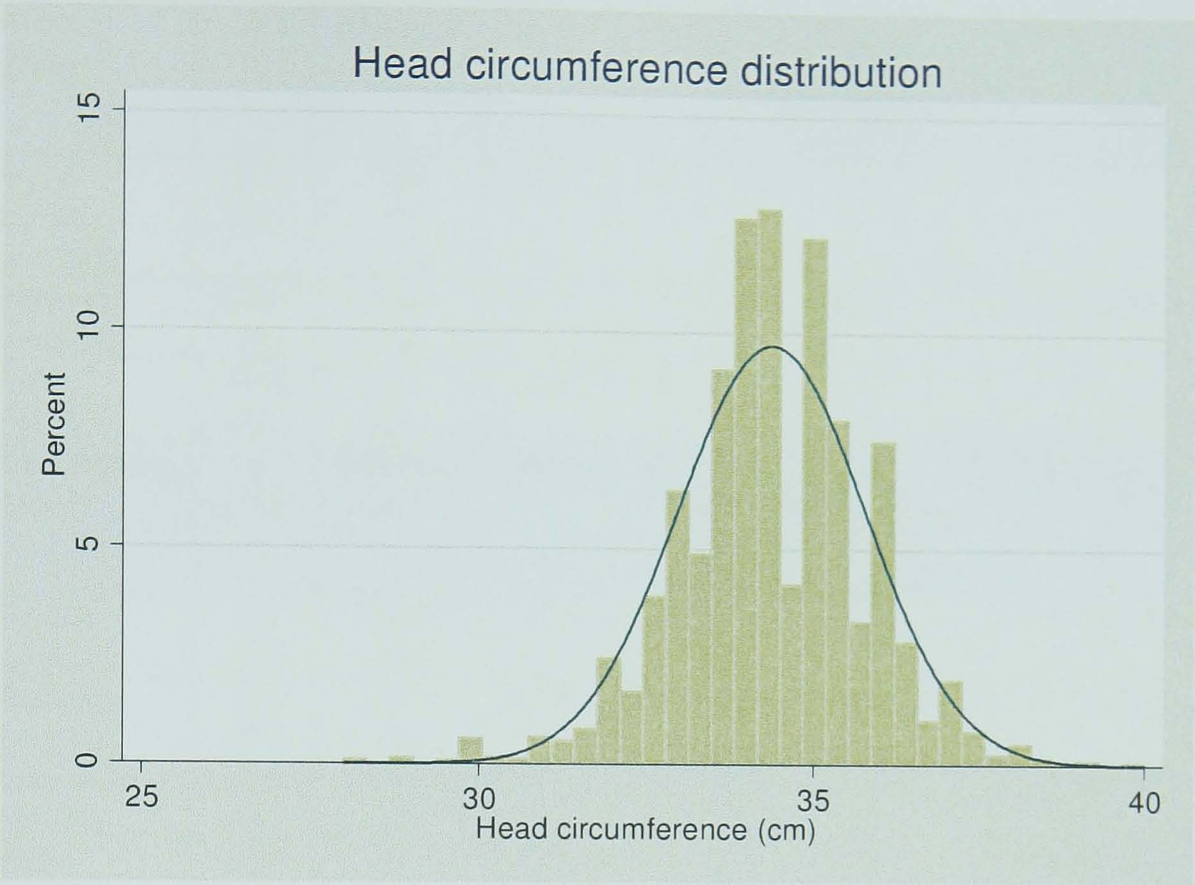


Table 20 Head circumference distribution (cm)

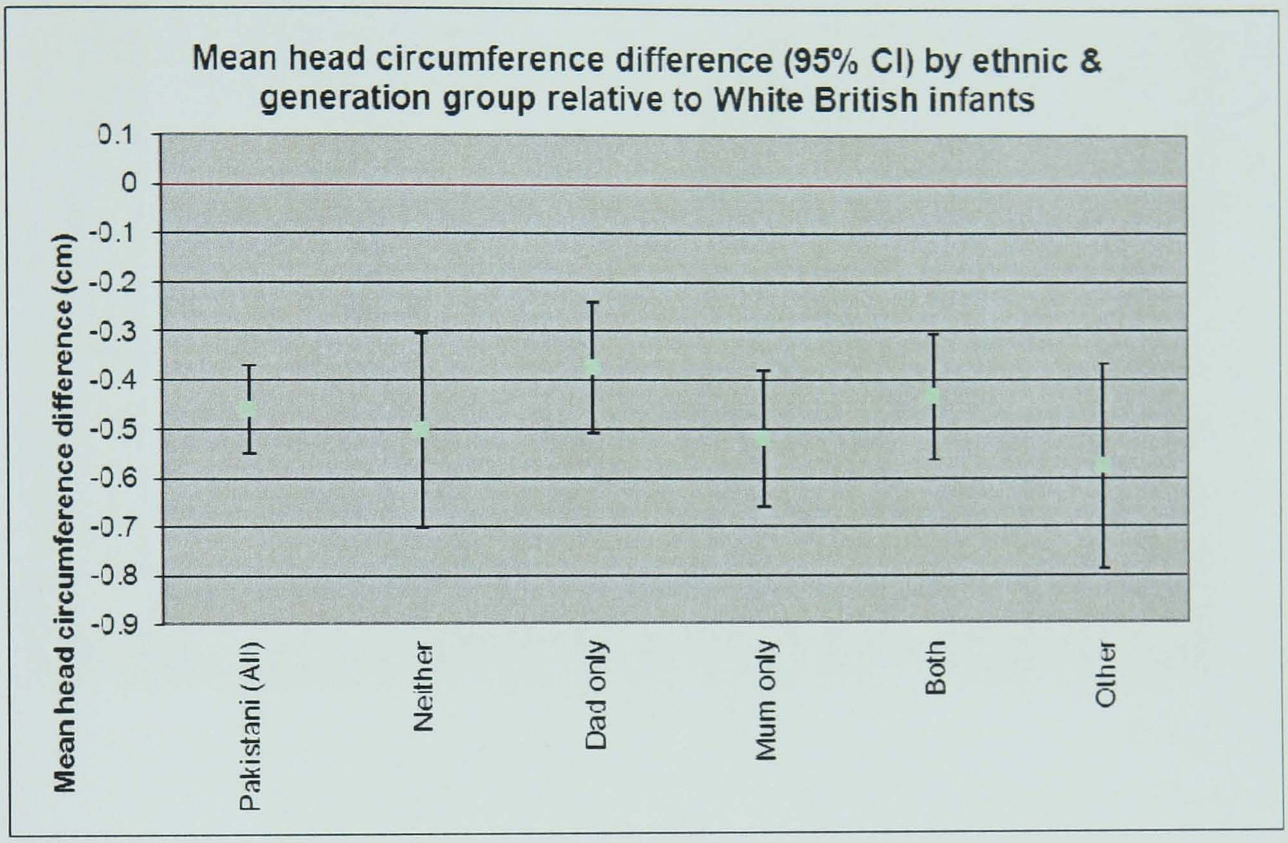
Head circumference (cm)	
N	3705
Mean	34.38
SD	1.41
Min	28
25th centile	33.50
Median	34.40
75th centile	35.20
Max	40
Missing	354

Table 21 Head circumference by ethnic and generation group* (cm)

Ethnic group	n (%)	Missing (%)	Mean	SD	Mean difference (from White British)	95% CI
White British (n=1838)	1672 (91)	166 (9)	34.63	1.42		
Pakistani (n=2221)	2033 (92)	188 (8)	34.17	1.37	-0.45	(-0.55, -0.37)
Total (4059)	*3705 (91)*	*354 (9)*	*34.38*	*1.41*		
Generation group	**n (%)**	**Missing (%)**	**Mean**	**SD**	**Mean difference** (from White British)	**95% CI**
Neither (n=232)	209 (90)	23 (10)	34.13	1.36	-0.50	(-0.70, -0.30)
Dad only (n=584)	536 (92)	48 (8)	34.26	1.32	-0.37	(-0.51, -0.24)
Mum only (n=523)	482 (92)	41 (8)	34.11	1.41	-0.52	(-0.66, -0.38)
Both (n=675)	620 (92)	55 (8)	34.19	1.35	-0.44	(-0.56, -0.31)
Other (n=207)	186 (90)	21 (10)	34.06	1.45	-0.58	(-0.79, -0.37)
Total (2221)	*2033 (92)*	*188 (8)*	*34.17*	*1.37*	-0.45	(-0.55, -0.37)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 50 Mean head circumference difference (cm) relative to White British infants by ethnic and generation groups*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

5.3.2.2 Abdominal circumference

Mean abdominal circumference for the sample as a whole was 31.37cm (sd 2.49). Infants of White British origin had a mean abdominal circumference of 32.05cm compared with 30.81cm for Pakistani origin infants (mean difference -1.24cm 95% CI -1.39, -1.08). Abdominal circumference distribution (normal) is reported in table 22 and figure 51 Figure 52 shows mean differences by ethnic and generation group.

Figure 51 Abdominal circumference distribution (cm)

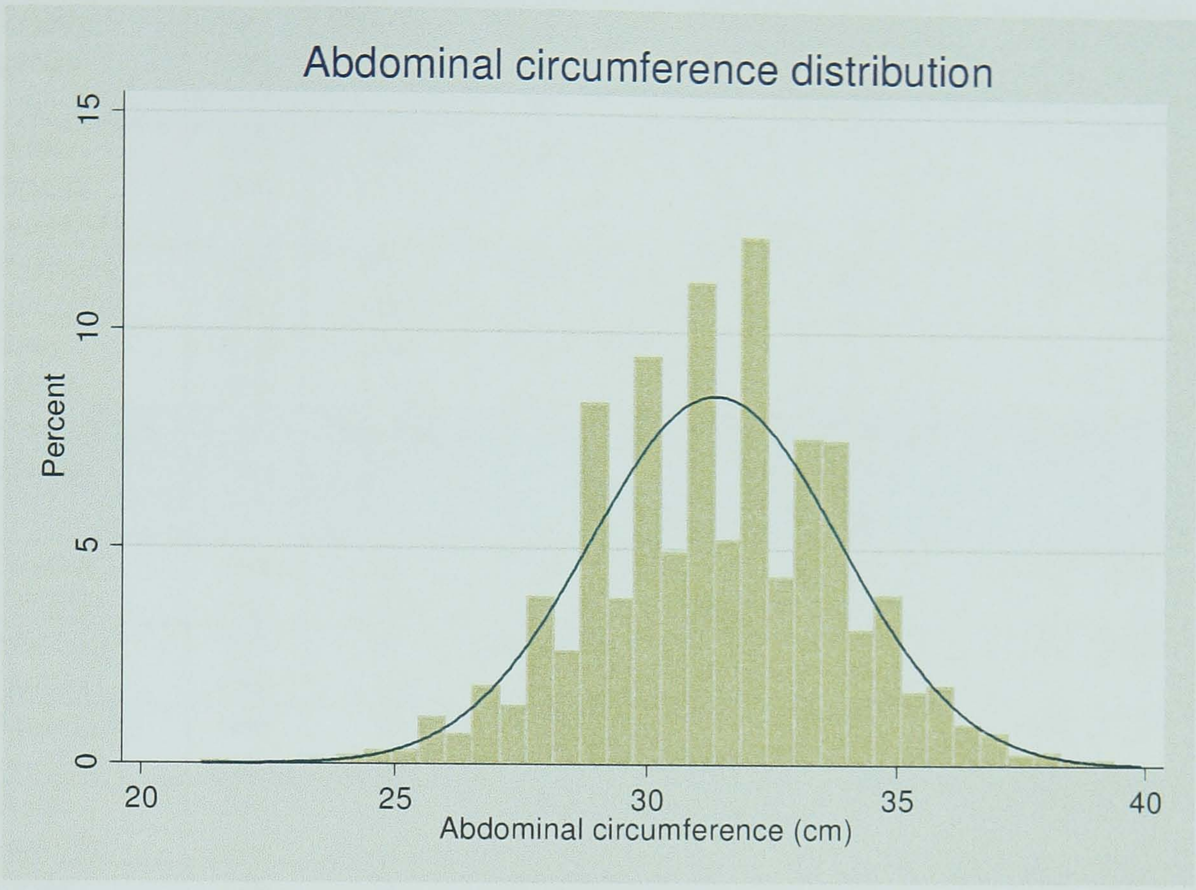


Table 72 Abdominal circumference distribution (cm))

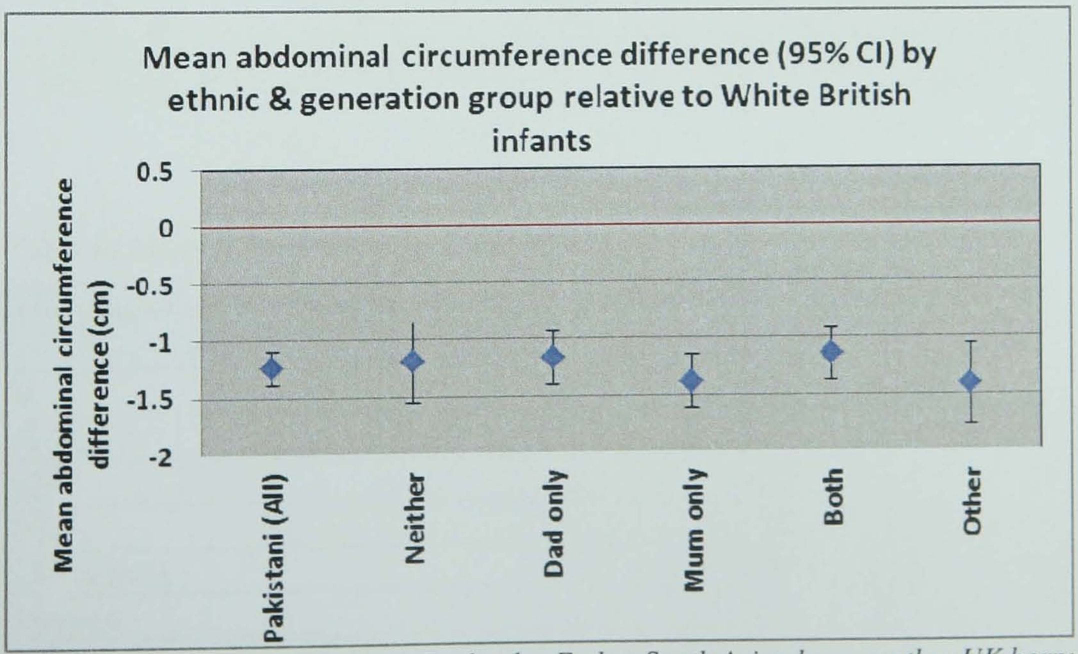
Abdominal circumference (cm)	
N	3619
Mean	31.37
SD	2.49
Min	21.2
25^{th} centile	29.8
Median	31.3
75^{th} centile	33
Max	39.9
Missing	440

Table 23 Abdominal circumference by ethnic and generation group* (cm)

Ethnic group	n (%)	Missing (%)	Mean	SD	Mean difference (from White British)	95% CI
White British (n=1838)	1629 (89)	209 (11)	32.05	2.42		
Pakistani (n=2221)	1990 (90)	231 (10)	30.81	2.42	-1.24	(-1.39, -1.08)
Total (4059)	*3619 (89)*	*440 (11)*	*31.37*	*2.50*		
Generation group	**n (%)**	**Missing (%)**	**Mean**	**SD**	**Mean difference (from White British)**	**95% CI**
Neither (n=232)	204 (88)	28 (12)	30.86	2.45	-1.20	(-1.55, -0.84)
Dad only (n=584)	527 (90)	57 (10)	30.89	2.24	-1.17	(-1.40, -0.93)
Mum only (n=523)	469 (90)	54 (10)	30.67	2.57	-1.39	(-1.63, -1.14)
Both (n=675)	604 (89)	71 (11)	30.90	2.38	-1.15	(-1.38, -0.93)
Other (n=207)	186 (90)	21 (10)	30.64	2.61	-1.42	(-1.78, -1.05)
Total (2221)	*1990 (90)*	*231 (10)*	*30.81*	*2.42*	-1.24	(-1.39, -1.08)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 52 Mean abdominal circumference difference (cm) relative to White British infants by ethnic and generation groups*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

5.3.2.3 Mid upper arm circumference (MUA)

As with the previous circumference measurements, MUA circumference measurements were normally distributed and showed similar ethnic variation (Tables 24 and 25 and Figure 53). Pakistani infants had a smaller mean MUA circumference than White British infants (10.97cm and 10.70cm respectively) although as seen in Figure 52 the difference is small (mean difference -0.27cm 95% CI -0.33, -0.21), as are the differences across generations.

Figure 53 Mid upper arm circumference distribution (cm)

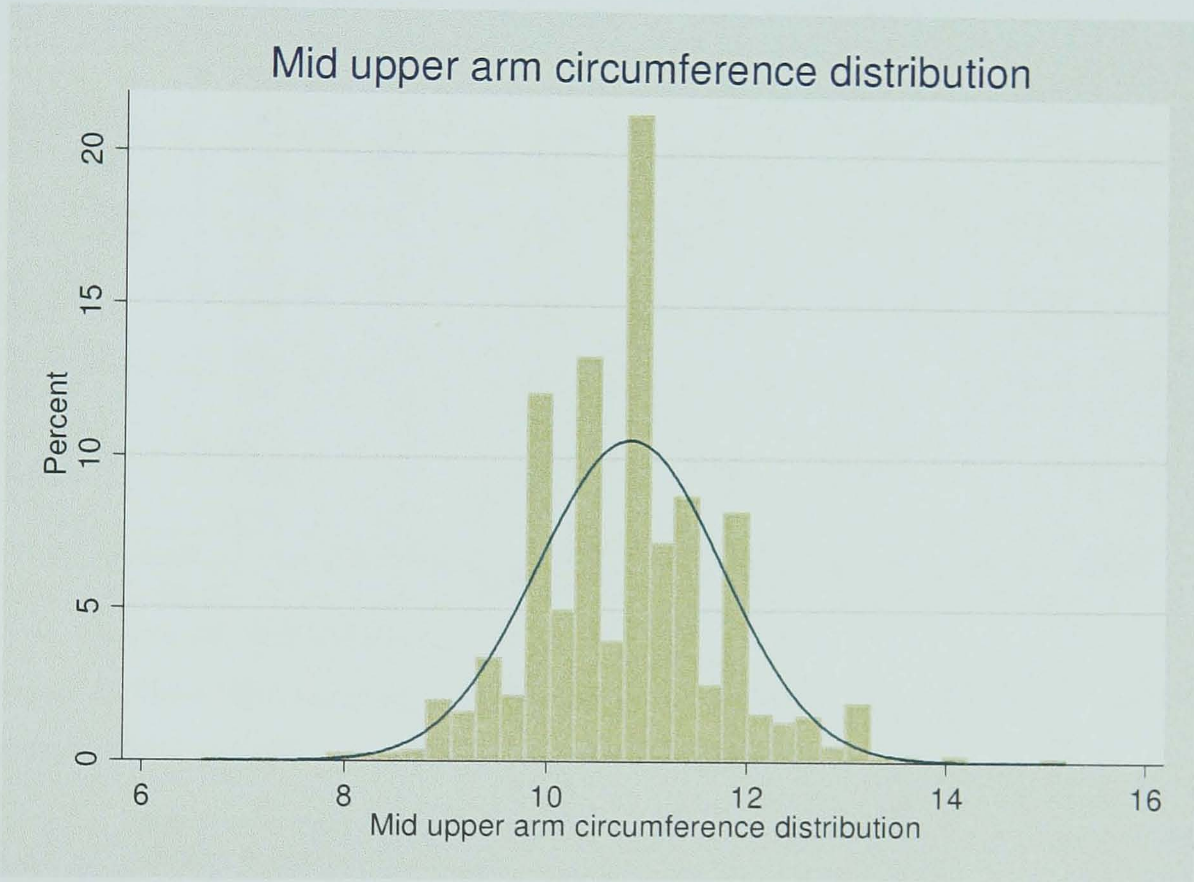


Table 24 MUA circumference (cm) distribution

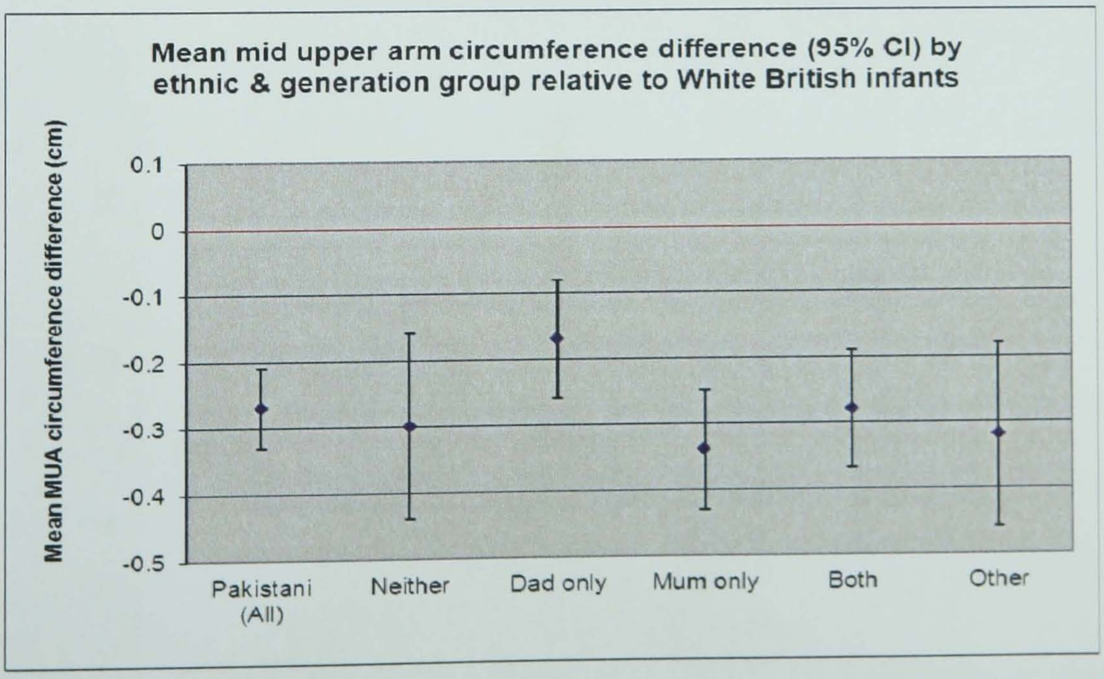
Mid upper arm circumference (cm)	
N	3617
Mean	10.82
SD	0.93
Min	6.6
25th centile	10.2
Median	11
75th centile	11.3
Max	15.2
Missing	442

Table 25 MUA circumference by ethnic and generation group* (cm)

Ethnic group	n (%)	Missing (%)	Mean	SD	Mean difference (from White British)	95% CI
White British (n=1838)	1634 (89)	204 (11)	10.97	0.91		
Pakistani (n=2221)	1983 (89)	238 (11)	10.70	0.92	-0.27	(-0.33, -0.21)
Total (4059)	*3617 (89)*	*442 (11)*	*10.82*	*0.93*		
Generation group	**n (%)**	**Missing (%)**	**Mean**	**SD**	**Mean difference** (from White British)	**95% CI**
Neither (n=232)	204 (88)	28 (12)	10.67	0.89	-0.30	(-0.44, -0.17)
Dad only (n=584)	524 (90)	60 (10)	10.80	0.91	-0.17	(-0.26, -0.08)
Mum only (n=523)	468 (90)	55 (10)	10.64	0.90	-0.34	(-0.43, -0.24)
Both (n=675)	603 (89)	72 (11)	10.69	0.94	-0.28	(-0.37, -0.19)
Other (n=207)	184 (89)	23 (11)	10.65	0.93	-0.32	(-0.46, -0.18)
Total (2221)	*1983 (89)*	*238 (11)*	*10.70*	*0.92*	*-0.27*	*(-0.33, -0.21)*

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 54 Mean MUA circumference difference (cm) relative to White British infants by ethnic and generation groups*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

5.3.3 Skinfold thickness measurements

Skinfold thicknesses are considered to be a more precise way of measuring fat than is weight or weight for length and ratios of central (subscapular) to peripheral (e.g. triceps) skinfolds are frequently used to indicate central distribution of fat. Subscapular and triceps skinfold thickness measurements were collected for this thesis and their distributions are presented below.

5.3.3.1 Subscapular skinfold thickness

Table 26 and Figure 55 show the distribution (normal) of subscapular skinfold thickness measurements. Figure 55 highlights a peak at around 5mm which probably reflects a tendency to round measurements to what is perceived to be a common value for this measurement. Pakistani infants had smaller mean measurements than the White British infants but the mean difference was just -0.19mm (95% CI -0.27, -0.11). There was some variation across generation groups but once again the differences were small (Table 27 & Figure 56).

Figure 55 Subscapular skinfold thickness distribution (mm)

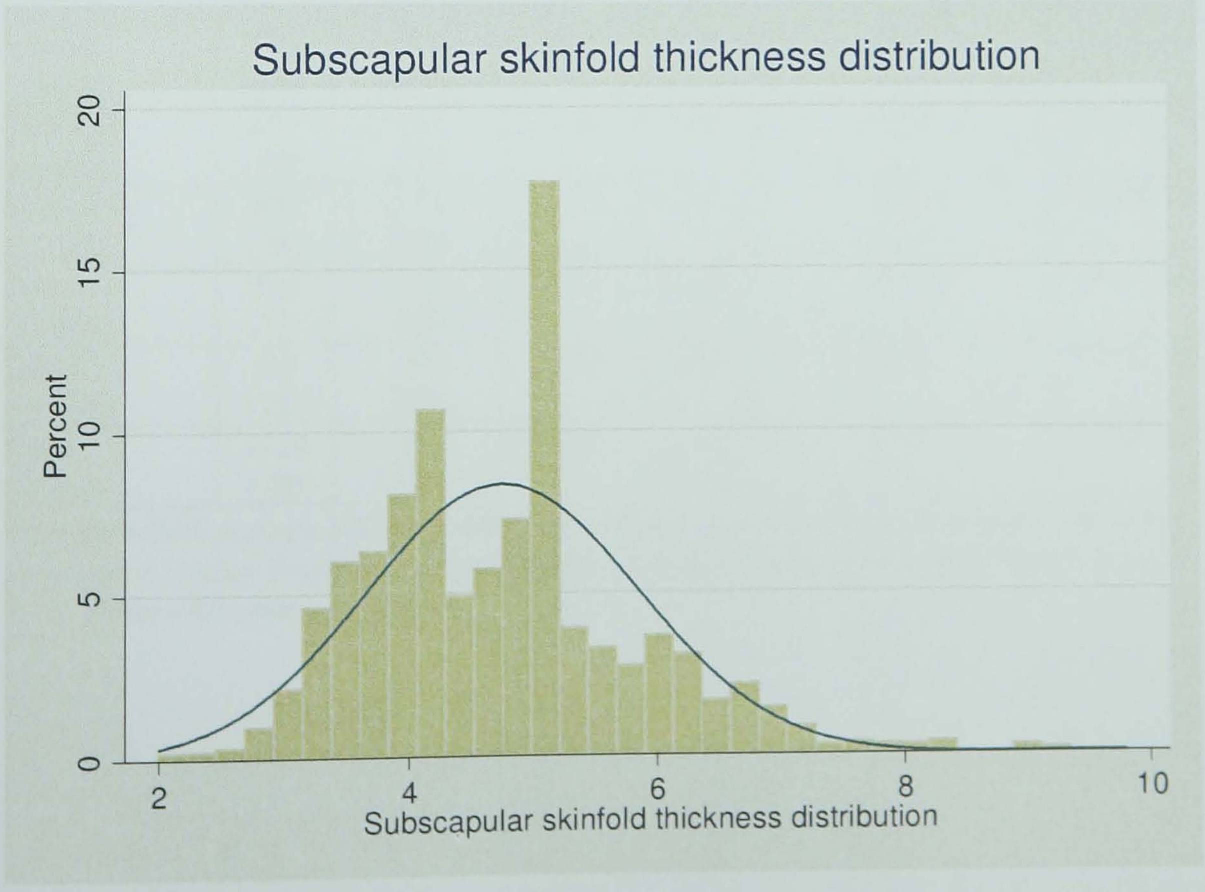


Table 26 Distribution of subscapular skinfold thickness

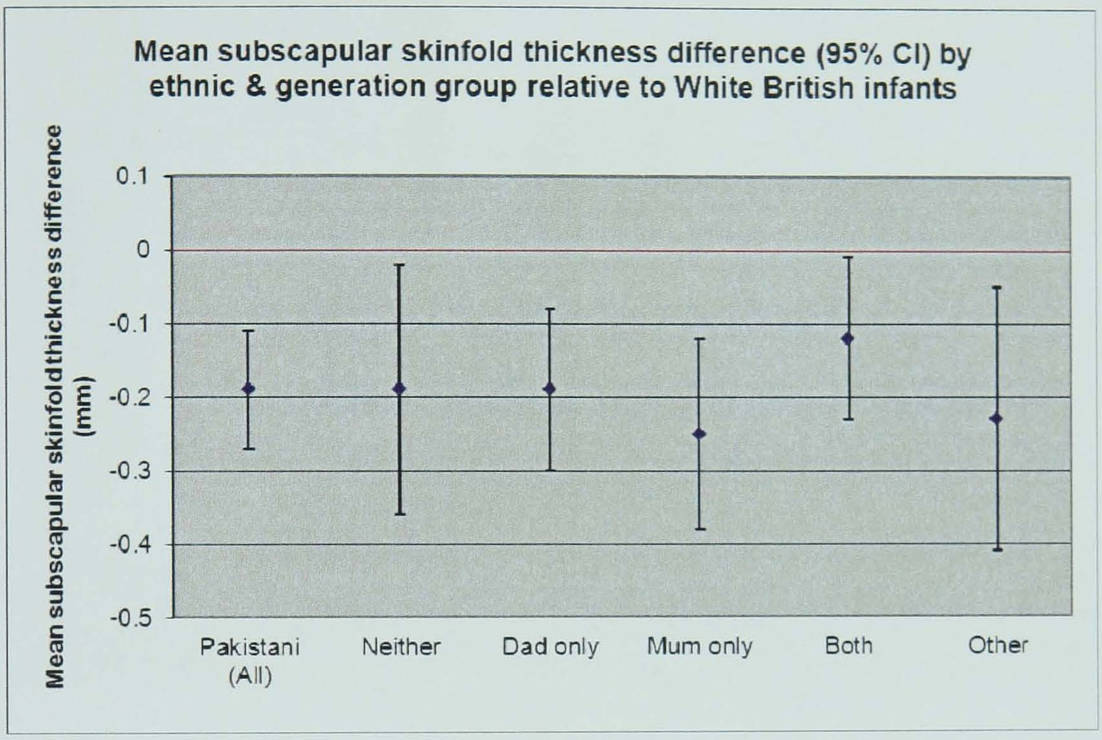
Subscapular skinfold thickness (mm)	
N	3010
Mean	4.75
SD	1.10
Min	2
25th centile	4
Median	4.6
75th centile	5.2
Max	9.8
Missing	1049

Table 27 Subscapular skinfold thickness by ethnic and generation group* (mm)

Ethnic group	n (%)	Missing (%)	Mean	SD	Mean difference (from White British)	95% CI
White British (n=1838)	1286 (70)	552 (30)	4.86	1.12		
Pakistani (n=2221)	1724 (78)	497 (22)	4.67	1.08	-0.19	(-0.27, -0.11)
Total (4059)	*3010 (74)*	*1049 (26)*	*4.75*	*1.10*		
Generation group	**n (%)**	**Missing (%)**	**Mean**	**SD**	**Mean difference** (from White British)	**95% CI**
Neither (n=232)	177 (76)	55 (24)	4.68	1.06	-0.19	(-0.36, -0.01)
Dad only (n=584)	457 (78)	127 (22)	4.67	1.08	-0.19	(-0.30, -0.07)
Mum only (n=523)	409 (78)	114 (22)	4.61	1.02	-0.25	(-0.38, -0.13)
Both (n=675)	520 (77)	155 (23)	4.74	1.14	-0.12	(-0.23, -0.01)
Other (n=207)	161 (78)	46 (22)	4.63	1.01	-0.23	(-0.41, -0.05)
Total (2221)	*1724 (78)*	*497 (22)*	*4.67*	*1.08*	*-0.19*	*(-0.27, -0.11)*

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 86 Mean subscapular skinfold thickness difference (mm) relative to White British infants by ethnic and generation groups*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

5.3.3.2 Triceps skinfold thickness

A similar (to that seen for subscapular skinfold) mean difference between the two ethnic groups was seen for triceps skinfold thickness (-0.21mm 95% CI -0.29, -0.14). The distribution is shown in Table 28 and Figure 57 and mean differences for Pakistani origin infants by generation relative to White British infants follow a similar pattern to that seen for subscapular skinfold thickness and are presented in Figure 58.

Figure 57 Triceps skinfold thickness distribution (mm)

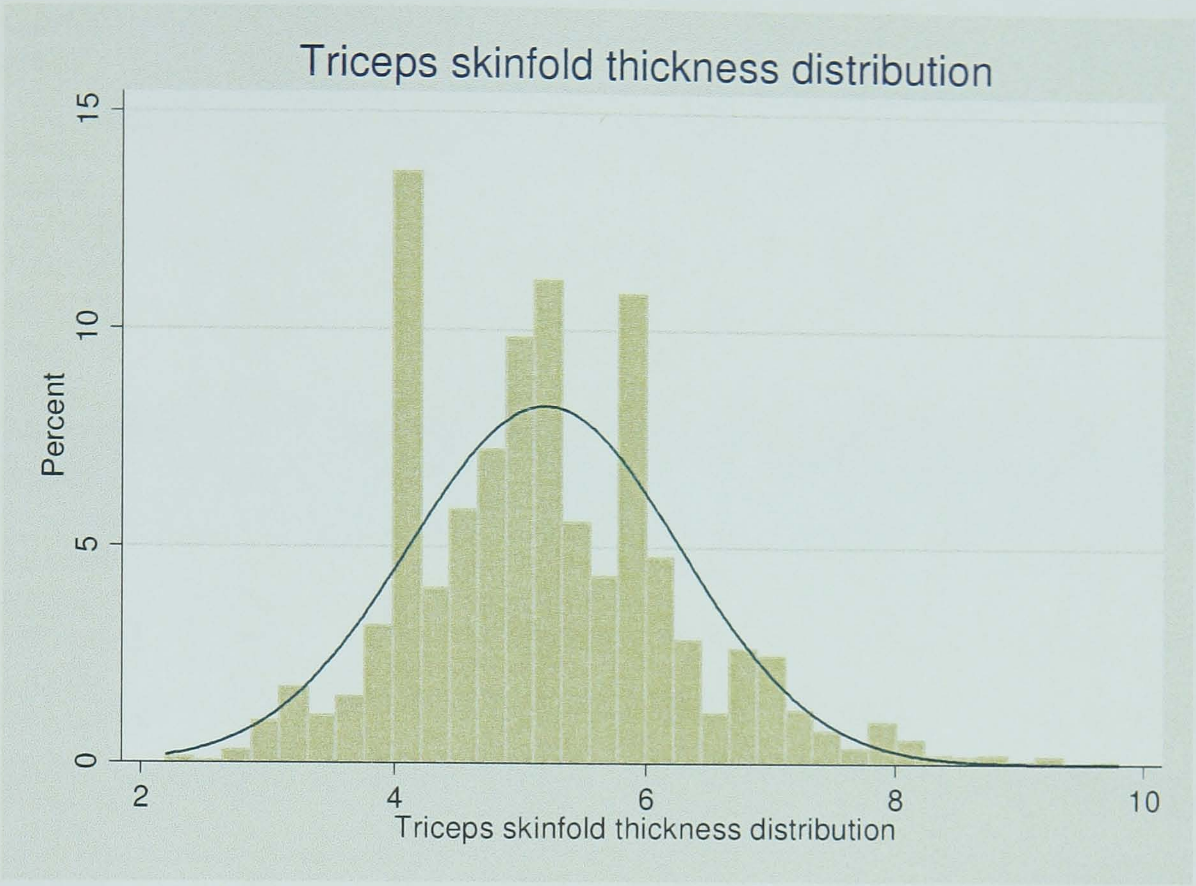


Table 28 Distribution of triceps skinfold thickness

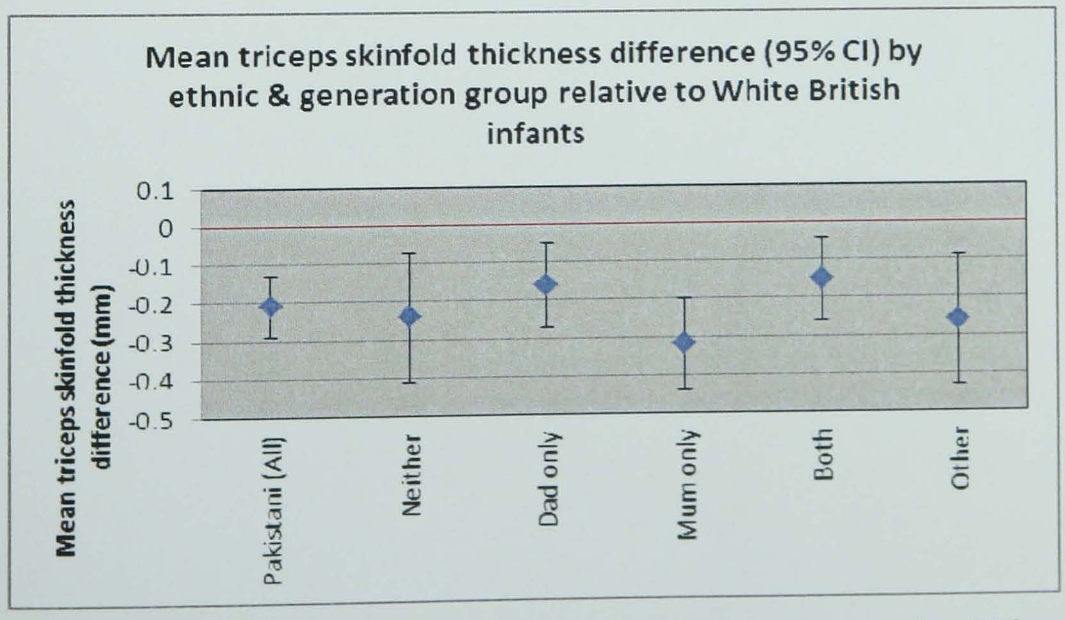
Triceps skinfold thickness (mm)	
N	3021
Mean	5.19
SD	1.08
Min	2.2
25th centile	4.4
Median	5.2
75th centile	5.8
Max	9.8
Missing	1038

Table 29 Triceps skinfold thickness by ethnic and generation group* (mm)

Ethnic group	n (%)	Missing (%)	Mean	SD	Mean difference (from White British)	95% CI
White British (n=1838)	1291 (70)	547 (30)	5.32	1.09		
Pakistani (n=2221)	1730 (78)	491 (22)	5.10	1.06	-0.21	(-0.29, -0.14)
Total (4059)	*3021 (74)*	*1038 (26)*	*5.19*	*1.08*		
Generation group	**n (%)**	**Missing (%)**	**Mean**	**SD**	**Mean difference** (from White British)	**95% CI**
Pakistani 1 (n=232)	177 (76)	55 (24)	5.07	1.16	-0.24	(-0.41, -0.07)
Pakistani 3 (n=584)	459 (79)	125 (21)	5.16	1.09	-0.16	(-0.27, -0.05)
Pakistani 4 (n=523)	410 (78)	113 (22)	4.99	0.98	-0.32	(-0.44, -0.20)
Pakistani 2 (n=675)	522 (77)	153 (23)	5.17	1.10	-0.15	(-0.26, -0.04)
Pakistani 5 (n=207)	162 (78)	45 (22)	5.06	0.90	-0.26	(-0.43, -0.08)
Total (2221)	1730 (78)	491 (22)	5.10	0.03	-0.21	(-0.29, -0.14)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 58 Mean triceps skinfold thickness difference (mm) relative to White British infants by ethnic and generation groups*



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Some evidence of digit preference can be seen for all measurements other than birthweight, with evidence that measurements have been rounded to whole numbers (Figure 49 and distribution graphs for measurements reported earlier in this chapter figures 49; 53; 55; 57). A summary of all anthropometric measurements (numbers, means, mean differences) is presented in Table 30.

5.3.4 Correlations between birth size measurements

Correlation coefficients (using listwise deletions) were calculated to measure the strength and direction of th linear relationship between measurements. Correlations (with p-values) between all birth size measurements are shown in Tables 31-33. All measurements showed a positive correlation with birthweight and the three circumference measurements (head, MUA and abdominal) all showed a positive correlation with each other, but the correlation with skinfold measurements, whilst still positive, was weaker. Results were similar for each ethnic group although the correlation between head circumference and skinfold measurements was smaller among Pakistani infants.

Table 30 Anthropometric measurements by ethnic and generation group (means & sd)

	White *n=1838*		Pakistani All *n=2221*		Neither *n=232*		Dad only *n=584*		Mum only *n=523*		Both *n=675*		Other *n=207*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Birthweight (g)	**3421**	490	**3194**	458	**3181**	444	**3205**	434	**3178**	479	**3206**	461	**3173**	472
Head circumference (cm)	**34.63**	1.42	**34.17**	1.37	**34.13**	1.36	**34.26**	1.32	**34.11**	1.41	**34.19**	1.35	**34.06**	1.45
Abdominal circumference (cm)	**32.05**	2.42	**30.81**	2.42	**30.86**	2.45	**30.89**	2.24	**30.67**	2.57	**30.90**	2.38	**30.64**	2.61
MUA circumference (cm)	**10.97**	0.91	**10.70**	0.92	**10.67**	0.89	**10.80**	0.91	**10.64**	0.90	**10.69**	0.94	**10.65**	0.93
Subscapular skinfold (mm)	**4.86**	1.12	**4.67**	1.08	**4.68**	1.06	**4.67**	1.08	**4.61**	1.02	**4.74**	1.14	**4.63**	1.01
Triceps skinfold (mm)	**5.32**	1.09	**5.10**	1.06	**5.07**	1.16	**5.16**	1.09	**4.99**	0.98	**5.17**	1.10	**5.06**	0.90

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 31 Correlations (p-value) between birth size measurements (all infants with data on all outcomes n=2871)

	Birthweight	Head circumference	Abdominal circumference	MUA circumference	SSF thickness	TSF thickness	Subscapular : triceps ratio
Birthweight	1.0000						
Head circumference	0.6497 P=0.000	1.0000					
Abdominal circumference	0.5820 P=0.000	0.4878 P=0.000	1.0000				
MUA circumference	0.6560 P=0.000	0.4516 P=0.000	0.5117 P=0.000	1.0000			
SSF thickness	0.5114 P=0.000	0.2906 P=0.000	0.3393 P=0.000	0.3855 P=0.000	1.0000		
TSF thickness	0.5630 P=0.000	0.3302 P=0.000	0.3497 P=0.000	0.4188 P=0.000	0.7539 P=0.000	1.0000	
Subscapular : triceps ratio	0.0049 P=0.794	-0.0171 P=0.359	0.0267 P=0.153	0.0097 P=0.603	0.4492 P=0.000	-0.2281 P=0.000	1.0000

Table 32 Correlations between birth size measurements (Pakistani infants with data on all outcomes n=1643)

	Birthweight	Head circumference	Abdominal circumference	MUA circumference	SSF thickness	TSF thickness	Subscapular : triceps ratio
Birthweight	1.0000						
Head circumference	0.6252 P=0.000	1.0000					
Abdominal circumference	0.5364 P=0.000	0.4510 P=0.000	1.0000				
MUA circumference	0.6476 P=0.000	0.4361 P=0.000	0.4998 P=0.000	1.0000			
SSF thickness	0.4998 P=0.000	0.2424 P=0.000	0.3378 P=0.000	0.3677 P=0.000	1.0000		
TSF thickness	0.5544 P=0.000	0.2893 P=0.000	0.3408 P=0.000	0.3995 P=0.000	0.7531 P=0.000	1.0000	
Subscapular : triceps ratio	-0.0046 P=0.851	-0.0384 P=0.119	0.0339 P=0.169	0.0043 P=0.861	0.4461 P=0.000	-0.2329 P=0.000	1.0000

Table 33 Correlations between birth size measurements (White British infants with data on all outcomes n=1228)

	Birthweight	Head circumference	Abdominal circumference	MUA circumference	SSF thickness	TSF thickness	Subscapular : triceps ratio
Birthweight	1.0000						
Head circumference	0.6514 P=0.000	1.0000					
Abdominal circumference	0.5842 P=0.000	0.4859 P=0.000	1.0000				
MUA circumference	0.6534	0.4455 P=0.000	0.4992 P=0.000	1.0000			
SSF thickness	0.4998 P=0.000	0.3282 P=0.000	0.3171 P=0.000	0.3935 P=0.000	1.0000		
TSF thickness	0.5146 P=0.000	0.3578 P=0.000	0.3321 P=0.000	0.4277 P=0.000	0.7531	1.0000	
Subscapular : triceps ratio	-0.0186 P=0.515	-0.0111 P=0.698	0.0208 P=0.000	0.0182 P=0.523	0.4581 P=0.000	-0.2238 P=0.000	1.0000

5.3.5 Cord blood leptin analysis

A consecutive sub-sample of cord blood samples was obtained (n=1838). As cord blood leptin concentration had a positively skewed distribution (Figure 59; Table 34) it was log transformed to achieve approximate normality (Figure 58).

Figure 59 Cord blood leptin distribution (ng/ml)

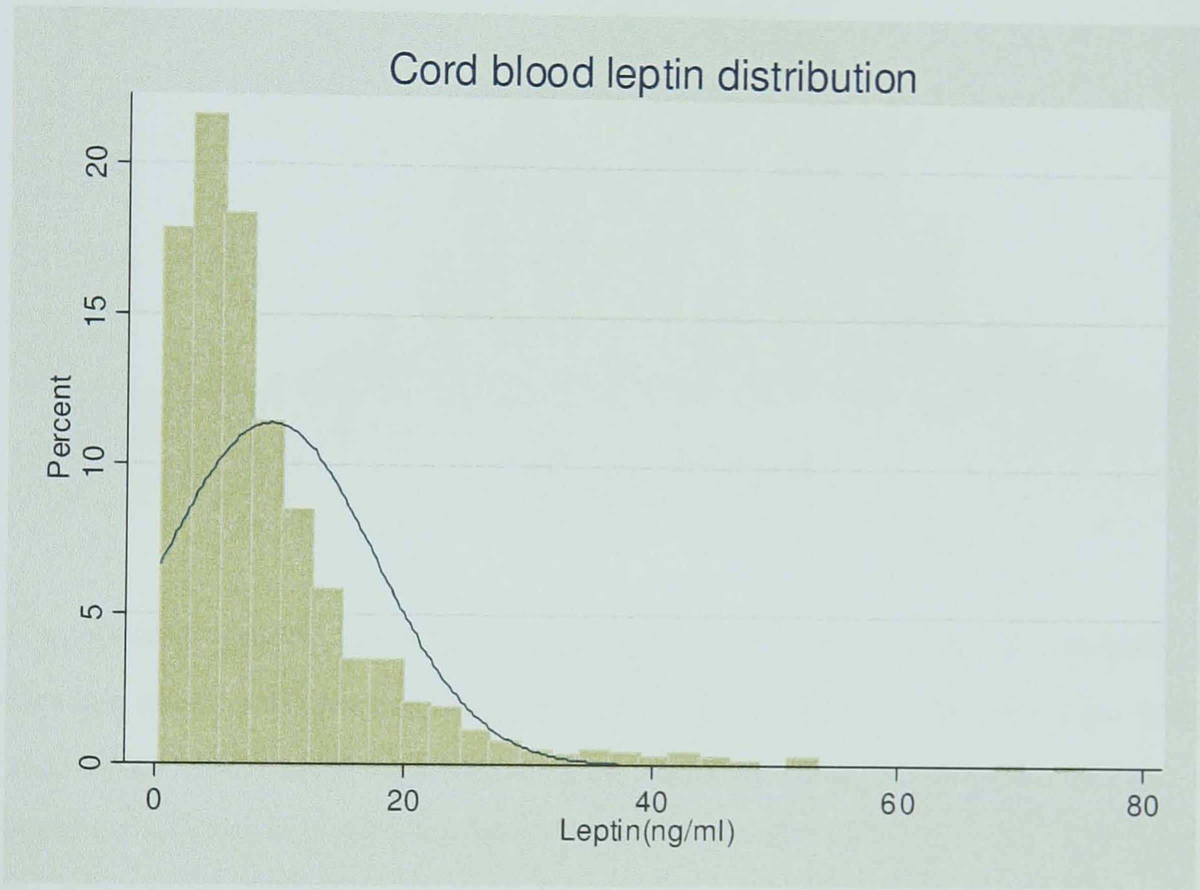
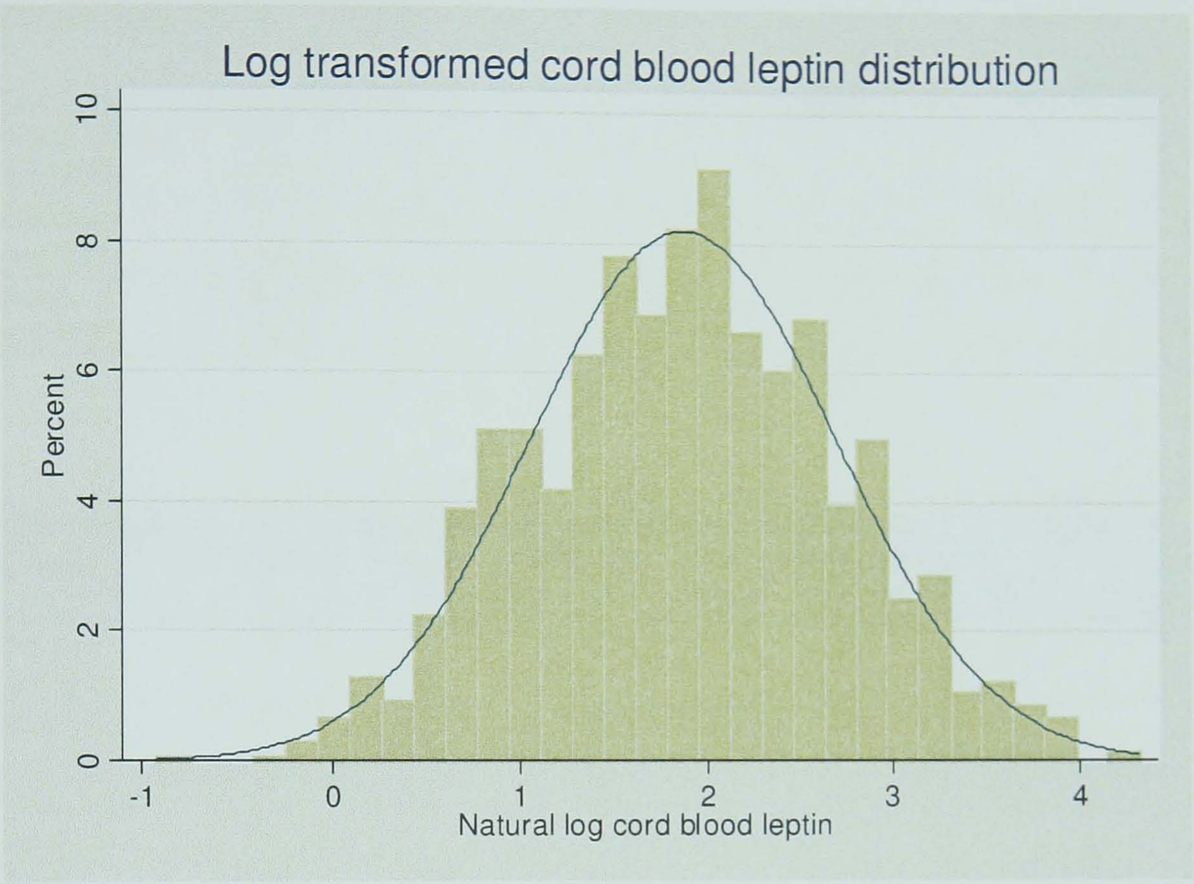


Table 84 Distribution of cord blood leptin

Cord blood leptin (ng/ml)	
N	1388
Mean	9.14
SD	8.44
Min	0.4
25th centile	3.7
Median	6.6
75th centile	11.8
Max	75.1
Skewness	2.48
Kurtosis	11.96

Figure 60 Natural log cord blood leptin distribution



Transformed variables were used in the regression analysis, therefore comparisons between ethnic and generation groups are presented as ratios of geometric means (null value = 1). Pakistani ethnicity was associated with 11 % higher cord blood leptin concentration (ratio of geometric means 1.11 95% CI 1.02, 1.21). There were no substantive differences by Pakistani generation group although numbers were especially small in two of the generation categories (Table 35).

Table 35 Cord blood leptin by ethnic and generation group*

Ethnic group	n (%)	Geometric mean	95% CI	Ratio of geometric means	95% CI
White British (n=1838)	613 (33)	6.17	5.79, 6.58		
Pakistani (n=2221)	775 (35)	6.84	6.45, 7.25	1.11	1.02, 1.21
Total (n=4059)	*1388 (34)*	*6.54*	*6.26, 6.82*		

Generation group	n (%)	Geometric mean	95% CI	Ratio of geometric means	95% CI
Neither (n=232)	75	6.74	5.64, 8.05	1.09	0.90, 1.33
Dad only (n=584)	211	6.62	5.90, 7.42	1.07	0.94, 1.22
Mum only (n=523)	174	6.61	5.94, 7.35	1.07	0.93, 1.23
Both (n=675)	245	7.42	6.66, 8.27	1.20	1.07, 1.36
Other (n=207)	70	6.26	5.07, 7.73	1.01	0.83, 1.24
Total (n=2221)	*775*	*6.84*	*6.45, 7.25*	*1.11*	*1.02, 1.21*

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

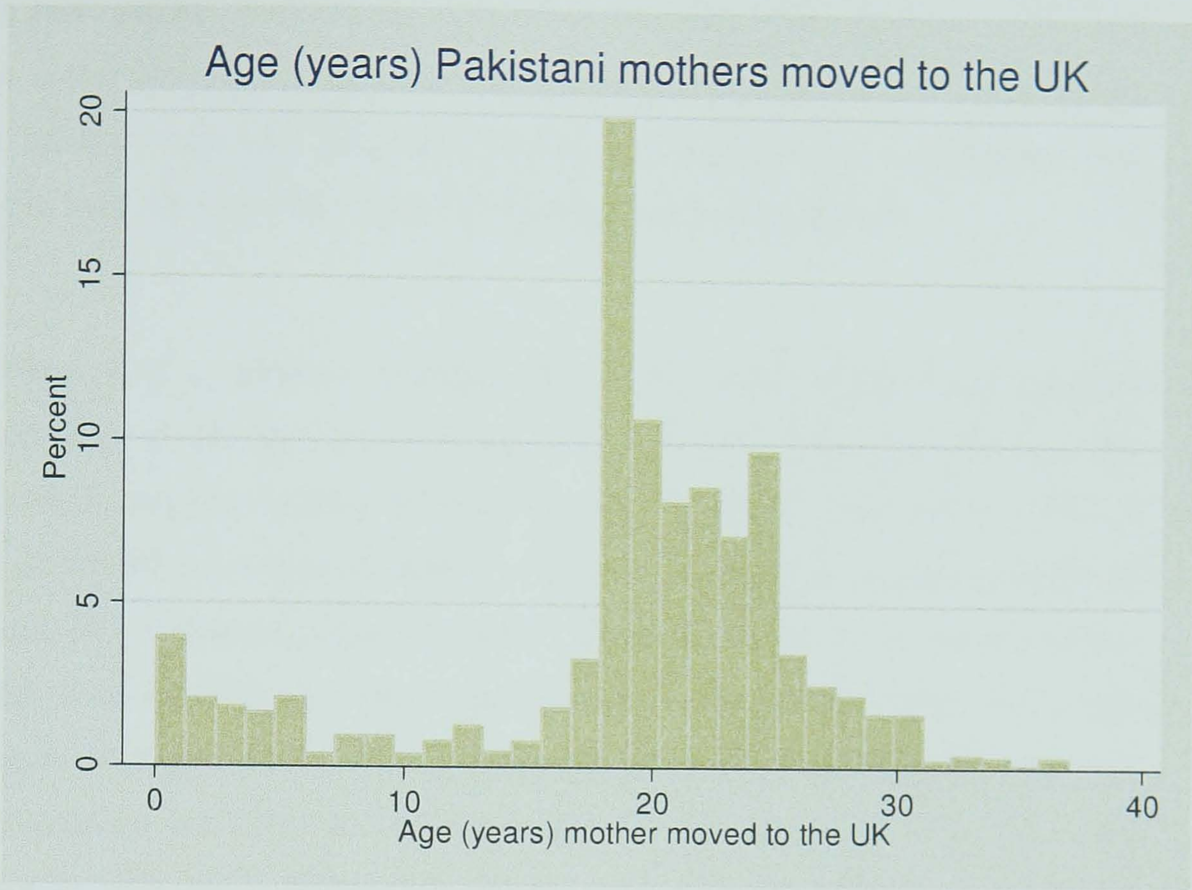
5.4 Distributions of explanatory and mediating/masking variables

5.4.1 Ethnicity

Of the sample of 4059, 1838 reported being of White British origin and 2221 reported being of Pakistani origin. Additional generational analyses of Pakistani origin mothers were undertaken by generation groups defined as described in chapter 3.

After the Other group, the smallest Pakistani generation group was that where both parents were UK born (Neither group) suggesting that despite the presence of a Pakistani community in Bradford for around half a century, the majority of infants (at least 80%) born within this cohort have at least one parent who was born in South Asia. Patterns of migration are complex but important. For example, as discussed in Chapter 2, there is some mobility between Bradford and Pakistan among the Pakistani community and it is not uncommon to migrate from South Asia to the UK in childhood. Hence place of birth recorded as South Asia may include individuals who were born in south Asia but spent much of their childhood in the UK. Figure 5.16 shows the age at which Pakistani mothers from the data set used for this thesis moved to the UK. Of the 1260 South Asian born Pakistani mothers, 141 (12%) moved to the UK at age 5 or under. A further 103 (8%) moved to the UK between the ages of 6 and 16. We did not collect similar information on grandparents and so for these cannot determine the age at which those born in South Asia came to live in the UK.

Figure 61 Age at which South Asian born Pakistani mothers moved to the UK (n=1260)

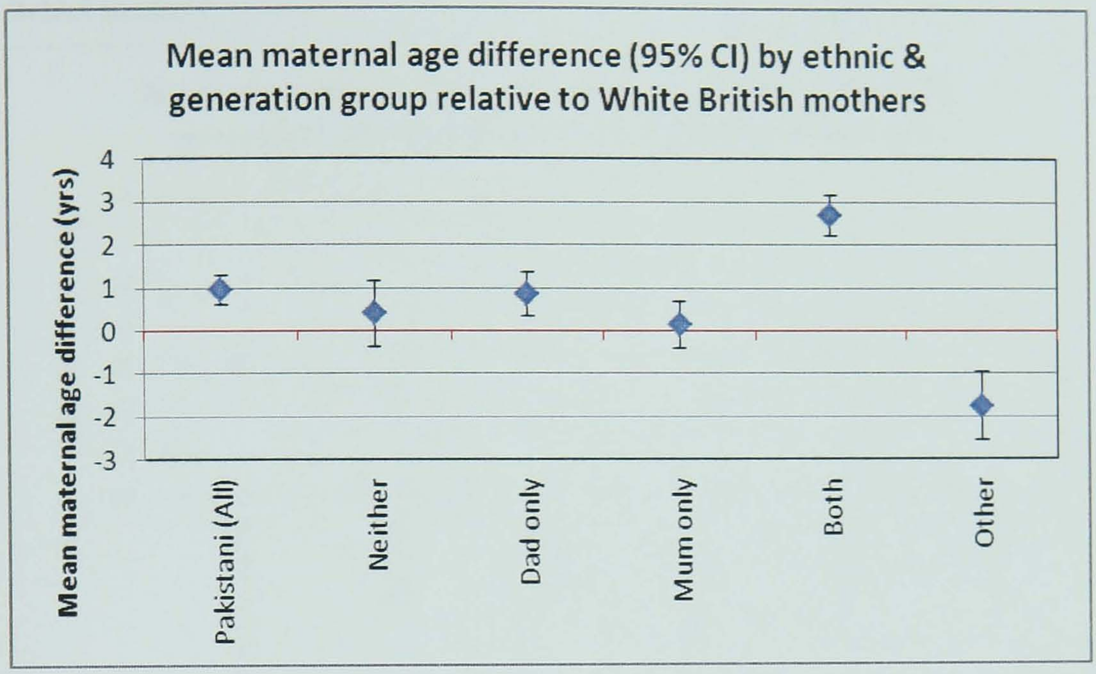


5.4.2 Mediating/masking variables

Mediating/masking variables varied across ethnic and generation groups (Tables 36 and 37). Mean gestational age was almost two days shorter in the Pakistani group (39.40 sd 1.15 compared to 39.59 sd 1.19 in the White British group). Local policy was used to calculate expected date of delivery (as described in Chapter 3) and these findings are consistent with national England and Wales data regarding gestational length (Moser et al., 2008) which showed slightly lower mean gestational lengths (39.0 weeks among Pakistani women, 39.31 among White British women) but include all deliveries not just term births. Pakistani origin mothers were slightly older than White British mothers (mean age 27.7 years and 26.8 years respectively, mean difference 0.95 years 95% CI 0.60, 1.29) and were shorter (mean difference -4.33cm 95% CI -4.69, -3.97), lighter (mean difference 7.78 kg 95% CI 6.82, 8.73) and had a lower mean BMI (mean difference -1.65 95% CI -2.02, -1.28) as shown in Figures 62-65. This is in contrast to national data that reported higher BMI among South Asian women (Health Survey for England, 2004). The proportion of Pakistani mothers with gestational diabetes was double that of White British mothers. By generation group, around 8% of mothers belonging to the Both group (where both parents were South Asian born) had gestational diabetes which was almost double the proportion in all other groups including the Mum only group where mothers were also born in South Asia. Hypertension in pregnancy was similar in both ethnic groups and across Pakistani generation groups.

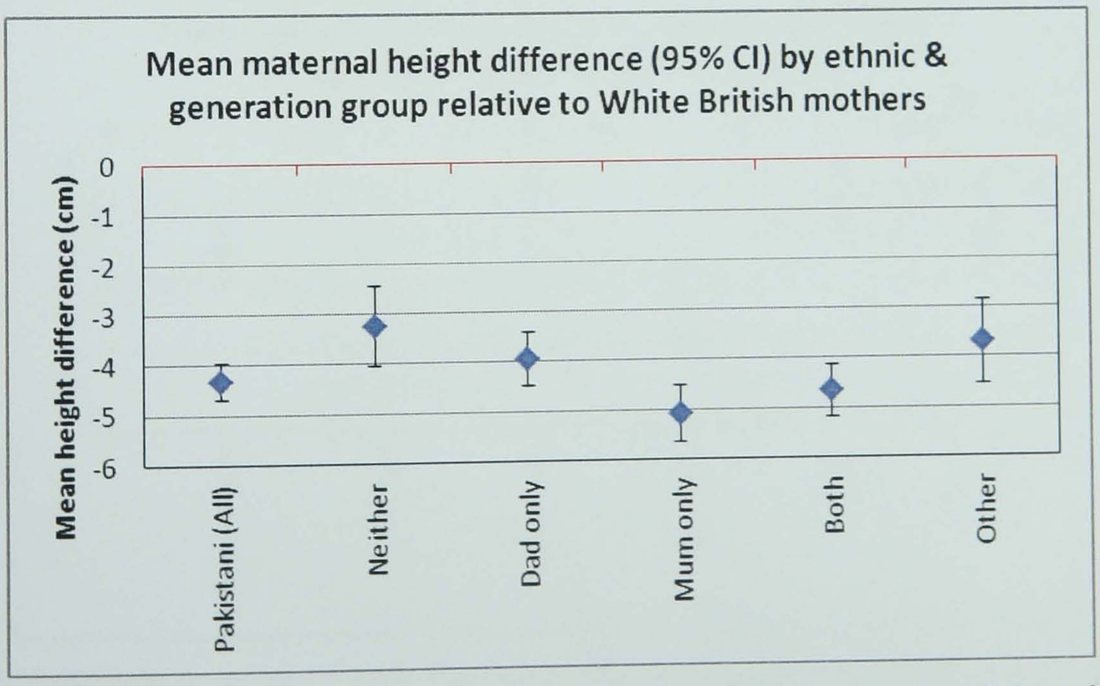
There were a number of differences in the behavioural/cultural maternal characteristics of the two ethnic groups and further dissimilarities between the generational categories of those of Pakistani origin (Table 36). For example, 35% of White British origin mothers smoked at some stage during their pregnancy compared with just 3% of Pakistani origin mothers. More UK born South Asian mothers reported smoking (6%) than South Asian born mothers (1%). There were some differences in higher parity, 3% of White British mothers reported parity of 4 or more compared with 8% of Pakistani origin mothers and again there was some variation by generation. Where both parents were UK born (Neither group) 4% of mothers reported parity of 4 or more, where both parents were South Asian born (Both group) this rose to 11%. Further, there were marked differences in employment and marital status between the two ethnic groups, 34% of White British mothers were married and 66% were currently working which contrasts sharply with the Pakistani origin mothers who were almost all married (98%) but were unlikely to be currently working (23%). However, whilst marital status was more or less consistent across all Pakistani generation groups (92-99% married), there were notable differences in employment. Almost half (40-45%) of mothers who were UK born were employed in contrast to 8-12% of mothers who were South Asian born.

Figure 62 Mean maternal age difference (95% CI) by ethnic and generation group* relative to White British mothers



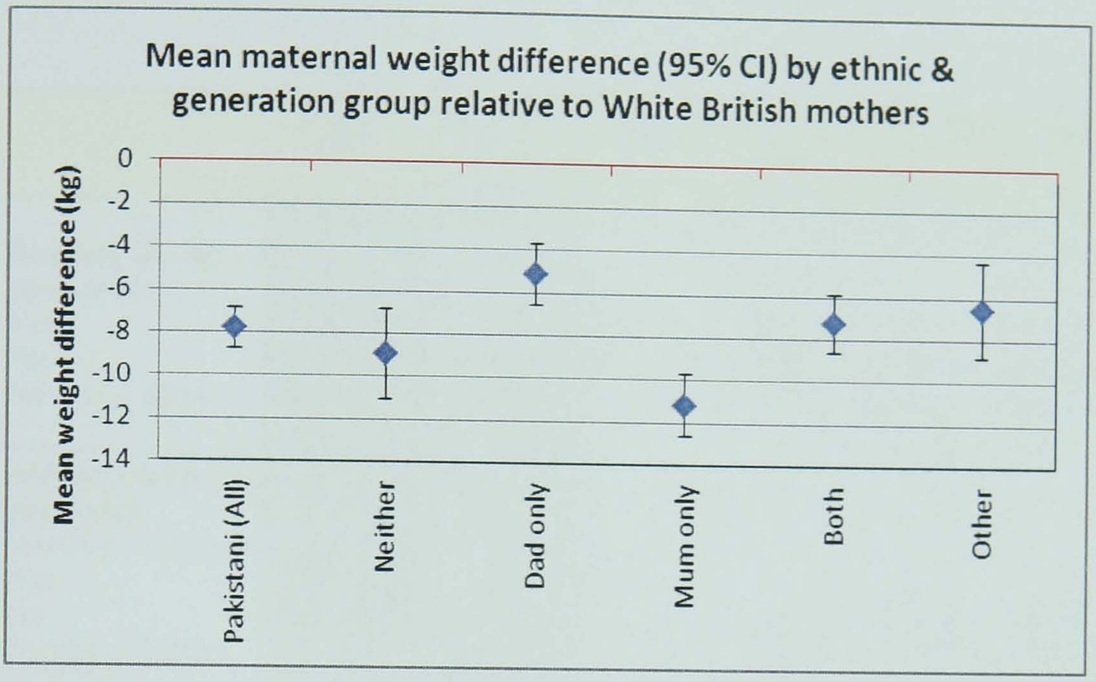
**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 63 Mean maternal height difference (95% CI) by ethnic and generation group* relative to White British mothers



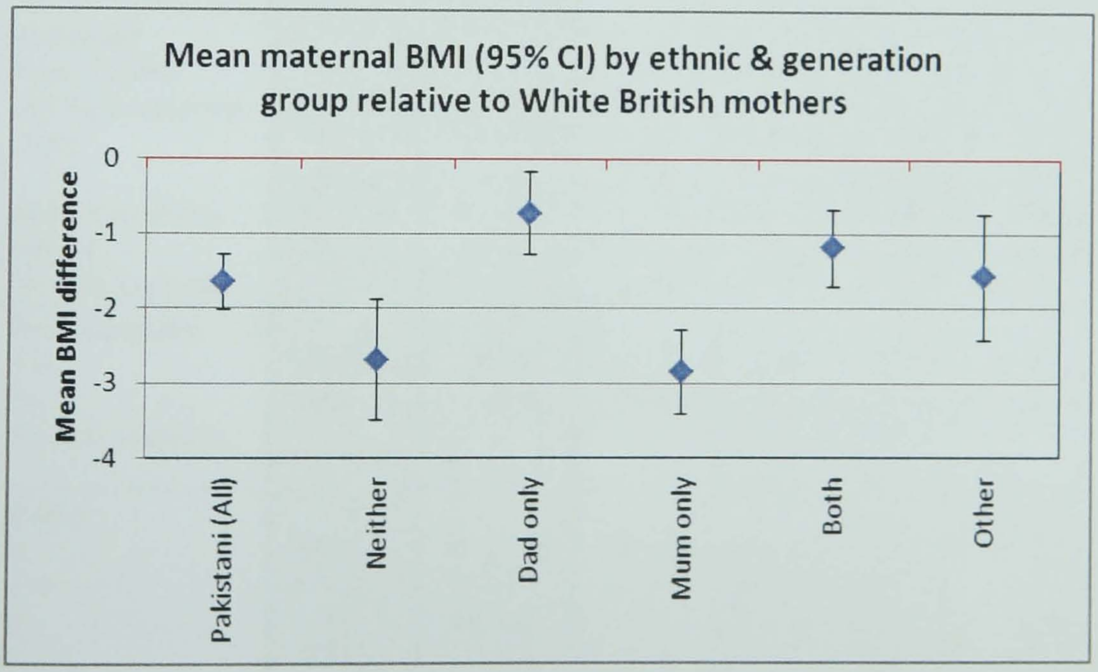
**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 64 Mean maternal weight difference by ethnic and generation group* relative to White British mothers



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Figure 65 Mean maternal BMI difference by ethnic and generation group* relative to White British mothers



**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 36 Potential explanatory factors of birth size by ethnic and generation group* (categorical). Figures are numbers (%)

	White (1838)	Pakistani *all groups* (2221)	Neither (232)	Dad only (584)	Mum only (523)	Both (675)	Other (207)
Smoking during pregnancy							
Yes	**648 (35)**	**76 (3)**	14 (6)	35 (6)	4 (0.8)	8 (1)	15 (7)
No	**1188(65)**	**2138 (96)**	218 (94)	547 (93)	515 (98)	666 (99)	192 (93)
No data available	**2 (0.1)**	**7 (0.3)**		2 (0.3)	4 (0.8)	1 (0.2)	
Alcohol during pregnancy *(once/wk or more)*							
Yes	**193 (11)**	**0**	0	0	0	0	0
No	**1644(89)**	**2214(99)**	232 (100)	583 (99)	519 (99)	674 (99)	206 (99)
No data available	**1 (0.1)**	**7 (0.3)**		1 (0.2)	4 (0.8)	1 (0.2)	1 (0.5)
Maternal glycaemia during pregnancy							
No diabetes	**1791 (97.4)**	**2103 (94.7)**	225 (97)	554 (95)	501 (96)	624 (92)	199 (96)
Existing diabetes	**1 (0.1)**	**2 (0.1)**				2 (0.3)	
Gestational diabetes	**46 (2.5)**	**116 (5.2)**	7 (3)	30 (5)	22 (4)	49 (7.7)	8 (4)
No data available							
Maternal hypertension during pregnancy							
None	**1720 (94.6)**	**2114 (95)**	219 (9.4)	555 (95)	499 (95.5)	642 (95)	199 (96)
Mild to moderate	**97 (5.3)**	**85 (4)**		24 (4.2)	15 (2.8)	29 (4.4)	5 (2.5)
Severe	**21 (1.1)**	**22 (1)**	12 (5.2)	5 (0.8)	9 (1.7)	4 (0.6)	3 (1.5)
No data available			1 (0.4)				
Pre-eclampsia							
Yes	**32 (98)**	**41 (2)**	4 (2)	16 (97)	8 (98)	8 (1)	5 (98)
No	**1806 (2)**	**2180 (98)**	228 (98)	568 (3)	515 (2)	667 (99)	202 (2)
No data available							
Parity							
0	**850 (46)**	**672 (30)**	101 (44)	181 (31)	145 (28)	146 (22)	99 (48)
1	**577 (31)**	**597 (27)**	52 (23)	157 (27)	155 (30)	174 (26)	59 (28)
2	**228 (13)**	**460 (21)**	45 (19)	116 (20)	113 (21)	153 (23)	33 (16)
3	**78 (4)**	**257 (11)**	17 (7)	73 (12)	53 (10)	105 (15)	9 (4)
4 or more	**55 (3)**	**172 (8)**	9 (4)	39 (7)	41 (8)	78 (11)	5 (3)
No data available	**50 (3)**	**63 (3)**	8 (3)	18 (3)	16 (3)	19 (3)	2 (1)
Household income:							
£10,999 & under	**481 (26)**	**497 (22)**	45 (19)	151(26)	113 (22)	127 (19)	61 (29)
£11,000-£19,999	**329 (18)**	**533 (24)**	59 (25)	184 (32)	87 (17)	156 (23)	47 (23)
£20,000 - £29,999	**382 (21)**	**226 (10)**	36 (16)	88 (15)	35 (6)	47 (7)	20 (10)
£30,000 & over	**503 (27)**	**128 (6)**	37 (16)	40 (7)	15 (3)	22 (3)	14 (7)
Don't know	**121 (7)**	**798 (36)**	49 (21)	109 (19)	263 (50)	316 (47)	61 (29)
Declined to answer	**22 (1)**	**37 (2)**	6 (3)	11 (2)	9 (2)	7 (1)	4 (2)
No data available		**2 (0.1)**		1 (0.2)	1 (0.2)		

	White (1838)	Pakistani *all groups* (2221)	Pakistani 1 (232)	Pakistani 3 (584)	Pakistani 4 (523)	Pakistani 2 (675)	Pakistani 5 (207)
Housing tenure:							
Buying with mortgage/loan	**955 (52)**	**1088 (49)**	113 (49)	320 (55)	238 (46)	331 (49)	86 (41)
Owns outright	**71 (4)**	**594 (26)**	63 (27)	139 (24)	202 (38)	141 (21)	49 (24)
Rents -Local Authority/Housing Association	**294 (16)**	**125 (6)**	12 (5)	27 (5)	24 (5)	42 (6)	20 (10)
Rents –Private	**425 (23)**	**199 (9)**	15 (7)	28 (5)	20 (4)	113 (17)	23 (11)
Rents- Other	**23 (1)**	**22 (1)**	1 (0.4)	3 (0.5)	4 (0.8)	10 (2)	4 (2)
Lives rent free *(eg with relatives)*	**54 (3)**	**153 (7)**	24 (10)	62 (10)	22 (4)	27 (4)	18 (9)
Part rent/part mortgage *(shared ownership)*	**3 (0.2)**	**5 (0.2)**		2 (0.3)		2 (0.3)	1 (0.5)
Don't know	**2 (0.1)**	**27 (1)**	4 (2)	2 (0.3)	13 (2)	4 (0.6)	4 (2)
No data available	**11 (0.6)**	**8 (0.4)**		1 (0.2)		5 (0.7)	2 (1)
Receipt of means tested benefits							
yes	**663 (36)**	**1026 (46)**	91 (39)	318 (54)	218 (42)	320 (48)	663 (36)
No	**1169 (64)**	**1190 (54)**	140 (61)	266 (46)	304 (58)	353 (52)	1169(64)
Marital status							
Married	**619 (34)**	**2171 (98)**	224 (97)	571 (98)	518 (99)	669 (99)	189 (92)
Single	**1157(63)**	**23 (1)**	3 (1)	5 (1)	2 (0.5)	0	13 (6)
Other	**60 (3)**	**25 (1)**	5 (2)	7 (1)	3 (0.5)	5 (1)	5 (2)
No data available	**2 (0.1)**	**2 (0.1)**		1 (0.2)		1 (0.2)	
Living with partner							
Yes	**1336(73)**	**2083 (94)**	215 (93)	544 (93)	507 (97)	643 (96)	174 (84)
No	**500 (27)**	**132 (6)**	15 (7)	39 (7)	15 (3)	30 (4)	33 (16)
Consanguinity (related to father of the baby)							
Yes	**4 (0.2)**	**1436 (65)**	0 (39)	419 (72)	376 (72)	444 (66)	107 (52)
No	**1834 (99.8)**	**784 (35)**	142 (61)	165 (28)	147 (28)	230 (34)	100 (48)
Don't know		**1 (0.1)**				1 (0.2)	
Gender:							
Male	**941 (51)**	**1140 (51)**	126 (54)	318 (54)	247 (47)	339 (50)	110 (53)
Female	**897 (49)**	**1081 (49)**	106 (46)	266 (46)	276 (53)	336 (50)	97 (47)
Low birth weight <2500g	**42 (2)**	**116 (5)**	13 (6)	28 (5)	29 (6)	36 (5)	10 (5)

Table 37 Potential explanatory factors by ethnic and generational group (continuous). Figures are means (sd)

	White (1838)	Pakistani (2221)	Neither (232)	Dad only (584)	Mum only (523)	Both (675)	Other (207)	Total (4059)
Maternal age (yrs)	**26.78 (6.16)**	**27.73 (5.09)**	27.17 (4.75)	27.64 (4.75)	26.92 (4.87)	29.47 (5.21)	25.02 (4.73)	27.30 (5.62)
Maternal height (m) *Missing (n)*	**1.64 (6.18)** *9*	**1.60 (5.61)** *21*	1.61 (5.47) *2*	1.60 (5.55) *4*	1.59 (5.51) *4*	1.59 (5.59) *9*	1.60 (5.94) *2*	161.63 (6.26)
Maternal weight (kg) *Missing (n)*	**78.39 (16.87)** *62*	**70.62 (13.51)** *86*	69.44 (11.42) *9*	73.25(14.71) *30*	67.21(11.78) *10*	71.12 (13.49) *25*	71.80 (14.57) *12*	74.15 (15.62)
Maternal BMI *Missing (n)*	**27.03 (6.14)** *155*	**25.38 (5.31)** *174*	24.34 (4.72) *21*	26.31 (5.74) *38*	24.18 (4.56) *37*	25.84 (5.35) *60*	25.45 (5.56) *18*	26.13 (5.76)
Gestation at delivery (weeks)	**39.59 (1.19)**	**39.40 (1.15)**	39.35 (1.17)	39.38 (1.11)	39.51 (1.15)	39.36 (1.17)	39.33 (1.15)	39.48 (1.17)
Birthweight (g)	**3421 (490.1)**	**3194 (458.0)**	3181 (444.4)	3206 (434.8)	3178 (479.1)	3206 (461.6)	3173 (472.7)	3297 (486.0)

5.5 Summary

In this chapter details of the representativeness of the sample used in this thesis are described, missing data have been summarised and the distributions of birth size outcomes presented. Further, the characteristics of study particpants by ethnic and generation groups have been described. These results show marked differences between Pakistani and White British origin infants. In the following chapter multiple regression models are used to adjust these difference for explanatory and mediating factors.

Chapter 6
Results

This study provided an opportunity to investigate the association between ethnicity and and size at birth. The thorough and wide-ranging information collected in the BiB study has allowed a detailed exploration of the association of ethnicity (including generation of migration) with birth size and adiposity and of the role that socioeconomic position, maternal behaviour and pregnancy might play in any of these associations. In this chapter results are presented in the following three sections:

- **Multivariable analysis of ethnic differences in birth size**

A series of multivariable models examining the associations between ethnicity and birth size and what mechanisms might explain or mask these are presented.

- **Multivariable analysis of differences in birth size by Pakistani generation**

A series of multivariable models examining the associations between each Pakistani generation group (compared to White British infants) and birth size and what mechanisms might explain or mask these are presented.

- **The association between ethnicity and adiposity**

In this section associations of ethnicity and Pakistani generation with adiposity are explored. These associations are explored using two measures of adiposity. First skinfold z-scores were used to examine whether, despite their smaller size, Pakistani origin infants are relatively more adipose than White British infants. Second, cord blood leptin measurements are used as an indicator of fat mass at birth to explore ethnic differences in in this. As in other analyses multivariable regression models are used to explore the extent to which socioeconomic position, maternal behaviour or pregnancy characteristics might explain or mask any associations.

6.1 Multivariable analysis of ethnic differences in birth size

Table 38 shows the association of ethnicity (Pakistani versus White British) with mean birthweight comparing the unadjusted association with the adjusted association, with adjustment for each potential explanatory / masking factor, in turn and finally with adjustment for all of them. The numbers of participants with complete data on each mediating factor varies and therefore this table also allows exploration of whether there is evidence of selection bias in the complete case analyses (those with data on all potential mediating variables; presented in final row of table) compared to those with maximal data (i.e. complete data on exposure, outcome and individual mediator variable; first row of table). In those with maximal data the unadjusted association showed that in this cohort, birthweight of infants of Pakistani origin was on average 228g (-257, -198) lower than that of White British origin infants. This unadjusted difference was similar amongst all subgroups with data on each individual potential mediator and also in the subgroup with complete data on all potential mediators (mean difference -229 95% CI -259, -198), suggesting that missing data on covariables did not result in important selection bias.

The effect of adjustment for potential explanatory / masking factors on the association between ethnicity and birthweight varied. In general adjustment for maternal age, alcohol consumption, infant sex, maternal hypertension, maternal gestational/existing diabetes and family socioeconomic position (SEP) had relatively little effect on the association. By contrast, adjustment for maternal smoking, parity and living with a partner resulted in an increase on average in the magnitude of the difference compared with the unadjusted association and adjustment for maternal height, BMI, and gestational age of infant reduced the magnitude of the association. Adjustment for smoking resulted in an average 55g increase in mean birthweight difference reflecting the higher number of White British smokers (35% compared with 3% of Pakistani mothers). Thus, smoking lowers mean birthweight among White British mothers (but less so for Pakistani mothers because so few smoke) and once its effect is removed the mean birthweight difference by ethnicity increases. The mean ethnic birthweight difference increases once the effect of parity is removed due to the greater parity on average among Pakistani mothers, compared with White British women, and the tendency for birthweight to increase with increasing parity. When analyses were restricted to just first pregnancies the mean birthweight difference comparing Pakistani infants to White British infants was -248g (95% CI -294, -202), based on 672 Pakistani infants and 850 White British infants. Living without a partner was considerably more common amongst White British compared to Pakistani origin mothers (27% compared with 6% of Pakistani mothers, see Chapter 5). And since birth size tended to be on average lower in those living without a partner, adjustment for this characteristic tended to increase the ethnic difference in birthweight.

As described in Chapter 5, Pakistani mothers were on average shorter, had a lower mean BMI and had a sightly shorter gestational length (around 2 days) than White British mothers, thus adjustment for these characteristics, all of which are associated with lower birthweight, resulted in a decrease in the magnitude of the association between ethnicity and birthweight. Whilst these analyses show that some characteristics mask the difference in mean birthweight between Pakistani and White British origin infants by more than 10g and some explain 10g or more of the difference, even with adjustment for all potential explanatory / masking variables, important differences remain with a mean difference in birthweight in the fully adjusted model (taking account of all potential explanatory / masking variables) of -189g (95% CI -228, -150).

Table 38 Mean birthweight difference (g) for Pakistani infants relative to White British infants with adjustment for potential explanatory / masking variables (number varies for each set of analyses because of differences in numbers for each explanatory variable

Covariable	Number	Unadjusted mean difference (g) *(95% CI)*	Adjusted mean difference (g) *(95% CI)*
No adjustment	4059	-228 *(-257, -198)*	
Smoking	4050	-228 *(-257, -199)*	-284 *(-316, -252)*
Alcohol	4051	-228 *(-257, -199)*	-231 *(-261, -201)*
Maternal age	4059	-228 *(-257, -198)*	-238 *(-267, -208)*
Maternal existing or gestational diabetes	4059	-228 *(-257, -198)*	-227 *(-257, -198)*
Maternal hypertension	4059	-228 *(-257, -198)*	-229 *(-259, -200)*
Maternal height	4029	-228 *(-258, -199)*	-155 *(-185, -124)*
Maternal BMI	3730	-228 *(-258, -198)*	-196 *(-226, -166)*
Parity	3946	-226 *(-256, -196)*	-255 *(-285, -225)*
Gestational age	4059	-228 *(-257, -198)*	-200 *(-227, -173)*
Baby's sex	4059	-228 *(-257, -198)*	-228 *(-267, -199)*
SEP: *Income, maternal education, housing tenure, receipt of means tested benefits**	4030	-228 *(-257, -199)*	-223 *(-259, -187)*
Living with a partner	4051	-227 *(-257, -198)*	-252 *(-282, -221)*
All above covariables	3604	-229 *(-259, -198)*	-189 *(-228, -150)*

* ***Receipt of means tested benefits*** *-any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Tables 39-43 show the same series of association analyses to those presented in Table 38 for birthweight, but for head circumference, abdominal circumference, MUA circumference, subscapular skinfold thickness and triceps skinfold thickness, respectively. As with birthweight, the first column of results – the unadjusted associations for the maximal sample and subgroups with complete data on each and then finally all potential explanatory / masking characteristics – are all very similar, suggesting that missing data on covariables has not resulted in important selection bias.

For all of these birth size measurements, on average Pakistani origin infants were smaller than White British infants. Furthermore, the pattern of changes in associations after adjustment for potential explanatory / masking characteristics were similar to those seen with birthweight. For example, for all other birth size outcomes adjustment for maternal age, alcohol consumption, infant sex and family socioeconomic position did not importantly change the magnitude of the unadjusted mean difference in birth size comparing Pakistani to White British origin infants. Maternal smoking and parity tended to mask the association with each birth size outcome and differences in maternal height and BMI explained some of the differences. Again, even when all potential explanatory / masking characteristics were taken into account there were important ethnic differences with on average Pakistani infants (compared to White British infants) having smaller head circumference (mean difference -0.4cm 95% CI -0.5, -0.3), abdominal circumference (-1.2cm 95% CI -1.5, -1.0), MUA circumference (-0.2cm 95% CI -0.3, -0.1), subscapular skinfold thickness (-0.2mm 95% CI -0.3, -0.1) and triceps skinfold thickness (-0.2mm 95% CI -0.3, -0.1) in the fully adjusted models.

Table 39 Mean head circumference difference (cm) for Pakistani infants relative to White British infants with adjustment for potential explanatory / masking variables (n=3318 to 3705)

Covariable	Number	Unadjusted mean difference(cm) *(95% CI)*	Adjusted mean difference (cm) *(95% CI)*
No adjustment	3705	-0.5 *(-0.5, -0.4)*	
Smoking	3697	-0.5 *(-0.6, -0.4)*	-0.6 *(-0.7, -0.5)*
Alcohol	3698	-0.5 *(-0.5, -0.4)*	-0.5 *(-0.6, -0.4)*
Maternal age	3705	-0.5 *(-0.6, -0.4)*	-0.5 *(-0.6, -0.4)*
Maternal existing or gestational diabetes	3705	-0.5 *(-0.6, -0.4)*	-0.5 *(-0.6, -0.4)*
Maternal hypertension	3705	-0.5 *(-0.6, -0.4)*	-0.5 *(-0.6, -0.4)*
Maternal height	3679	-0.5 *(-0.6, -0.4)*	-0.3 *(-0.4, -0.2)*
Maternal BMI	3431	-0.5 *(-0.6, -0.4)*	-0.4 *(-0.5, -0.3)*
Parity	3607	-0.5 *(-.6, -0.4)*	-0.5 *(-0.6, -0.4)*
Gestational age	3705	-0.5 *(-0.6, -0.4)*	-0.4 *(-0.5, -0.3)*
Baby's sex	3705	-0.5 *(-0.6, -0.4)*	-0.5 *(-0.6, -0.4)*
SEP:			
*Income, maternal education, housing tenure, receipt of means tested benefits**	3680	-0.5 *(-0.5, -0.4)*	-0.5 *(-0.6, -0.3)*
Living with a partner	3697	-0.5 *(-0.6, -0.4)*	-0.5 *(-0.6, 0.4)*
All above covariables	3318	-0.5 (-0.6, -0.4)	-0.4 (-0.5, -0.3)

* ***Receipt of means tested benefits*** *-any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Table 40 Mean abdominal circumference difference (cm) for Pakistani infants relative to White British infants with adjustment for potential explanatory / masking variables (n=3234 to 3619)

Covariable	Number	Unadjusted mean difference(cm) *(95% CI)*	Adjusted mean difference (cm) *(95% CI)*
No adjustment	3619	-1.2 *(-1.4, -1.1)*	
Smoking	3611	-1.2 *(-1.4, -1.1)*	-1.4 *(-1.6, -1.2)*
Alcohol	3612	-1.2 *(-1.4, -1.1)*	-1.3 *(-1.4, -1.1)*
Maternal age	3619	-1.2 *(-1.4, -1.1)*	-1.3 *(-1.2, -1.1)*
Maternal existing or gestational diabetes	3619	-1.2 *(-1.4, -1.1)*	-1.2 *(-1.4, -1.1)*
Maternal hypertension	3619	-1.2 *(-1.4, -1.1)*	-1.2 *(-1.4, -1.1)*
Maternal height	3593	-1.2 *(-1.4, -1.1)*	-1.1 *(-1.2, -0.9)*
Maternal BMI	3346	-1.2 *(-1.4, -1.1)*	-1.1 *(-1.3, -1.0)*
Parity	3523	-1.2 *(-1.4, -1.1)*	-1.4 *(-1.5, -1.2)*
Gestational age	3619	-1.2 *(-1.4, -1.1)*	-1.2 *(-1.3, -1.0)*
Baby's sex	3619	-1.2 *(-1.4, -1.1)*	-1.2 *(-1.4, -1.1)*
SEP: *Income, maternal education, housing tenure, receipt of means tested benefits**	3595	-1.2 *(-1.4, -1.1)*	-1.3 *(-1.5, -1.1)*
Living with a partner	3611	-1.2 *(-1.4, -1.1)*	-1.3 *(-1.5, -1.1)*
All above covariables	3234	-1.2 (-1.4, -1.0)	-1.2 (-1.5, -1.0)

* ***Receipt of means tested benefits*** *-any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Table 41 Mean MUA circumference difference (cm) for Pakistani infants relative to White British infants with adjustment for potential explanatory / masking variables (n=3232 to 3617)

Covariable	Number	Unadjusted mean difference(cm) *(95% CI)*	Adjusted mean difference (cm) *(95% CI)*
No adjustment	3617	-0.3 *(-0.3, -0.2)*	
Smoking	3609	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.4, -0.2)*
Alcohol	3610	-0.3 *(-0.3, -0.2)*	-0.3 *(-.3, -0.2)*
Maternal age	3617	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.4, -0.2)*
Maternal existing or gestational diabetes	3617	-0.3 *(-0.3, -0.2)*	-0.3 (-0.3, -0.2)
Maternal hypertension	3617	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.3, -0.2)*
Maternal height	3592	-0.3 *(-0.3, -0.2)*	-0.2 *(-0.3, -0.1)*
Maternal BMI	3344	-0.3 *(-0.3, -0.2)*	-0.2 *(-0.3, -0.2)*
Parity	3521	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.4, -0.3)*
Gestational age	3617	-0.3 *(-0.3, -0.2)*	-0.2 *(-0.3, -0.2)*
Baby's sex	3617	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.3, -0.2)*
SEP: *Income, maternal education, housing tenure, receipt of means tested benefits**	3593	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.4, -0.2)*
Living with a partner	3609	-0.3 *(-0.3, -0.2)*	-0.3 *(-0.4, -0.2)*
All above covariables	3232	-0.3 (-0.3, -0.2)	-0.2 (-0.3, -0.1)

* ***Receipt of means tested benefits*** *-any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Table 42 Mean subscapular skinfold thickness difference (mm) for Pakistani infants relative to White British infants with adjustment for potential explanatory / masking variables (n=2704 to 3010)

Covariable	Number	Unadjusted mean difference(mm) *(95% CI)*	Adjusted mean difference (mm) *(95% CI)*
No adjustment	3010	-0.2 (-0.3, -0.1)	
Smoking	3004	-0.2 *(-0.3, -0.1)*	-0.3 *(-0.4, -0.2)*
Alcohol	3005	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal age	3010	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal existing or gestational diabetes	3010	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal hypertension	3010	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal height	2990	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.2, -0.1)*
Maternal BMI	2800	-0.2 *(-0.3, -0.1)*	-0.1 *(-0.2, -0.0)*
Parity	2932	-0.2 *(-0.3. -0.1)*	-0.3 *(-0.4, -0.2)*
Gestational age	3010	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Baby's sex	3010	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
SEP: *Income, maternal education, housing tenure, receipt of means tested benefits**	2991	-0.2 *(-0.3, -0.1)*	-0.2 *(-03, -0.1)*
Living with a partner	3002	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
All above covariables	2704	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)

* ***Receipt of means tested benefits*** *-any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Table 43 Mean triceps skinfold thickness difference (mm) for Pakistani infants relative to White British infants with adjustment for potential explanatory / masking variables (n=2715 to 3021)

Covariable	Number	Unadjusted mean difference (mm) *(95% CI)*	Adjusted mean difference (mm) *(95% CI)*
No adjustment	3021	-0.2 (-0.3, -0.1)	
Smoking	3015	-0.2 *(-0.3, -0.1)*	-0.3 *(-0.4, -0.2)*
Alcohol	3016	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal age	3021	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.2)*
Maternal existing or gestational diabetes	3021	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal hypertension	3021	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Maternal height	3001	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.2, -0.1)*
Maternal BMI	2811	-0.2 *(-0.3, -0.1)*	-0.1 *(-0.2, -0.1)*
Parity	2943	-0.2 *(-0.3, -0.1)*	-0.3 *(-0.4, -0.2)*
Gestational age	3021	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
Baby's sex	3021	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.1)*
SEP: *Income, maternal education, housing tenure, receipt of means tested benefits**	3002	-0.2 *(-03, -0.1)*	-0.2 *(-0.3, -0.1)*
Living with a partner	3013	-0.2 *(-0.3, -0.1)*	-0.2 *(-0.3, -0.2)*
All above covariables	2715	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)

* ***Receipt of means tested benefits*** *-any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

6.2 Multivariable analysis of differences in birth size by Pakistani generation

Table 44 shows the association of Pakistani generation group (each generation group versus the White British group) with birthweight adjusting for each explanatory / mediating factor in turn and then with adjustment for all potential mediators. As in section 6.1, the number of participants with complete data on each factor varies therefore the number shown (column 2) represents the number with data for the outcome variable and the explanatory / mediating factor. The unadjusted difference was generally similar across all subgroups with two exceptions. In the subgroup with data on maternal BMI (the smallest subgroup for a single covariable) the unadjusted birthweight differences comparing each gestational group to White British infants were somewhat smaller than for the maximal sample or other subgroups. Similarly, the differences in the subgroup with data on all covariables were slightly smaller. In general these findings suggest no important selection bias relating to missing data on covariables, with the possible exception of missing maternal BMI data which may have resulted in some bias leading to a slight underestimation of the differences.

All Pakistani generation groups had on average a significantly lower birthweight than White British infants. The Both group (both parents South Asian born) and Dad only group (mother UK born, father South Asian born) had the smallest unadjusted differences and the Mum only group (mother South Asian born, father UK born) and Other group had the largest differences. The unadjusted mean difference (based on the full sample n=4059) ranged from -215g (95% CI -257, -173) in the Both group (both parents South Asian born) to -248g (95% CI -316, -180) in the Other group. The effect of adjustment for explanatory / mediating factors varied by generation group. This was on the whole explained by differences in these characteristics among the generation groups. For example, whilst smoking and living with a partner maintained a similar pattern across the generation groups (i.e. the effect of adjustment was similar in all generation groups), adjusting for parity resulted in a relatively higher increase in mean difference in the Dad only, Mum only and Both groups, reflecting proportionately higher mean parity in these groups and the tendency for birthweight to increase with higher parity.

Adjustment for maternal height reduced the magnitude of the difference compared to the unadjusted association in all groups but the greatest effect was seen in Mum only and Both groups where mothers were South Asian born and were on average 1cm smaller than mothers from the Neither, Dad only and Other groups. Similarly, BMI explained some of the difference in mean birthweight between Pakistani and White British origin infants but the magnitude varied by generation group consistent with differences in mean BMI across the groups. Adjustment had the greatest effect in the Neither and Mum only groups (a decrease of 52g and 55g respectively) reflecting lower mean BMI in these groups (i.e. BMI is higher in White British mothers and is associated with higher birthweight therefore once its effect is removed mean differences decrease, mean BMI is lowest in the Neither and Mum only groups thus adjustment has the greatest effect in these groups). Likewise, adjustment for gestational age had the least effect on mean difference where mothers had on average longer gestation (Mum only group). Maternal age had little effect on the mean difference between White British origin infants and the Pakistani group as a whole (see above) however analysis by generation identified an increase in the mean difference in birthweight between the Both group (both parents South Asian born) and White British infants after adjustment for maternal age, by around 20g reflecting the higher mean maternal age in this group (30 years compared to 28 years for Pakistani mothers as a whole and 27 years in White British mothers) and the trend towards lower birthweight when mothers are aged 30 and over (Chapter 2). Adjustment for alcohol, diabetes, hypertension, sex and socioeconomic position did not result in any substantive differences and similar patterns remained across generation groups before and after adjustment for these characteristics.

Prior to adjustment, the smallest mean birthweight differences were in the Dad only and Both groups (where the baby's father was South Asian born) and the largest differences were within the Neither, Mum only and Other groups (where the baby's father was generally UK born). However, this observation changed once all potential expanatory / mediating factors were taken into account. After adjustment for all covariables the smallest birthweight differences were in the Neither group (both parents UK born) and Both group (both parents South Asian born). This was the result of the differing distributions of some covariables in each group and hence the differing effect of adjustment for these as described above.

Whilst full adjustment for potential explanatory / mediating factors affected the generation groups differently, important differences in mean birthweight relative to White British origin infants remained across all generation groups (figure 66), ranging from -163 (95% CI -227, -99) in the Neither group (both parents UK born) to -203 (95% CI -252, -155) in the Dad only group (mother UK born, father South Asian born).

Table 44 Mean birthweight difference (g) for Pakistani infants by generation group* relative to White British infants with adjustment for potential explanatory / masking variables (number varies for each set of analyses due to differences in numbers for each explanatory variable)**

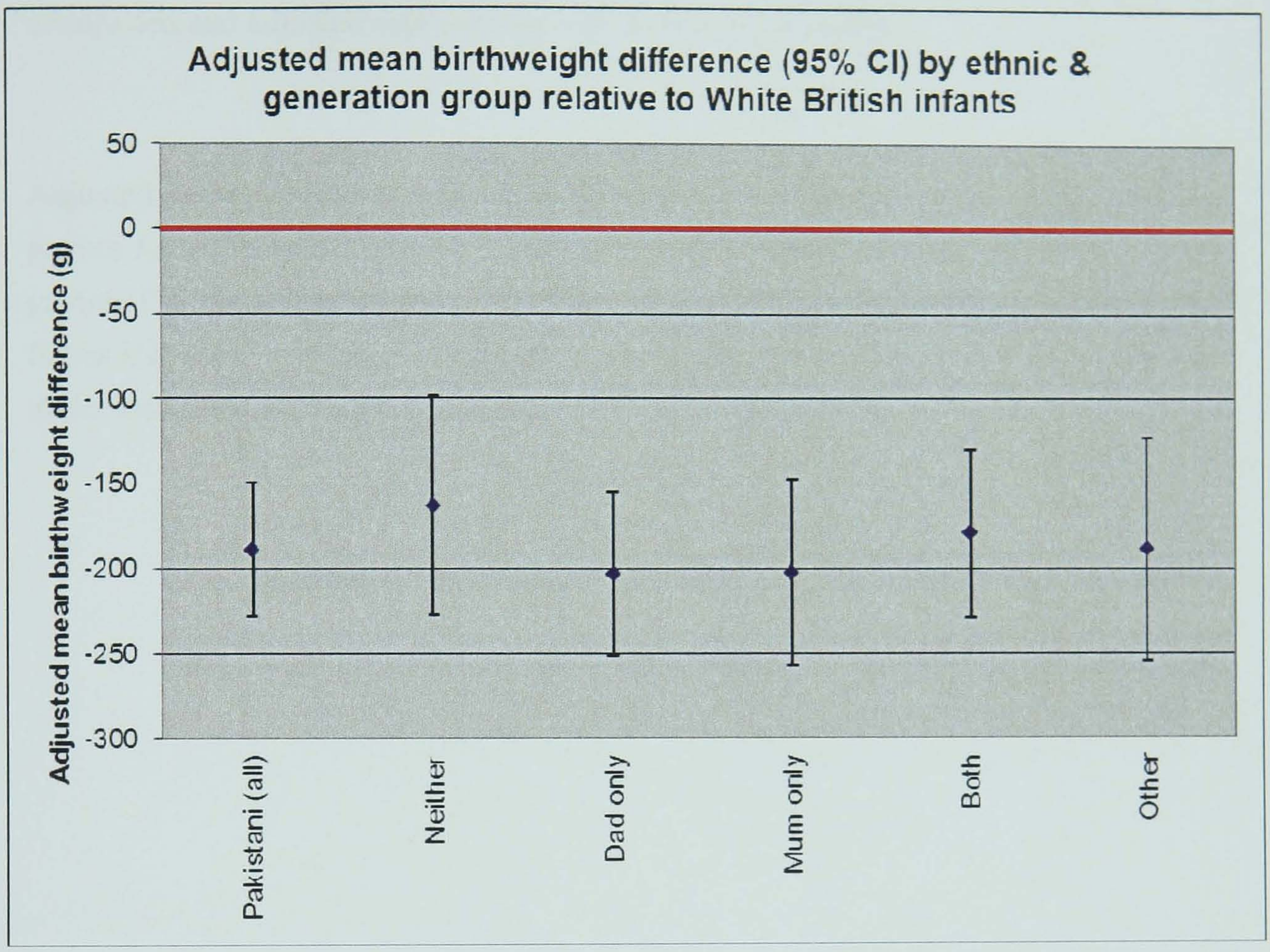
Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Smoking (n=4050)			
Neither	232	-240 (-305, -176)	-291 (-357, -266)
Dad only	582	-215 (-259, -171)	-266 (-311, -221)
Mum only	519	-246 (-293, -200)	-307 (-355, -259)
Both	674	-215 (-257, -173)	-275 (-319, -231)
Other	207	-248 (-316, -180)	-297 (-366, -229)
Alcohol (n=4051)			
Neither	232	-240 (-305, -175)	-243 (-308, -178)
Dad only	583	-216 (-260, -171)	-219 (-263, -174)
Mum only	519	-246 (-292, -200)	-249 (-296, -203)
Both	674	-215 (-256, -173)	-218 (-260, -175)
Other	206	-248 (-317, -180)	-252 (-320, -183)
Maternal age (n=4059)			
Neither	232	-240 (-305, -175)	-245 (-310, -181)
Dad only	584	-216 (-260, -172)	-224 (-269, -180)
Mum only	523	-243 (-289, -197)	-250 (-296, -203)
Both	675	-215 (-257, -173)	-238 (-281, -196)
Other	207	-248 (-316, -180)	-242 (-309, -174)
Maternal existing or gestational diabetes (n=4059)			
Neither	232	-240 (-305, -175)	-240 (-305, -175)
Dad only	584	-216 (-260, -172)	-215 (-259, -171)
Mum only	523	-243 (-289, -197)	-243 (-289, -197)
Both	675	-215 (-257, -173)	-214 (-256, -173)
Other	207	-248 (-316, -180)	-248 (-316, -180)
Maternal hypertension (n=4059)			
Neither	232	-240 (-305, -175)	-242 (-306, -177)
Dad only	584	-216 (-260, -172)	-217 (-261, -174)
Mum only	523	-243 (-289, -197)	-245 (-291, -199)
Both	675	-215 (-257, -173)	-217 (-259, -176)
Other	207	-248 (-316, -180)	-251 (-319, -183)
Maternal height (n=4029)			
Neither	230	-237 (-302, -172)	-181 (-245, -117)
Dad only	580	-218 (-262, -174)	-150 (-195, -106)
Mum only	519	-246 (-292, -200)	-159 (-206, -113)
Both	666	-215 (-257, -173)	-135 (-178, -92)
Other	205	-247 (-315, -178)	-183 (-251, -116)
Maternal BMI (n=3730)			
Neither	211	-214 (-282, -147)	-162 (-227, -96)
Dad only	546	-225 (-270, -179)	-210 (-255, -166)
Mum only	486	-254 (-302, -207)	-199 (-245, -152)
Both	615	-204 (-247, -161)	-181 (-222, -138)
Other	189	-265 (-335, -194)	-234 (-303, -165)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Parity (n=3946)			
Neither	224	-242 (-307, -176)	-250 (-315, -184)
Dad only	566	-216 (-261, -171)	-243 (-288, -198)
Mum only	507	-243 (-290, -197)	-275 (-322, -228)
Both	656	-210 (-252, -168)	-255 (-299, -212)
Other	205	-244 (-313, -176)	-244 (-312, -176)
Gestational age (n=4059)			
Neither	232	-240 (-305, -175)	-203 (-264, -143)
Dad only	584	-216 (-260, -172)	-186 (-227, -145)
Mum only	523	-243 (-289, -197)	-233 (-276, -191)
Both	675	-215 (-257, -173)	-182 (-221, -143)
Other	207	-248 (-316, -180)	-210 (-274, -147)
Baby's sex (n=4059)			
Neither	232	-240 (-305, -175)	-244 (-308, -180)
Dad only	584	-216 (-260, -172)	-220 (-264, -176)
Mum only	523	-243 (-289, -197)	-238 (-283, -193)
Both	675	-215 (-257, -173)	-214 (-254, -172)
Other	207	-248 (-316, -180)	-251 (-318, -184)
SEP (n=4030) *Income, maternal education, housing tenure, receipt of means tested benefits***			
Neither	231	-248 (-303, -174)	-246 (-313, -179)
Dad only	582	-216 (-260, -172)	-217 (-265, -168)
Mum only	520	-246 (-292, -200)	-240 (-294, -186)
Both	666	-217 (-258, -175)	-209 (-257, -162)
Other	204	-242 (-310, -173)	-228 (-299, -158)
Living with a partner (n=4051)			
Neither	230	-243 (-308, -178)	-267 (-332, -202)
Dad only	583	-215 (-259, -171)	-238 (-283, -194)
Mum only	522	-243 (-289, -197)	-271 (-318, -224)
Both	673	-214 (-256, -173)	-240 (-283, -198)
Other	207	-248 (-316, -180)	-261 (-329, -193)
All above covariables (n=3604)			
Neither	202	-220 (-288, -151)	-163 (-227, -99)
Dad only	526	-225 (-271, -179)	-203 (-252, -155)
Mum only	468	-260 (-309, -212)	-202 (-257, -147)
Both	588	-200 (-244, -156)	-179 (-228, -130)
Other	185	-258 (-329, -186)	-188 (-254, -122)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

*****Receipt of means tested benefits** -any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Figure 66 Adjusted* mean birthweight difference (g) relative to White British infants by ethnic and generation groups**



**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*

***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Tables 45 to 49 and figures 67 to 71 show the same analyses as those presented above for birthweight but for head circumference, abdominal circumference, MUA circumference, subscapular skinfold thickness and triceps skinfold thickness. As above the tables show the association of Pakistani generation group (each generation group versus White British infants) with adjustment for each explanatory / mediating factor in turn and then with adjustment for all potential mediators. Again, the unadjusted difference was generally similar across all subgroups with slightly weaker differences in the subgroup with data on maternal BMI and hence the subgroup with complete data on all covariables. The effect of adjustment for explanatory / mediating factors on circumference and skinfold measurements was similar to that described above for birthweight (i.e. adjustment had the greatest effect in the Neither, Mum only and Other groups) although differences between unadjusted and adjusted associations were on the whole small.

Adjusted mean differences relative to White British origin infants followed a similar pattern for all measurements and were generally smallest in the Neither group (both parents UK born) and largest in the Mum only group (mother South Asian born and father UK born), although not all were statistically significant. Differences did not differ markedly across generations.

Table 45 Mean head circumference difference (cm) for Pakistani infants by generation group* relative to White British infants with adjustment for potential explanatory / masking variables (n=3318 to 3705)

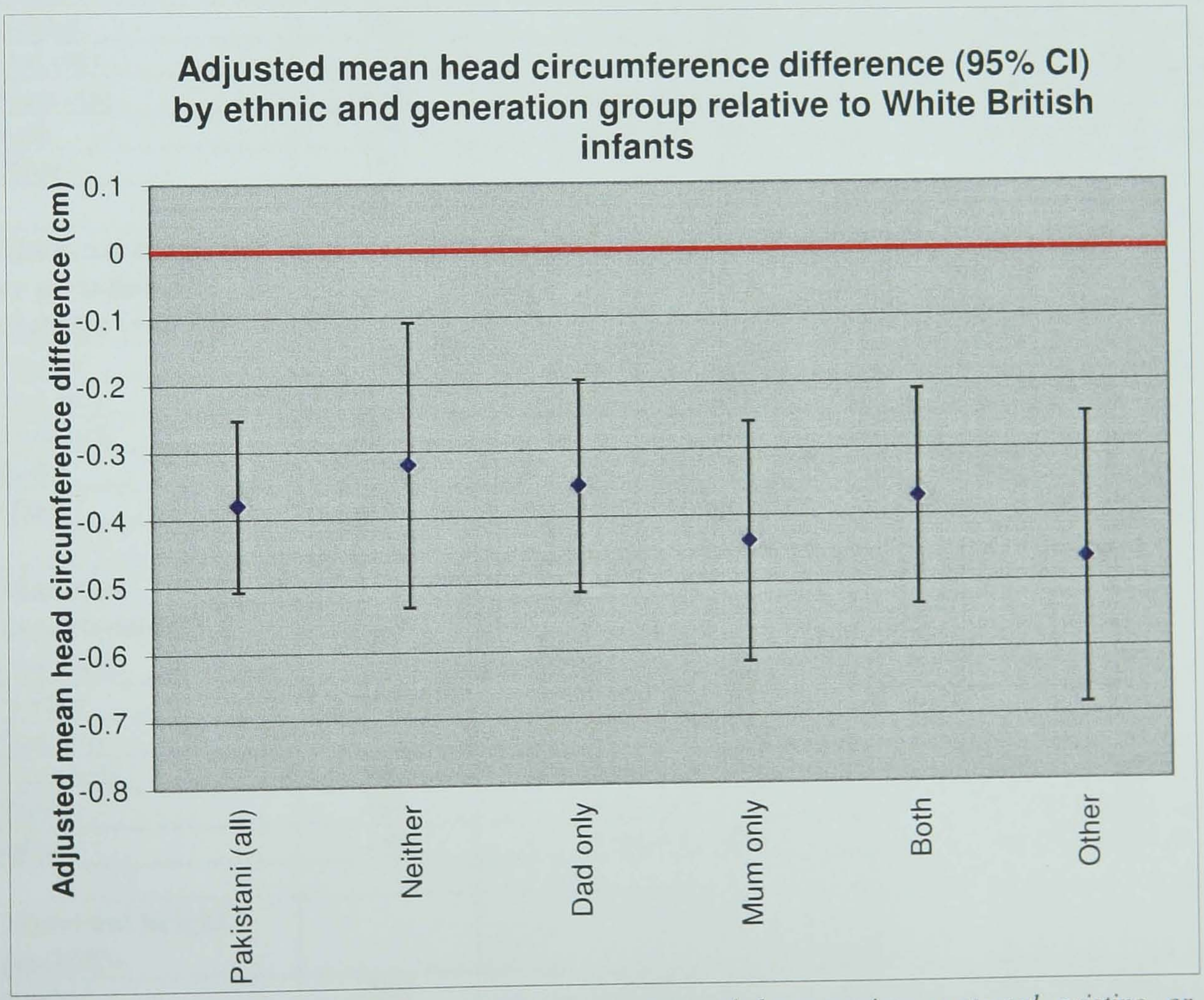
Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Smoking (n-3697)			
Neither	209	-0.5 (-0.7, -0.3)	-0.6 (-0.8, -0.4)
Dad only	534	-0.4 (-0.5, -0.2)	-0.5 (-0.6, -0.4)
Mum only	479	-0.5 (-0.7, -0.4)	-0.7 (-0.8, -0.5)
Both	619	-0.4 (-0.6, -0.3)	-0.6 (-0.7, -0.5)
Other	186	-0.6 (-0.8, -0.4)	-0.7 (-0.9, -0.5)
Alcohol (n=3698)			
Neither	209	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	535	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.3)
Mum only	479	-0.5 (-0.7, -0.4)	-0.5 (-0.7, -0.4)
Both	619	-0.4 (-0.6, -0.3)	-0.4 (-0.6, -0.3)
Other	185	-0.6 (-0.8, -0.4)	-0.6 (-0.8, -0.4)
Maternal age (n=3705)			
Neither	209	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	536	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.3)
Mum only	482	-0.5 (-0.7, -0.4)	-0.5 (-0.7, -0.4)
Both	620	-0.4 (-0.6, -0.3)	-0.5 (-0.6, -0.4)
Other	186	-0.6 (-0.8, -0.4)	-0.6 (-0.8, -0.4)
Maternal existing or gestational diabetes (n=3705)			
Neither	209	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	536	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.2)
Mum only	482	-0.5 (-0.7, -0.4)	-0.5 (-0.7, -0.4)
Both	620	-0.4 (-0.6, -0.3)	-0.4 (-0.6, -0.3)
Other	186	-0.6 (-0.9, -0.4)	-0.6 (-0.8, -0.4)
Maternal hypertension (n=3705)			
Neither	209	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	536	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.2)
Mum only	482	-0.5 (-0.7, -0.4)	-0.5 (-0.7, -0.4)
Both	620	-0.4 (-0.6, -0.3)	-0.4 (-0.6, -0.3)
Other	186	-0.6 (-0.8, -0.4)	-0.6 (-0.8, -0.4)
Maternal height (n=3679)			
Neither	208	-0.5 (-0.7, -0.3)	-0.4 (-0.6, -0.2)
Dad only	533	-0.4 (-0.5, -0.2)	-0.3 (-0.4, -0.1)
Mum only	478	-0.5 (-0.7, -0.4)	-0.4 (-0.5, -0.2)
Both	611	-0.4 (-0.6, -0.3)	-0.3 (-0.4, -0.2)
Other	185	-0.6 (-0.8, -0.4)	-0.5 (-0.7, -0.3)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Maternal BMI (n=3431)			
Neither	192	-0.4 (-0.6, -0.2)	-0.3 (-0.5, -0.1)
Dad only	504	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.2)
Mum only	448	-0.5 (-0.7, -0.4)	-0.4 (-0.6, -0.3)
Both	569	-0.4 (-0.6, -0.3)	-0.4 (-0.5, -0.3)
Other	172	-0.6 (-0.8, -0.4)	-0.5 (-0.8, -0.3)
Parity (n=3607)			
Neither	201	-0.5 (-0.7, -0.2)	-0.5 (-0.7, -0.3)
Dad only	520	-0.4 (-0.5, -0.3)	-0.4 (-0.6, -0.3)
Mum only	467	-0.5 (-0.7, -0.4)	-0.6 (-0.7, -0.5)
Both	604	-0.4 (-0.6, -0.3)	-0.5 (-0.6, -0.4)
Other	184	-0.6 (-0.8, -0.4)	-0.6 (-0.8, -0.4)
Gestational age (n=3705)			
Neither	209	-0.5 (-0.7, -0.3)	-0.4 (-0.6, -0.2)
Dad only	536	-0.4 (-0.5, -0.2)	-0.3 (-0.4, -0.2)
Mum only	482	-0.5 (-0.7, -0.4)	-0.5 (-0.6, -0.4)
Both	620	-0.4 (-0.6, -0.3)	-0.4 (-0.5, -0.2)
Other	186	-0.6 (-0.8, -0.4)	-0.5 (-0.7, -0.3)
Baby's sex (n=3705)			
Neither	209	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	536	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.3)
Mum only	482	-0.5 (-0.7, -0.4)	-0.5 (-0.6, -0.4)
Both	620	-0.4 (-0.6, -0.3)	-0.4 (-0.6, -0.3)
Other	186	-0.6 (-0.8, -0.4)	-0.6 (-0.8, -0.4)
SEP (n=3680) *Income, maternal education, housing tenure, receipt of means tested benefits***			
Neither	208	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	534	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.2)
Mum only	479	-0.5 (-0.7, -0.4)	-0.5 (-0.7, -0.4)
Both	611	-0.4 (-0.6, -0.3)	-0.4 (-0.6, -0.3)
Other	184	-0.6 (-0.8, -0.3)	-0.5 (-0.8, -0.3)
Living with a partner (n=3697)			
Neither	207	-0.5 (-0.7, -0.3)	-0.5 (-0.7, -0.3)
Dad only	535	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.3)
Mum only	481	-0.5 (-0.7, -0.4)	-0.5 (-0.7, -0.4)
Both	618	-0.4 (-0.6, -0.3)	-0.5 (-0.6, -0.3)
Other	186	-0.6 (-0.8, -0.4)	-0.6 (-0.8, -0.4)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
All above covariables (n=3318)			
Neither	183	-0.4 (-0.6, -0.2)	-0.3 (-0.5, -0.1)
Dad only	486	-0.4 (-0.5, -0.2)	-0.4 (-0.5, -0.2)
Mum only	432	-0.6 (-0.7, -0.4)	-0.4 (-0.6, -0.3)
Both	544	-0.4 (-0.6, -0.3)	-0.4 (-0.5, -0.2)
Other	168	-0.6 (-0.8, -0.4)	-0.5 (-0.7, -0.2)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*
***Receipt of means tested benefits -any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Figure 67 Adjusted* mean head circumference difference (cm) relative to White British infants by ethnic and generation groups**



**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*
***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 46 Mean abdominal difference (cm) for Pakistani infants by generation group* relative to White British infants with adjustment for potential explanatory / masking variables (n=3234 to 3619)**

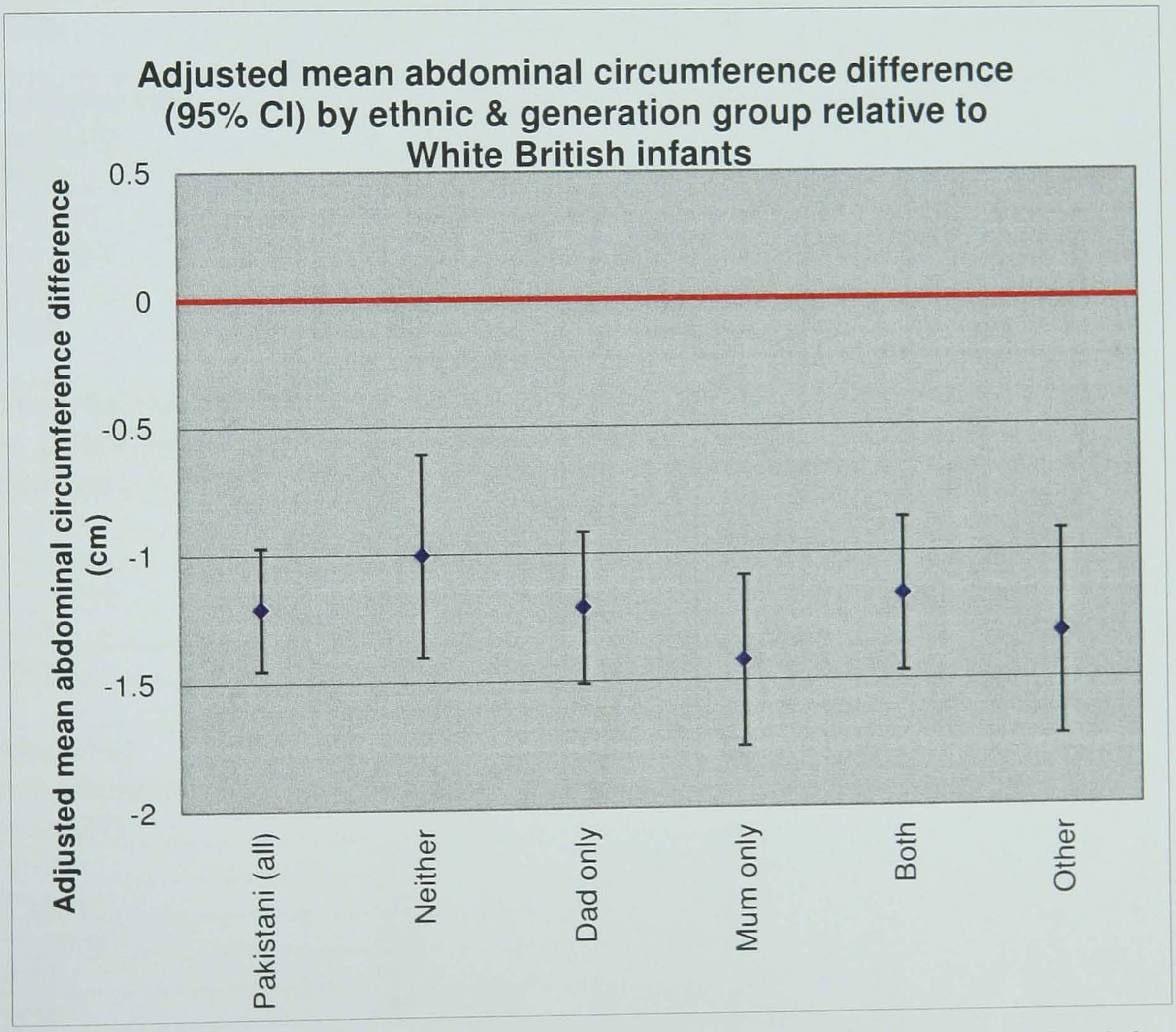
Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Smoking (n=3611)			
Neither	204	-1.2 (-1.6, -0.9)	-1.3 (-1.7, -1.0)
Dad only	525	-1.2 (-1.4, -0.9)	-1.3 (-1.6, -1.1)
Mum only	466	-1.4 (-1.7, -1.2)	-1.6 (-1.8, -1.3)
Both	603	-1.2 (-1.4, -0.9)	-1.3 (-1.5, -1.1)
Other	186	-1.4 (-1.8, -1.0)	-1.6 (-1.9, -1.2)
Alcohol (n=3612)			
Neither	204	-1.2 (-1.6, -0.8)	-1.2 (-1.6, -0.9)
Dad only	526	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Mum only	466	-1.4 (-1.7, -1.2)	-1.4 (-1.7, -1.2)
Both	603	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Other	185	-1.4 (-1.8, -1.0)	-1.4 (-1.8, -1.0)
Maternal age (n=3619)			
Neither	204	-1.2 (-1.6, -0.8)	-1.2 (-1.6, -0.9)
Dad only	527	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Mum only	469	-1.4 (-1.6, -1.1)	-1.4 (-1.6, -1.1)
Both	604	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -1.0)
Other	186	-1.4 (-1.8, -1.1)	-1.4 (-1.8, -1.0)
Maternal existing or gestational diabetes (n=3619)			
Neither	204	-1.2 (-1.5, -0.8)	-1.2 (-1.5, -0.8)
Dad only	527	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Mum only	469	-1.4 (-1.6, -1.1)	-1.3 (-1.6, -1.1)
Both	604	-1.2 (-1.4, -0.9)	-1.1 (-1.4, -0.9)
Other	186	-1.4 (-1.8, -1.0)	-1.4 (-1.8, -1.0)
Maternal hypertension (n=3619)			
Neither	204	-1.2 (-1.5, -0.8)	-1.2 (-1.6, -0.9)
Dad only	527	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Mum only	469	-1.4 (-1.6, -1.1)	-1.3 (-1.6, -1.1)
Both	604	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Other	186	-1.4 (-1.8, -1.0)	-1.4 (-1.8, -1.0)
Maternal height (n=3593)			
Neither	203	-1.2 (-1.5, -0.8)	-1.1 (-1.4, -0.7)
Dad only	524	-1.2 (-1.4, -0.9)	-1.0 (-1.3, -0.8)
Mum only	465	-1.4 (-1.6, -1.1)	-1.2 (-1.4, -0.9)
Both	595	-1.2 (-1.4, -0.9)	-1.0 (-1.2, -0.7)
Other	185	-1.4 (-1.8, -1.1)	-1.3 (-1.6, -0.9)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Maternal BMI (n=3346)			
Neither	186	-1.1 (-1.5, -0.7)	-1.0 (-1.3, -0.6)
Dad only	495	-1.2 (-1.4, -0.9)	-1.1 (-1.4, -0.9)
Mum only	436	-1.4 (-1.6, -1.1)	-1.2 (-1.5, -1.0)
Both	554	-1.1 (-1.4, -0.9)	-1.0 (-1.3, -0.8)
Other	172	-1.5 (-1.8, -1.1)	-1.4 (-1.8, -1.0)
Parity (n=3523)			
Neither	196	-1.2 (-1.6, -0.8)	-1.2 (-1.6, -0.9)
Dad only	510	-1.2 (-1.4, -0.9)	-1.3 (-1.5, -1.0)
Mum only	454	-1.4 (-1.6, -1.1)	-1.5 (-1.8, -1.3)
Both	588	-1.1 (-1.4, -0.9)	-1.3 (-1.6, -1.0)
Other	184	-1.4 (-1.8, -1.1)	-1.4 (-1.8, -1.1)
Gestational age (n=3619)			
Neither	204	-1.2 (-1.6, -0.8)	-1.1 (-1.4, -0.8)
Dad only	527	-1.2 (-1.4, -0.9)	-1.1 (-1.3, -0.9)
Mum only	469	-1.4 (-1.6, -1.1)	-1.4 (-1.6, -1.1)
Both	604	-1.2 (-1.4, -0.9)	-1.1 (-1.3, -0.8)
Other	186	-1.4 (-1.8, -1.1)	-1.3 (-1.7, -1.0)
Baby's sex (n=3619)			
Neither	204	-1.2 (-1.6, -0.8)	-1.2 (-1.6, -0.9)
Dad only	527	-1.2 (-1.4, -0.9)	-1.2 (-1.4, -0.9)
Mum only	469	-1.4 (-1.6, -1.1)	-1.4 (-1.6, -1.1)
Both	604	-1.2 (-1.4, -0.9)	-1.1 (-1.4, -0.9)
Other	186	-1.4 (-1.8, -1.1)	-1.4 (-1.8, -1.1)
SEP (n=3595) *Income, maternal education, housing tenure, receipt of means tested benefits***			
Neither	203	-1.2 (-1.5, -0.8)	-1.3 (-1.6, -0.9)
Dad only	525	-1.2 (-1.4, -0.9)	-1.2 (-1.5, -1.0)
Mum only	467	-1.4 (-1.6, -1.1)	-1.5 (-1.8, -1.2)
Both	596	-1.1 (-1.4, -0.9)	-1.3 (-1.5, -1.0)
Other	184	-1.4 (-1.8, -1.0)	-1.4 (-1.8, -1.1)
Living with a partner (n=3611)			
Neither	202	-1.2 (-1.6, -0.9)	-1.3 (-1.6, -0.9)
Dad only	526	-1.2 (-1.4, -0.9)	-1.2 (-1.5, -1.0)
Mum only	468	-1.4 (-1.6, -1.1)	-1.5 (-1.7, -1.2)
Both	602	-1.2 (-1.4, -0.9)	-1.2 (-1.5, -1.0)
Other	186	-1.4 (-1.8, -1.1)	-1.5 (-1.8, -1.1)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
All above covariables (n=3234)			
Neither	177	-1.1 (-1.5, -0.7)	-1.0 (-1.4, -0.6)
Dad only	476	-1.2 (-1.4, -0.9)	-1.2 (-1.5, -0.9)
Mum only	419	-1.4 (-1.7, -1.1)	-1.4 (-1.8, -1.1)
Both	530	-1.1 (-1.3, -0.9)	-1.2 (-1.5, -0.9)
Other	168	-1.4 (-1.8, -1.0)	-1.3 (-1.7, -0.9)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories **Receipt of means tested benefits -any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Figure 68 Adjusted* mean abdominal circumference difference (cm) relative to White British infants by ethnic and generation groups**



*

Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner

***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 47 Mean MUA circumference difference (cm) for Pakistani infants by generation group* relative to White British infants with adjustment for potential explanatory / masking variables (n=3232 to 3617)

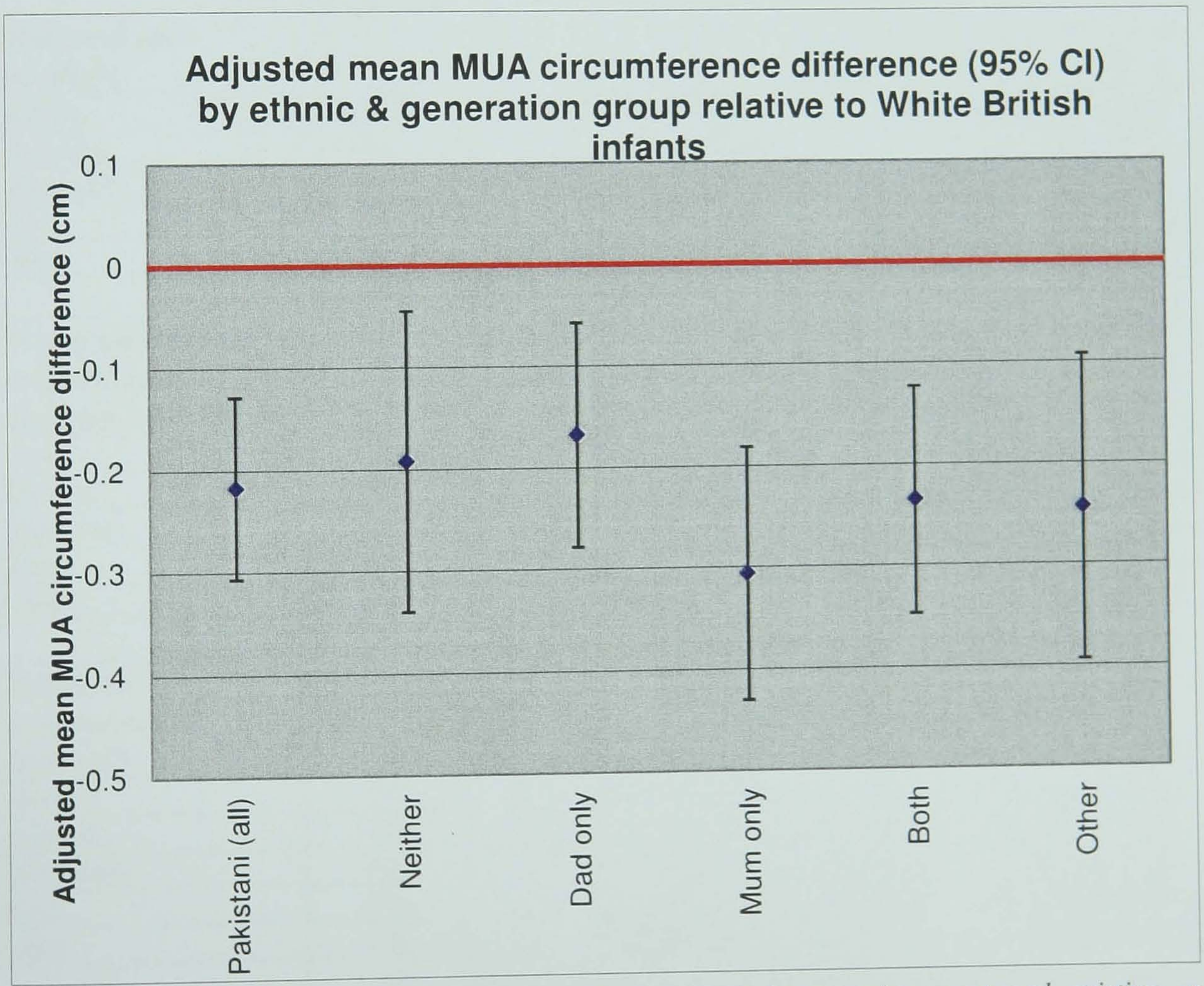
Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Smoking (n=3609)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Dad only	522	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	465	-0.3 (-0.4, -0.3)	-0.4 (-0.5, -0.3)
Both	602	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.4 (-0.5, -0.2)
Alcohol (n=3610)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Dad only	523	-0.2 (-0.3, -0.1)	-0.8 (-0.3, -0.1)
Mum only	465	-0.3 (-0.4, -0.3)	-0.3 (-0.4, -0.3)
Both	602	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	183	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
Maternal age (n=3617)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Dad only	524	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	468	-0.3 (-0.4, -0.2)	-0.4 (-0.5, -0.3)
Both	603	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
Maternal existing or gestational diabetes (n=3617)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Dad only	524	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	468	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	603	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
Maternal hypertension (n=3617)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Dad only	524	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	468	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	603	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
Maternal height (n=3617)			
Neither	203	-0.3 (-0.4, -0.2)	-0.3 (-0.4,-0.1)
Dad only	521	-0.2 (-0.3, -0.1)	-0.1 (-0.2, 0.0)
Mum only	464	-0.3 (-0.4, -0.3)	-0.3 (-0.4, -0.2)
Both	594	-0.3 (-0.4, -0.2)	-0.2 (-0.3, -0.1)
Other	183	-0.3 (-0.5, -0.2)	-0.3 (-0.4, -0.1)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Maternal BMI (n=3344)			
Neither	186	-0.3 (-0.4, -0.1)	-0.2 (-0.3, -0.1)
Dad only	492	-0.2 (-0.3, -0.1)	-0.2 (-0.2, -0.1)
Mum only	435	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	553	-0.3 (-0.4, -0.2)	-0.2 (-0.3, -0.1)
Other	170	-0.4 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
Parity (n=3521)			
Neither	196	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Dad only	508	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	454	-0.3 (-0.4, -0.2)	-0.4 (-0.5, -0.3)
Both	587	-0.3 (-0.4, -0.2)	-0.4 (-0.4, -0.3)
Other	182	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
Gestational age (n=3617)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.1)
Dad only	524	-0.2 (-0.3, -0.1)	-0.1 (-0.2, -0.1)
Mum only	468	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	603	-0.3 (-0.4, -0.2)	-0.2 (-0.3, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.3 (-0.4, -0.1)
Baby's sex (n=3617)			
Neither	204	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Dad only	524	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	468	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	603	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)
SEP (n=3593) *Income, maternal education, housing tenure, receipt of means tested benefits***			
Neither	203	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Dad only	522	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	466	-0.3 (-0.4, -0.2)	-0.4 (-0.5, -0.2)
Both	595	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	182	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Living with a partner (n=3609)			
Neither	202	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Dad only	523	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	467	-0.3 (-0.4, -0.3)	-0.4 (-0.5, -0.3)
Both	601	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Other	184	-0.3 (-0.5, -0.2)	-0.3 (-0.5, -0.2)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
All above covariables (n=3232)			
Neither	177	-0.3 (-0.4, -0.1)	-0.2 (-0.3, 0.0)
Dad only	474	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	419	-0.4 (-0.5, -0.3)	-0.3 (-0.4, -0.2)
Both	529	-0.3 (-0.4, -0.2)	-0.2 (-0.3, -0.1)
Other	166	-0.3 (-0.5, -0.2)	-0.2 (-0.4, -0.1)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*
***Receipt of means tested benefits -any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Figure 69 Adjusted* mean MUA circumference difference (cm) relative to White British infants by ethnic and generation groups**



**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*
***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 48 Mean subscapular skinfold difference (mm) for Pakistani infants by generation group* relative to White British infants with adjustment for potential explanatory / masking variables (n=2704 to 3010)

Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Smoking (n=3004)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, -0.1)
Dad only	455	-0.2 (-0.3, -0.1)	-0.2 (-0.4, -0.1)
Mum only	406	-0.3 (-0.4, -0.1)	-0.3 (-0.5, -0.2)
Both	520	-0.1 (-0.2, 0.0)	-0.2 (-0.3, -0.1)
Other	161	-0.2 (-0.4, -0.1)	-0.3 (-0.5, -0.1)
Alcohol (n=3005)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	456	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	406	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	520	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	160	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Maternal age (n=3010)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	457	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.2)
Both	520	-0.1 (-0.2, 0.0)	-0.2 (-0.3, -0.1)
Other	161	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Maternal existing or gestational diabetes (n=3010)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	457	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	520	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	161	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Maternal hypertension (n=3010)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	457	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	520	-0.1 (-0.2, 0.0)	-0.1 9-0.2, 0.0)
Other	161	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Maternal height (n=2990)			
Neither	176	-0.2 (-0.4, 0.0)	-0.2 (-0.3, 0.0)
Dad only	454	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	407	-0.3 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Both	514	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	160	-0.2 (-0.4, -0.1)	-0.2 (-0.4, 0.0)

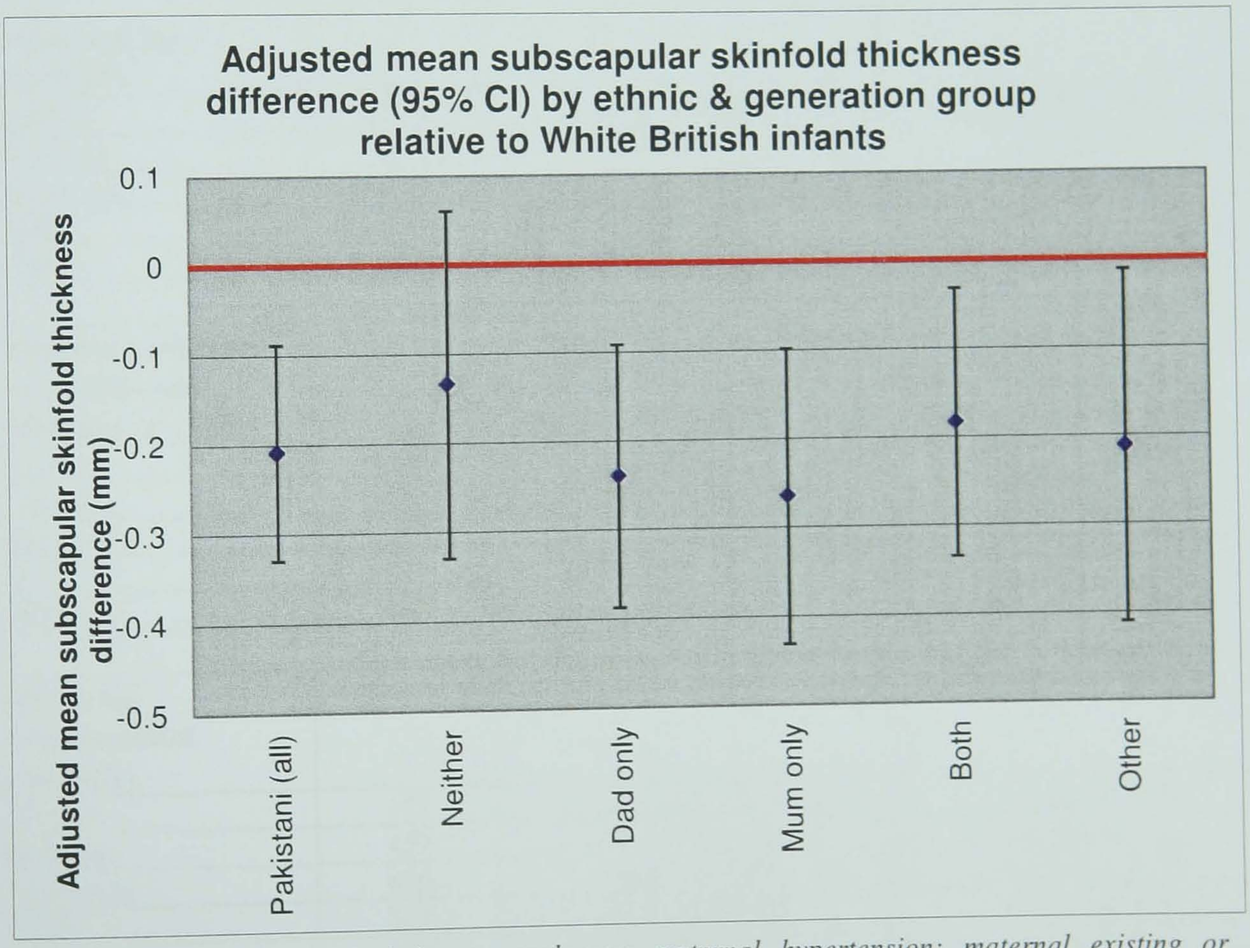
Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Maternal BMI (n=2800)			
Neither	163	-0.1 (-0.3, 0.1)	-0.0 (-0.2, 0.1)
Dad only	433	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	383	-0.3 (-0.4, -0.1)	-0.2 (-0.3, 0.0)
Both	485	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	150	-0.3 (-0.4, -0.1)	-0.2 (-0.4, 0.0)
Parity (n=2932)			
Neither	172	-0.2 (-0.4, 0.0)	-0.2 (-0.4, -0.1)
Dad only	444	-0.2 (-0.3, -0.1)	-0.3 (-0.4, -0.1)
Mum only	397	-0.3 (-0.4, -0.1)	-0.4 (-0.5, -0.2)
Both	507	-0.1 (-0.2, 0.0)	-0.3 (-0.4, -0.2)
Other	160	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Gestational age (n=3010)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	457	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	520	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	161	-0.2 (-0.4, -0.1)	-0.2 (-0.4, 0.0)
Baby's sex (n=3010)			
Neither	177	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	457	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	520	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	161	-0.2 (-0.4, -0.1)	-0.2 (-0.4 -0.1)
SEP (n=2991) *Income, maternal education, housing tenure, receipt of means tested benefits***			
Neither	176	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	455	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	408	-0.3 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Both	513	-0.1 (-0.2, 0.0)	-0.1 (-0.2, 0.0)
Other	159	-0.2 (-0.4, -0.1)	-0.2 (-0.4, 0.0)
Living with a partner (n=3002)			
Neither	175	-0.2 (-0.4, 0.0)	-0.2 (-0.4, -0.1)
Dad only	456	-0.2 (-0.3, -0.1)	-0.2 (-0.4, -0.1)
Mum only	408	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.2)
Both	518	-0.1 (-0.2, 0.0)	-0.2 (-0.3, -0.1)
Other	161	-0.2 (-0.4, -0.1)	-0.3 (-0.4, -0.1)

Covariable	Number	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)
All above covariables (n=2704)			
Neither	157	-0.1 (-0.3, 0.0)	-0.1 (-0.3, 0.1)
Dad only	415	-0.2 (-0.3, -0.1)	-0.2 (-0.4, -0.1)
Mum only	369	-0.2 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	464	-0.1 (-0.2, 0.0)	-0.2 (-0.3, 0.0)
Other	146	-0.2 (-0.4, -0.1)	-0.2 (-0.4, 0.0)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

***Receipt of means tested benefits -any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Figure 70 Adjusted* mean subscapular skinfold thickness difference (mm) relative to White British infants by ethnic and generation groups**



**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*

***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 49 Mean triceps skinfold thickness difference (mm) for Pakistani infants by generation group* relative to White British infants with adjustment for potential explanatory / mediating variables (n=2715 to 3010)

Covariable	Number	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)
Smoking (n=3015)			
Neither	177	-0.2 (-0.4, -0.1)	-0.3 (-0.5, -0.1)
Dad only	457	-0.2 (-0.3, 0.0)	-0.2 (-0.4, -0.1)
Mum only	407	-0.3 (-0.5, -0.2)	-0.4 (-0.5, -0.3)
Both	522	-0.2 (-0.3, 0.0)	-0.2 (-0.3, -0.1)
Other	162	-0.3 (-0.4, -0.1)	-0.3 (-0.5, -0.1)
Alcohol (n=3016)			
Neither	177	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Dad only	458	-0.2 (-0.3, -0.1)	-0.2 (-0.3, 0.0)
Mum only	407	-0.3 (-0.5, -0.2)	-0.3 (-0.4, -0.2)
Both	522	-0.2 (-0.3, 0.0)	-0.2 (-0.3, 0.0)
Other	161	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Maternal age (n=3021)			
Neither	177	-0.2 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Dad only	459	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Mum only	410	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Both	522	-0.2 (-0.3, 0.0)	-0.2 (-0.3, -0.1)
Other	162	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Maternal existing or gestational diabetes (n=3021)			
Neither	177	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Dad only	459	-0.2 (-0.3, 0.0)	-0.2 (-0.3, 0.0)
Mum only	410	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	522	-0.1 (-0.3, 0.0)	-0.2 (-0.3, 0.0)
Other	162	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Maternal hypertension (n=3021)			
Neither	177	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Dad only	459	-0.2 (-0.3, 0.0)	-0.2 (-0.3, -0.1)
Mum only	410	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.1)
Both	522	-0.1 (-0.3, 0.0)	-0.2 (-0.3, 0.0)
Other	162	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Maternal height (n=3001)			
Neither	176	-0.2 (-0.4, -0.1)	-0.2 (-0.4, 0.0)
Dad only	456	-0.2 (-0.3, -0.1)	-0.1 (-0.2, 0.0)
Mum only	408	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.1)
Both	516	-0.2 (-0.3, 0.0)	-0.1 (-0.2, 0.0)
Other	161	-0.3 (-0.4, -0.1)	-0.2 (-0.4, -0.1)

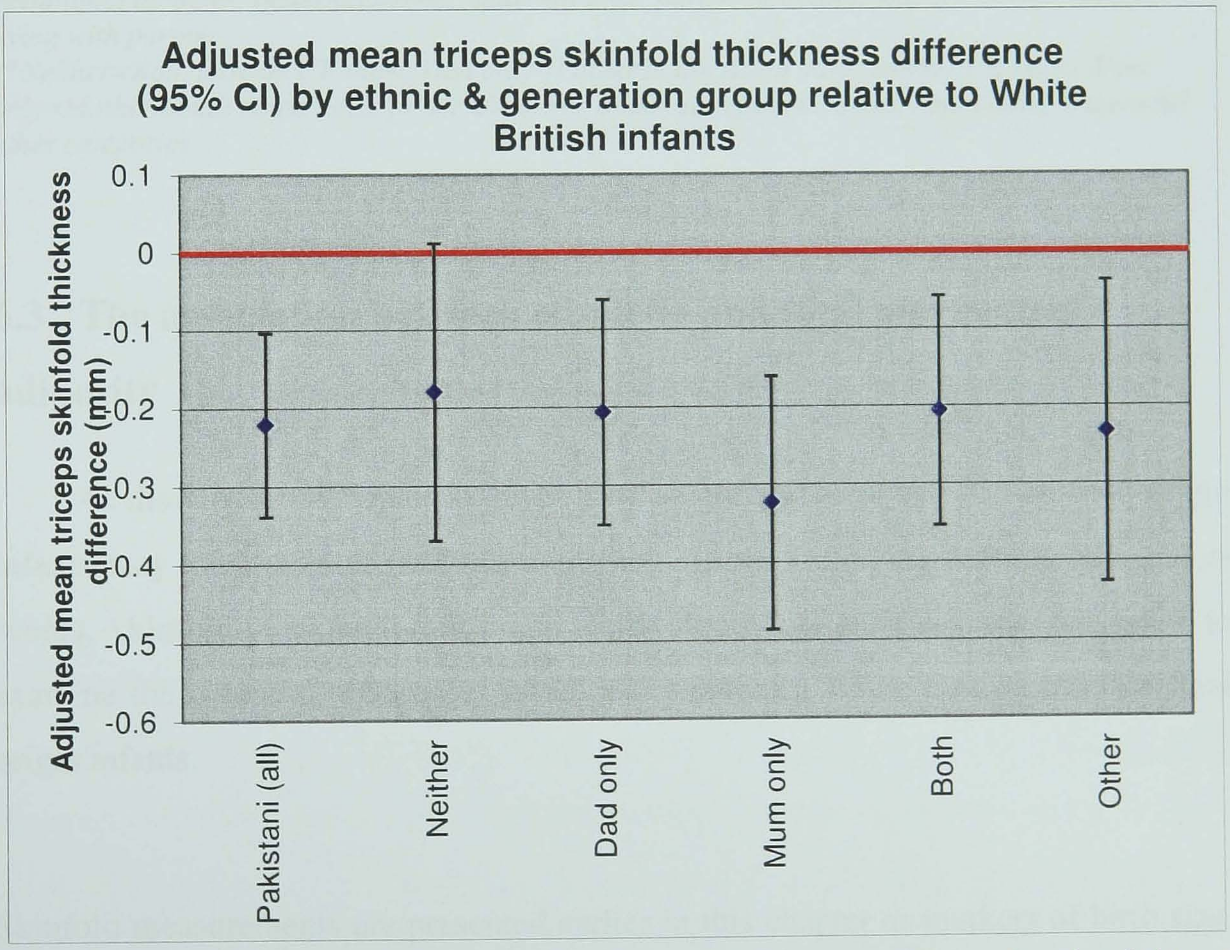
Covariable	Number	Unadjusted mean difference *(95% CI)*	Adjusted mean difference *(95% CI)*
Maternal BMI (n=2811)			
Neither	163	-0.2 (-0.4, 0.0)	-0.1 (-0.3, 0.1)
Dad only	435	-0.2 (-0.3, 0.0)	-0.1 (-0.3, 0.0)
Mum only	384	-0.3 (-0.4, -0.2)	-0.2 (-0.3, -0.1)
Both	487	-0.1 (-0.3, 0.0)	-0.1 (-0.2, 0.0)
Other	151	-0.3 (-0.5, 0.1)	-0.2 (-0.4, 0.0)
Parity (n=2943)			
Neither	172	-0.3 (-0.4, -0.1)	-0.3 (-0.5, -0.1)
Dad only	446	-0.1 (-0.3, 0.0)	-0.2 (-0.3, -0.1)
Mum only	398	-0.3 (-0.4, -0.2)	-0.4 (-0.5, -0.3)
Both	509	-0.2 (-0.3, 0.0)	-0.3 (-0.4, -0.1)
Other	161	-0.3 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Gestational age (n=3021)			
Neither	177	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Dad only	459	-0.2 (-0.3, -0.1)	-0.1 (-0.3, 0.0)
Mum only	410	-0.3 (-0.4, -0.2)	-0.3 (-0.4, -0.2)
Both	522	-0.2 (-0.3, 0.0)	-0.1 (-0.2, 0.0)
Other	162	-0.3 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Baby's sex (n=3021)			
Neither	177	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Dad only	459	-0.2 (-0.3, -0.1)	-0.2 (-0.3, 0.0)
Mum only	410	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Both	522	-0.2 (-0.3, 0.0)	-0.2 (-0.3, 0.0)
Other	162	-0.3 (-0.4, -0.1)	-0.3 (-0.4,-0.1)
SEP (n=3002) *Income, maternal education, housing tenure, receipt of means tested benefits***			
Neither	176	-0.2 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Dad only	457	-0.2 (-0.3, 0.0)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Both	515	-0.1 (-0.3, 0.0)	-0.1 (-0.3, 0.0)
Other	160	-0.3 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Living with a partner (n=3013)			
Neither	175	-0.2 (-0.4, -0.1)	-0.3 (-0.5, -0.1)
Dad only	458	-0.2 (-0.3, 0.0)	-0.2 (-0.3, -0.1)
Mum only	409	-0.3 (-0.5, -0.2)	-0.4 (-0.5, -0.3)
Both	520	-0.1 (-0.1, 0.0)	-0.2 (-0.3, -0.1)
Other	162	-0.3 (-0.4, -0.1)	-0.3 (-0.5, -0.1)

Covariable	Number	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)
All above covariables (n=2715)			
Neither	157	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	417	-0.1 (-0.3, 0.0)	-0.2 (-0.4, -0.1)
Mum only	370	-0.3 (-0.4, -0.2)	-0.3 (-0.5, -0.2)
Both	466	-0.1 (-0.3, 0.0)	-0.2 (-0.4, -0.1)
Other	147	-0.3 (-0.4, -0.1)	-0.2 (-0.4, 0.0)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

***Receipt of means tested benefits -any of: Income Support; Job Seekers Allowance; Working Tax Credit; Housing Benefit*

Figure 71 Adjusted* mean triceps skinfold thickness difference (mm) relative to White British infants by ethnic and generation groups**



**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*

***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

6.3 Differences between generational groups

In all models described above, each generation group is compared with the White British group. Confidence intervals all overlap for each birth size measurement suggesting that differences between generation groups (as opposed to differences relative to the White British group) are not significantly different. In addition Table 50 shows mean birthweight differences for the Dad only, Mum only, Both and Other groups relative to the Neither group. None of the differences were significant.

Table 50 Mean birthweight differences* (95% CI) between generation groups (using Neither group as the reference group)**

Dad only	Mum only	Both	Other
-39 (-104, 25)	-38 (-106, 30)	-23 (-89, 43)	-32 (-112, 47)

**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*
***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

6.3 The association between ethnicity and total and central adiposity

As discussed in Chapter 2, lower birthweight and birth size in Pakistani origin infants may mask greater (central) adiposity. In the following section, adjusted z-scores, skinfold thickness ratios and cord blood leptin values are presented to examine the potential differences in adiposity between White British and Pakistani origin infants.

Skinfold measurements are presented earlier in this chapter as markers of birth size, here they are used as proxy indicators of total body fat. Subscapular skinfold thickness is a measure of central subcutaneous fat, by contrast triceps skinfold thickness is a measure of peripheral subcutaneous fat. In this section I examine z-scores of the birth size outcomes to explore evidence that Pakistani origin infants are relatively more adipose than White British infants. Z-scores allow measurements that are usually measured with different units (e.g. grams and mm) to be compared by making the units the same (see below). If the hypothesis is correct that Pakistani infants are more adipose (relative to general size) than White British infants then the z-score difference for skinfolds should be smaller than that for birthweight and head circumference. Furthermore, with mutual adjustment the skinfolds difference should attenuate (i.e. there is less ethnic difference in fat once general size is taken into account) or even reverse (i.e. greater fat in Pakistani infants than White British infants once general size is taken into account). If any greater relative adiposity in Pakistani infants is particularly centrally distributed then the subscapular skinfold thickness and subscapular to triceps ratio should be particularly small, and possibly in the opposite direction (greater in Pakistani compared to White british infants) once birthweight is taken into account. In addition to examining these associations, I have also used cord blood leptin as a marker for total fat at birth in a subgroup of the cohort on whom measurements were completed (see Chapter 5).

6.3.1 Z Scores

Z-scores represent the number of standard deviations below or above the reference mean or median value. A negative z-score i.e. less than 0, represents a value less than the mean, a positive z-score i.e. greater than 0, represents a value above the mean and if equal to 0 it represents a value equal to the mean. (eg a z-score of -1 represents a score that is one standard deviation less than the mean). Table 51 shows mean z-score differences of Pakistani infants relative to White British infants for each measurement adjusted for smoking; maternal height; maternal BMI; parity; gestational age; sex and living with a partner. To maintain statistical power, some variables that had no effect in the regression models for each birth size measurement (reported earlier in this chapter) were removed from the models (alcohol; maternal age; maternal diabetes; maternal hypertension; SEP). Differences were least for triceps and subscapular measurements and greatest for birthweight. This pattern was generally maintained across all the generation groups although where the baby's mother is South Asian born and father UK born (Mum only group), mean z-score differences with White British infants for both subscapular and triceps skinfold thickness are notably larger than the equivalent differences for any other group. Once differences in birthweight between Pakistani and White British origin infants were accounted for, mean z-score differences for all measurements were reduced but remained negative differences for head and abdominal circumference. For mid-upper arm circumference and both skinfold thickness measurements, differences generally became positive thus suggesting that despite being smaller and lighter, Pakistani infants are relatively more adipose than White British origin infants.

Table 51 Adjusted mean z-score differences* for Pakistani infants relative to White British infants (95% CI) for all anthropometric measurements

	Birthweight	Head circumference	Abdominal circumference	Mid-upper arm circumference	Subscapular skinfold	Triceps skinfold
Pakistani (All)	-0.44 (0-.51, -0.37)	-0.32 (-0.40, -0.24)	-0.48 (-0.56, -0.40)	-0.23 (-0.31, -0.15)	-0.21 (-0.30, -0.12)	-0.20 (-0.29, -0.11)
Neither**	-0.37 (-0.50, -0.23)	-0.26 (-0.41, -0.10)	-0.39 (-0.54, -0.24)	-0.19 (-0.35, -0.04)	-0.11 (-0.28, 0.05)	-0.13 (-0.30, 0.03)
Dad only**	-0.46 (-0.56, -0.36)	-0.29 (-0.40, -0.19)	-0.47 (-0.58, -0.37)	-0.16 (-0.27, -0.05)	-0.23 (-0.35, -0.11)	-0.17 (-0.29, -0.05)
Mum only**	-0.48 (-0.58, -0.37)	-0.37 (-0.48, -0.25)	-0.54 (-0.66, -0.42)	-0.32 (-0.44, -0.20)	-0.25 (-0.38, -0.12)	-0.30 (-0.43, -0.17)
Both**	-0.42 (-0.51, -0.32)	-0.32 (-0.42, -0.21)	-0.45 (-0.56, -0.34)	-0.26 (-0.36, -0.15)	-0.19 (-0.31, -0.07)	-0.19 (-0.31, -0.07)
Other**	-0.44 (-0.58, -0.30)	-0.38 (-0.54, -0.23)	-0.51 (-0.67, -0.36)	-0.27 (-0.43, -0.11)	-0.20 (-0.37, -0.03)	-0.25 (-0.37, -0.03)

** Adjusted for gestational age; sex; smoking; maternal height; maternal BMI; parity; living with a partner*
***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

Table 52 Adjusted mean z-score differences* for Pakistani infants relative to White British infants (95% CI) for all anthropometric measurements with further adjustment for birthweight

	Head circumference	Abdominal circumference	Mid-upper arm circumference	Subscapular skinfold	Triceps skinfold
Pakistani (All)	-0.10 (-0.17, 0.03)	-0.28 (-0.35, -0.21)	0.01 (-0.06, 0.08)	0.02 (0.06, 0.10)	0.04 (-0.04, 0.12)
Neither**	-0.05 (-0.18, 0.09)	-0.22 (-0.36, -0.09)	0.02 (-0.11, 0.15)	0.09 (-0.06, 0.24)	0.08 (-0.06, 0.23)
Dad only**	-0.06 (-0.16, 0.03)	-0.27 (-0.37, -0.17)	0.09 (0.00, 0.19)	0.01 (-0.10, 0.11)	0.07 (-0.03, 0.18)
Mum only**	-0.14 (-0.24, -0.04)	-0.34 (-0.45, -0.23)	-0.06 (-0.16, 0.03)	0.01 (-0.12, 0.11)	-0.05 (-0.16, 0.06)
Both**	-0.10 (-0.20, -0.01)	-0.26 (-0.36, -0.17)	0.02 (-0.11, 0.10)	0.02 (0.08, 0.13)	0.03 (-0.07, 0.14)
Other**	-0.15 (-0.29, -0.01)	-0.30 (-0.43, -0.16)	0.01 (-0.12, 0.14)	0.05 (-0.10, 0.20)	0.05 (-0.10, 0.20)

** Adjusted for gestational age; sex; smoking; maternal height; maternal BMI; parity; living with a partner & birthweight*

***Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

6.3.2 Subscapular to triceps ratio (SS/TR)

Subscapular to triceps ratios (SS/TR) were calculated to assess regional differences in adiposity. I used linear regression models to estimate mean SS/TR ratio differences adjusting for a number of factors that could potentially explain or mask any difference. As discussed above if greater relative adiposity in Pakistani infants is particularly centrally distributed then the subscapular to triceps ratio should be greater in Pakistani compared to White british infants once birthweight is taken into account. These results show little difference in SS/TR between White British and Pakistani infants (Table 53) suggesting that despite greater overall adiposity, these Pakistani infants are not necessarily more centrally adipose.

Table 93 Mean subscapular to triceps ratio by ethnic and generation group* and Pakistani mean SS/TR differences relative to White british infants

	Number	Unadjusted mean SS/TR ratio (sd)	Unadjusted mean SS/TR ratio difference from White British (95% CI)	Adjusted mean SS/TR ratio difference** from White British (95% CI)	Adjusted mean SS/TR ratio difference with further adjustment for birthweight*** (95% CI)
White British	1285	0.92 (0.15)			
Pakistani (All)	1723	0.92 (0.14)	0.00 (-0.01, 0.01)	0.00 (-0.02, 0.01)	0.00 (-0.01, 0.01)
Neither	176	0.93 (0.15)	0.01 (-0.01, 0.03)	0.01 (-0.02, 0.04)	0.01 (-0.02, 0.02)
Dad only	457	0.92 (0.15)	-0.01 (-0.02, 0.01)	-0.01 (-0.03, 0.01)	0.01 (-0.03, 0.01)
Mum only	409	0.93 (0.13)	0.01 (-0.01, 0.02)	0.00 (-0.02, 0.02)	0.01 (-0.01, 0.03)
Both	520	0.92 (0.15)	0.00 (-0.01, 0.02)	0.00 (-0.02, 0.01)	0.00 (-0.02, 0.02)
Other	161	0.92 (0.14)	0.00 (-0.02, 0.02)	0.00 (-0.03, 0.02)	0.00 (-0.03, 0.03)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*
*** Adjusted for gestational age; sex; smoking; maternal height; maternal BMI; parity; living with a partner*
** **Adjusted for gestational age; sex; smoking; maternal height; maternal BMI; parity; living with a partner & birthweight*

6.3.3 Cord blood leptin concentration

Anthropometric measurements (described above) were used in this thesis to explore differences in birth size and adiposity between White British and Pakistani origin infants. As discussed in Chapters 2 and 4 circumference and skinfold measurements are characteristically less reliable than for example, magnetic resonance imaging. However anthropometric estimates of percent body fat can be strengthened by measurement of the hormone leptin (a biomarker of fat mass).

Descriptive leptin analysis results are reported in Chapter 5. Here, regression analyses including factors reported to influence cord blood leptin values are shown. Leptin data were positively skewed (see Chapter 5) therefore transformed variables were used in the regression analysis and comparisons between ethnic and generation groups are presented as ratios of geometric means (null value = 1).

As discussed in Chapter 2, it is reported that cord leptin may be influenced by sex, gestation and mode of delivery. The proportion of males and females in this leptin sub-sample was almost the same in each ethnic group (White British males 51%; Pakistani males 50%) and gestational length was similar in the two ethnic groups. Mean gestation for White British infants with a leptin sample was 39.5 weeks (sd 1.18) compared with 39.4 weeks (sd 1.16) among Pakistani infants however adjusting for gestation had no effect.

There is some uncertainty regarding the effect of mode of delivery on cord blood leptin concentration but for the sub-sample as a whole, there was only a slight difference in leptin levels by mode of delivery (Table 54). However, when comparisons were made by ethnic group, leptin varied considerably by mode of delivery in White British infants. Cord blood leptin levels were 23% higher in those delivered by caeasarean section (LSCS) compared to those who underwent a vaginal delivery (ratio of geometric means 1.23 95% CI 1.06, 1.43). A difference was not seen in Pakistani infants for whom mode of delivery had little effect on leptin levels (ratio of geometric means 0.97 95% CI 0.84, 1.15).

Table 54 Cord blood leptin concentration (ng/ml) by mode of delivery. Values are geometric means (95% CI)

Ethnic group *(number with leptin sample)*	**Vaginal delivery n (%)**	**Vaginal delivery Geometric mean (95% CI)**	**LSCS n (%)**	**LSCS Geometric mean (95% CI)**	**Comparison* (95% CI)**
White British *(n=613)*	468 (76)	5.88 (5.47, 6.31)	145 (24)	7.23 (6.25, 8.35)	1.23 (1.06, 1.43)
Pakistani *(n=775)*	623 (80)	6.88 (6.46, 7.33)	152 (20)	6.68 (5.78, 7.72)	0.97 (0.84, 1.15)
All *(n=1388)*	1091 (79)	6.43 (1.81, 1.91)	297 (21)	6.94 (1.84, 2.04)	1.08 (0.97, 1.20)

*Ratio of geometric means

Tables 55 and 56 present ratios of geometric means for cord leptin values by ethnic and generation group before and after adjustment for potential explanatory / mediating variables. As with the z-score data presented above, a number of variables that had no effect on the mean difference for Pakistani infants relative to White British infants for birth size measurements were excluded from the regression model to maintain statistical power (alcohol; maternal age; maternal glycaemia;

maternal hypertension; SEP). As there is some evidence to suggest an association between mode of delivery and cord leptin values in White British infants, this variable was included in the regression model. The number of participants with complete data on each potential explanatory / mediating factor varied and was smallest for the subgroup with complete data on maternal BMI (n=1268). The unadjusted ratio of geometric means was slightly smaller for this subgroup than the other subgroups and consequently the ratio of geometric means was lower for the subgroup with data on all important variables. On the whole there is no evidence of selection bias however, missing maternal BMI data may have resulted in some bias leading to a slight underestimation of the differences.

In unadjusted analyses, cord leptin concentrations were on average 11% greater in Pakistani compared to White British infants (ratio of geometric means 1.11 95% CI 1.02, 1.21). Adjustment for maternal height, gestational age, sex and mode of delivery had almost no effect on this association, but adjustment for smoking, parity and living with a partner, each explained (i.e. reduced) some of the difference (ratio of geometric means 1.06 95% CI 0.96, 1.17; 1.07 95% CI 0.98, 1.18 and 1.07 95% CI 0.98, 0.17 respectively) and maternal BMI masked (i.e. increased) some of the difference (ratio of geometric means 1.17 95% CI 1.06, 1.28). Differences in birthweight between the two ethnic groups had the greatest effect on the difference thus once these differences were accounted for, the ratio of geometric means increased to 1.35 (95% CI 1.25, 1.47). This association remained the same following full adjustment for all important explanatory / masking variables (ratio of geometric means 1.35 95% CI 1.23, 1.49) indicating that on average Pakistani infants have a cord blood leptin value 35% higher than White British origin infants (Table 56). It is likely that the explanatory / masking variables shown above to affect the difference in cord leptin values between Pakistani and White British infants (smoking; parity; living with a partner; maternal BMI), do so through their association with birthweight and the positive correlation between birthweight and cord leptin concentration (discussed in Chapter 2 and shown in Figure 72).

Each generation group had on average higher cord leptin values than the White British infants with the the exception of the Other group. The unadjusted ratio of geometric means for this group was close to 1 (null value) and remained close to 1 following adjustment for each explanatory / mediating factor with the exception of adjustment for birthweight where the ratio of geometric means increased to 1.29 (95% CI 1.08, 1.56) (Table 56). The unadjusted ratio of geometric means was similar for the Neither, Dad only and Mum only groups but was markedly higher for the Both group (both parents South Asian born). This probably reflects differences in mean birthweight between generation groups (for those with a leptin sample) as shown in Chapter 5 (Table 13). As described above adjustment for maternal height, gestational age, sex and mode of delivery had little effect on ethnic and generational differences in leptin values. Adjustment for smoking and living with a partner maintained a similar pattern across the generation groups (i.e. the effect of adjustment was similar in all generation groups). Adjustment for BMI increased the ratio of geometric means for all generation groups but the increase was greatest in the Neither, Mum only and Other groups and least for the Dad only group consistent with differences in mean BMI across generation groups, i.e. higher BMI is associated with higher birthweight which in turn is associated with higher leptin. Within this sample, BMI is higher among White British mothers, therefore removing the effect of BMI reduces leptin values among White British infants thus increasing the difference between Pakistani and White British infants. The effect of adjustment is greater for the generation groups with the lowest mean BMI (Neither, Mum only and Other groups) and least for the group with the highest mean BMI (Dad only group). By contrast, adjustment for parity decreased the ratio of geometric means due to on average higher parity among Pakistani mothers and a tendency for birthweight to increase with increasing parity (i.e. increasing parity is associated with higher birthweight and there is some correlation between birthweight and cord leptin concentration, Figure 72). Removing the effect of parity decreased the ratio of geometric means most in the Both group (the group with the highest proportion of para 3 or greater mothers) and least in the Other group (the group with the smallest proportion of para 3 or greater mothers).

In summary, these results suggest that cord blood leptin was markedly higher in Pakistani infants compared to White British infants supporting the hypothesis that despite having a lower birthweight, these infants are more adipose.

Figure 72 Correlation between cord leptin concentration and birthweight

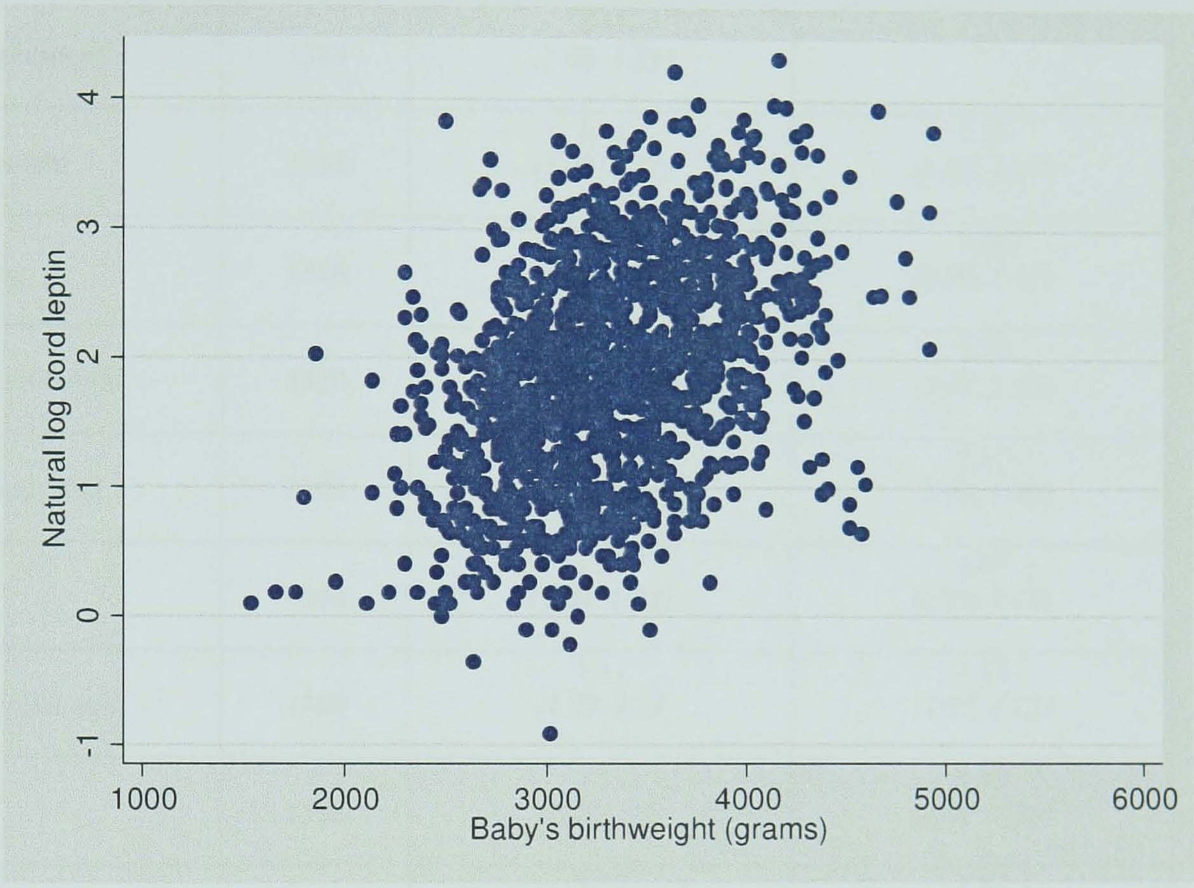


Table 55 Cord blood leptin concentration for Pakistani infants relative to White British infants with and without adjustment for potential explanatory / modifying variables (n= 1232 to 1388). Values are ratios of geometric means (95% CI)

Covariable	Number	Unadjusted ratio of geometric means *(95% CI)*	Adjusted ratio of geometric means *(95% CI)**
No adjustment	1388	1.11 *(1.02, 1.21)*	
Birthweight	1388	1.11 *(1.02, 1.21)*	1.35 (1.25, 1.47)
Smoking	1386	1.11 (1.02, 1.21)	1.06 (0.96, 1.17)
Maternal height	1380	1.10 (1.01, 1.20)	1.12 (1.01, 1.23)
Maternal BMI	1268	1.09 (0.99, 1.20)	1.17 (1.06, 1.28)
Parity	1348	1.11 (1.01, 1.21)	1.07 (0.98, 1.18)
Gestational age	1388	1.11 *(1.02, 1.21*	1.13 *(1.03, 1.23)*
Sex	1388	1.11 *(1.02, 1.21*	1.10 *(1.01, 1.20)*
Living with a partner	1384	1.11 (1.02, 1.21)	1.07 (0.98, 1.17)
Mode of delivery	1388	1.11 *(1.02, 1.21*	1.11 *(1.02, 1.21)*
All above covariables	1232	1.09 *(0.99, 1.19)*	1.35 *(1.23, 1.49)*

Table 56 Cord blood leptin concentration for Pakistani infants by generation* group relative to White British infants for each potential explanatory / modifying variable. Values are geometric means (95% CI)

Covariable	Number	Unadjusted ratio of geometric means *(95% CI)*	Adjusted ratio of geometric means** *(95% CI)*
No adjustment			
Neither	75	1.09 (0.90, 1.33)	
Dad only	211	1.07 (0.94, 1.22)	
Mum only	174	1.07 (0.93, 1.23)	
Both	245	1.20 (1.07, 1.36)	
Other	70	1.01 (0.83, 1.24)	
Birthweight			
Neither	75	1.09 (0.90, 1.33)	1.32 (1.10, 1.57)
Dad only	211	1.07 (0.94, 1.22)	1.31 (1.17, 1.48)
Mum only	174	1.07 (0.93, 1.23)	1.34 (1.18, 1.53)
Both	245	1.20 (1.07, 1.36)	1.41 (1.27, 1.58)
Other	70	1.01 (0.83, 1.24)	1.29 (1.08, 1.56)
Smoking			
Neither	75	1.09 (0.90, 1.33)	1.05 (0.86, 1.28)
Dad only	210	1.08 (0.95, 1.23)	1.04 (0.91, 1.19)
Mum only	173	1.06 (0.92, 1.22)	1.01 (0.88, 1.17)
Both	245	1.20 (1.07, 1.36)	1.15 (1.01, 1.31)
Other	70	1.01 (0.83, 1.24)	0.98 (0.80, 0.99)
Maternal height			
Neither	74	1.10 (0.90, 1.34)	1.11 (0.91, 1.35)
Dad only	211	1.07 (0.94, 1.22)	1.08 (0.95, 1.24)
Mum only	173	1.07 (0.93, 1.23)	1.08 (0.94, 1.25)
Both	242	1.20 (1.06, 1.35)	1.21 (1.06, 1.38)
Other	69	1.00 (0.81, 1.22)	1.01 (0.82, 1.24)
Maternal BMI			
Neither	68	1.10 (0.89, 1.36)	1.23 (1.00, 1.51)
Dad only	196	1.05 (0.92, 1.36)	1.09 (0.95, 1.24)
Mum only	155	1.03 (0.89, 1.20)	1.15 (1.00, 1.33)
Both	221	1.20 (1.05, 1.36)	1.27 (1.12, 1.43)
Other	67	0.98 (0.80, 1.21)	1.06 (0.87, 1.31)
Parity			
Neither	72	1.10 (0.90, 1.34)	1.08 (0.88, 1.32)
Dad only	204	1.07 (0.94, 1.22)	1.05 (0.92, 1.19)
Mum only	167	1.07 (0.93, 1.23)	1.04 (0.91, 1.19)
Both	238	1.20 (1.06, 1.35)	1.15 (1.01, 1.31)
Other	69	1.01 (0.83, 1.24)	1.00 (0.81, 1.22)
Gestational age			
Neither	75	1.09 (0.90, 1.33)	1.12 (0.93, 1.37)
Dad only	211	1.07 (0.94, 1.22)	1.08 (0.95, 1.23)
Mum only	174	1.07 (0.93, 1.23)	1.07 (0.94, 1.23)
Both	245	1.20 (1.07, 1.36)	1.23 (1.09, 1.38)
Other	70	1.01 (0.83, 1.24)	1.05 (0.86, 1.28)

Covariable	Number	Unadjusted ratio of geometric means *(95% CI)*	Adjusted ratio of geometric means** *(95% CI)*
Sex			
Neither	75	1.09 (0.90, 1.33)	1.11 (0.92, 1.35)
Dad only	211	1.07 (0.94, 1.22)	1.09 (0.96, 1.23)
Mum only	174	1.07 (0.93, 1.23)	1.05 (0.92, 1.20)
Both	245	1.20 (1.07, 1.36)	1.19 (1.06, 1.34)
Other	70	1.01 (0.83, 1.24)	0.98 (0.80, 1.19)
Living with a partner			
Neither	74	1.10 (0.90, 1.34)	1.07 (0.87, 1.30)
Dad only	211	1.07 (0.94, 1.22)	1.04 (0.91, 1.19)
Mum only	173	1.07 (0.93, 1.23)	1.03 (0.90, 1.19)
Both	244	1.20 (1.06, 1.36)	1.16 (1.03 91.32)
Other	70	1.01 (0.83, 1.24)	1.00 (0.81, 1.22)
Mode of delivery			
Neither	75	1.09 (0.90, 1.33)	1.10 (0.90, 1.33)
Dad only	211	1.07 (0.94, 1.22)	1.07 (0.94, 1.22)
Mum only	174	1.07 (0.93, 1.23)	1.08 (0.94, 1.24)
Both	245	1.20 (1.07, 1.36)	1.20 (1.07, 1.36)
Other	70	1.01 (0.83, 1.24)	1.02 (0.84, 1.26)
All above covariables			
Neither	66	1.09 (0.90, 1.33)	1.39 (1.17, 1.64)
Dad only	190	1.07 (0.94, 1.22)	1.35 (1.20, 1.51)
Mum only	148	1.07 (0.93, 1.23)	1.33 (1.18, 1.50)
Both	213	1.20 (1.07, 1.36)	1.43 (1.29, 1.59)
Other	66	1.01 (0.83, 1.24)	1.30 (1.09, 1.55)

**Neither=Both parents UK born; Dad only=Father South Asian born, mother UK born; Mum only=Mother South Asian born, father UK born; Both=Both parents South Asian born; Other=All other categories*

6.4 Sensitivity analysis

6.4.1 The potential effect of lower measurement reliability

Given the lower reliability for one of the BiB study administrators, analyses (the final fully adjusted models) were repeated for subscapular and triceps skinfold thickness (study administrators only measured skinfold thickness) with infants measured by this individual removed. None of the results differed with these exclusions with the exception of the subscapular skinfold mean difference for the Mum only group where the mean difference having excluded Administrator 7 measurements appeared to reduce, however this was essentially due to rounding and when presented to 2 decimal points the repeated mean difference (minus Administrator 7) is in fact more or less the same (-0.24 95% CI -0.42, -0.07) as the full sample mean difference (-0.25 95% CI -0.42, -0.08). Table 57 shows the ethnic and generational differences for subscapular and triceps skinfold thickness with infants measured by administrator 7 removed in the first column and with administrator 7 included in the second column.

Table 57 Adjusted mean skinfold measurement differences (mm) by ethnic and generation group relative to White British infants with Administrator 7 measurements removed / included

	Adjusted* mean Subscapular skinfold difference (95% CI) relative to White British infants by ethnic & generation group with Administrator 7 measurements removed (n=2543)	Adjusted* mean Subscapular skinfold difference (95% CI) relative to White British infants by ethnic & generation group with Administrator 7 measurements included (n=2704)
Pakistani (All)	-0.2 (-0.3, -0.1)	-0.2 (-0.3, -0.1)
Neither	-0.1 (-0.3, 0.0)	-0.1 (-0.3, 0.1)
Dad only	-0.2 (-0.4, -0.1)	-0.2 (-0.4, -0.1)
Mum only	-0.2 (-0.4, -0.1)	-0.3 (-0.4, -0.1)
Both	-0.2 (-0.3, 0.0)	-0.2 (-0.3, 0.0)
Other	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
	Adjusted* mean Triceps skinfold difference (95% CI) relative to White British infants by ethnic & generation group with Administrator 7 measurements removed (n=2554)	**Adjusted* mean Triceps skinfold difference (95% CI) relative to White British infants by ethnic & generation group with Administrator 7 measurements included (n=2715)**
Pakistani (All)	-0.2 (-0.3, -0.8)	-0.2 (-0.3, -0.1)
Neither	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)
Dad only	-0.2 (-0.3, 0.0)	-0.2 (-0.4, -0.1)
Mum only	-0.3 (-0.5, -0.1)	-0.3 (-0.5, -0.2)
Both	-0.2 (-0.3, 0.0)	-0.2 (-0.4, -0.1)
Other	-0.2 (-0.4, 0.0)	-0.2 (-0.4, 0.0)

**Adjusted for smoking; alcohol; maternal age; maternal hypertension; maternal existing or gestational diabetes; maternal height; maternal BMI; parity; gestation; sex; socioeconomic position; living with partner*

6.4.2 The effect of migration to the UK age 5 or under

Patterns of migration suggest a substantial number of South Asians migrate to the UK in childhood. Early data from the BiB cohort (discussed in Chapter 2) suggests that around 11% of mothers who stated they were born in Pakistan, moved to the UK before they reached school age (age 5 or under) therefore much of their childhood and development took place in the UK which could dilute any differences between the two generations (i.e. if we assume that maternal exposure to a UK environment during childhood might increase offspring birthweight, categorising those mothers who migrated at age 5 or under as South Asian born could reduce any difference between the two groups). In fact, removing these mothers from the South Asian born group marginally increased (rather than decreased) mean birthweight in this group (Table 58). Likewise, moving those mothers recorded as South Asian born but who migrated to the UK age 5 or under (n=141) into the UK born group reduced mean birthweight in this group. Mean birthweight among the 141 Pakistani mothers who migrated to the UK age 5 or under was markedly lower (3140g sd 468) than mean birthweight for infants of all UK born mothers (3193 sd 441) and also infants of all South Asian born mothers, suggesting no benefit in terms of offspring birthweight, from early childhood migration.

Table 58 Mean birthweight (g) of Pakistani infants according to mothers country of birth and age at migration to the UK

	Mean birthweight (sd)		Mean birthweight (sd)
All South Asian born Pakistani mothers (n=1260)	3193 (470)	**SA born Pakistani mothers excluding those who migrated to the UK age 5 or under (n=1119)**	**3200 (471)**
All UK born Pakistani mothers (n=937)	3193 (441)	**UK born Pakistani mothers and those South Asian born who migrated to the UK age 5 or under (n=1078)**	**3186 (444)**

**Total of 2221 Pakistani mothers in the study sample, 24 Pakistani mothers were born outside the UK or South Asia*

6.5 Summary

The analyses presented in this chapter have provided a detailed examination of ethnic differences in birth size. They describe marked differences in birthweight and other size measurements between Pakistani origin and White British origin infants. The effect of adjustment for potential explanatory / masking factors varied. Maternal height, maternal BMI and gestational age of the infant all explained some of the difference whilst smoking, parity and living with a partner all masked some of the difference. All other potential confounders had little or no effect and in general, this pattern was seen across all Pakistani generation groups. Overall, adjustment reduced the mean difference between Pakistani and White British origin infants across all measurements and all generation groups but important differences remained with no consistent evidence that differences reduce if mothers, fathers or both parents are born in the UK. Mean z-scores for all measurements were lower for Pakistani infants compared to White British origin infants but differences were least for MUA circumference and subscapular and triceps skinfold thickness measurements. Once differences in birthweight were accounted for, mean z-score differences for MUA, subscapular and triceps skinfold thickness became slightly positive. These findings, along with markedly higher cord leptin concentrations among Pakistani infants, suggest that despite their smaller size, Pakistani origin infants are more adipose relative to White British infants. The results presented in this chapter are discussed in more detail in the following Chapter (7).

Chapter 7
Discussion

This thesis has presented findings from analyses of differences in birth size between infants of Pakistani origin and White British origin infants. This has included a comprehensive exploration of potential mediating and masking characteristics and an in depth analysis across successive generations of migrant UK Pakistanis which took account of both maternal and paternal ancestry. This chapter reviews my overall findings, the methodological strengths and limitations of this study and its contribution to our understanding of ethnic variations in birth size and adiposity. First, I summarise the results reported in Chapters 5 and 6 and review these findings in the context of existing evidence. Second, the strengths and limitations of the study are discussed. Third, I consider the contribution of these findings to practice and further research.

7.1 Birth size differences between White British and Pakistani origin infants

7.1.1 Birthweight

In unadjusted analyses there were marked differences in birthweight between Pakistani and White British origin infants. Pakistani infants weighed on average 228g less than White British infants at birth. Maternal height, BMI and gestational age explained some of this difference, with adjustment for these characteristics resulting in some attenuation. Maternal smoking, parity and living with a partner, masked some of the difference such that adjustment for these characteristics enhanced some of the difference. The direction of change in the birthweight difference with adjustment for these characteristics was as expected from their known (and shown in this study) associations with ethnicity and birthweight. Other characteristics that I examined did not appear to markedly alter birthweight differences between Pakistani and White British origin infants in this study. Most notably, adjustment for maternal diabetes had no effect on the difference in birthweight between the two groups, which given the robust association between maternal glycaemia and greater adiposity and birth size (Ovanovic and Pettitt, 2001, Catalano et al., 2003, HAPO Study Co-operative Research Group, 2008) and also the established difference in gestational diabetes risk between women of South Asian and European origin (Dornhurst et al., 1992, Oldfield et al., 2007), which I also found here, was surprising. I used a clinical record of diagnosed gestational diabetes, but in this study this was based on the results of a GTT that was offered to all participants and completed on over 90% of the cohort. However, given the association of maternal glucose (both fasting and postload) with offspring birth size is continuous across the whole distribution (HAPO Study Co-operative Research Group, 2008), it is possible that a simple dichotomy of diabetes in pregnancy or not is inadequate to fully adjust for ethnic differences in maternal glycaemia in the association with birthweight. The actual values of fasting and postload glucose from the GTTs of participants in BiB have not yet been incorporated into the main dataset and so I did not have access to these data for this PhD. In future analyses on the whole cohort I will adjust for fasting and postload glucose as continuous variables (see below). Pakistani origin mothers had on average, a lower BMI than White British mothers and lower BMI is associated with lower birthweight. It is possible that the combined effect of adjustment for BMI and gestational diabetes results in neither having a marked effect on the birthweight difference in this study, though when I adjusted just for diabetes in pregnancy there was no marked effect on birthweight differences. Overall, full adjustment reduced the mean birthweight difference between Pakistani and White British infants by 40g.

The difference in birthweight was generally similar between each of the different Pakistani generational groups and White British origin infants, ranging from 215g to 248g in unadjusted analyses. Infants whose fathers were South Asian born (irrespective of where the mother was born) were the groups with the smallest difference in birthweight compared to White British infants and those whose fathers were UK born had the biggest difference in unadjusted analyses. The effect of adjustment followed a similar pattern across generation groups with some exceptions where characteristics differed between groups. For example, adjusting for parity increased the mean difference for those generational groups with the highest mean parity (i.e. those where just one or both parents were South Asian born). Adjustment for maternal height, BMI, maternal age and gestational age all varied by generation group but again reflected differences in these characteristics across groups. Patterns of smoking and living with a partner were similar for all generation groups and therefore the effect of adjustment on birthweight differences was similar for each generation group. In contrast to the unadjusted mean differences, the adjusted mean birthweight difference relative to White British infants, was least for Pakistani infants whose parents were both born in the UK (163g 95% CI -227, -99) and greatest in those where just one parent was born in South Asia. Of interest, the difference was similar in these analyses whether the father was born in South Asia and the mother born in the UK (-203 95% CI -252, -155) or the mother was born in South Asia but the father was born in the UK (-202 95% CI -257, -147). The mean birthweight difference for infants born to parents who were both born in South Asia was -179 (95% CI -228, -130). As with unadjusted results the confidence intervals for these adjusted differences overlap and there is no evidence that they differ from each other. To test this further I used multiple linear regression to compare differences in each measurement between generation groups (using the neither group as the baseline). None of the mean differences were statistically significant (all confidence intervals crossed zero). Thus, whilst the point estimates suggest some differences by generational group, these are small, and overall I find no evidence in this study that birthweight differences between Pakistani and White British origin infants vary by whether the Pakistani origin infants are first or second generation (whether this is defined by maternal or paternal place of birth). These findings are consistent with most previous studies that have examined whether birthweight differences between South Asian and White British origin infants differ by generation of the South Asian groups (Draper et al., 1995, Leon and Moser, 2010, Harding et al., 2004) that I discussed previously in Chapter 2 (summarised in Table 3). However, it is worth noting that these studies have based generation classification on maternal place of birth only (i.e. UK born mothers are classified as second generation as shown in Table 6). If the same criteria were applied to the data reported here, the groups in which fathers were UK born (whether mothers were UK or South Asian born) would become one 'second generation' group (i.e. all mothers UK born). Whilst I have found no strong evidence that birthweight differs by the different generational groups relative to White British infants, there were differences in parental characteristics between different groups that would be lost by a more crude differentiation based on maternal place of birth only. For example, there were marked differences in receipt of benefits, consanguinity, maternal weight and BMI between UK born mothers with a UK born partner and UK born mothers with a South Asian born partner (see Chapter 5; Tables 36 and 37). Furthermore, the possible 30-40g greater difference in birthweight where either one parent is South Asian born (but not the other), compared to when both parents are South Asian born or both parents are UK born, would not be observed if maternal and paternal origin had not been separated. Whilst this study has insufficient power to definitely show that this is not due to chance, I feel it warrants further exploration. It is possible that the main drivers of birthweight differences are attenuated when the two parents have had very different early life experiences related to place of birth, than when these have been similar (irrespective of whether this similarity is both born in the UK or both born in South Asia).

7.1.2 Circumference and skinfold measurements

Indeed it has been suggested that nutritional deprivation in utero results in fat preservation in order to protect vital brain tissue and that related to this, in South Asian infants born at term but with significantly lower birth weights than European populations, head circumference is reportedly 'preserved' (Yajnik et al., 2003). Abdominal circumference (a surrogate for visceral size) and MUA circumference (an indicator of muscle mass) have been shown to be smaller in South Asians than White Europeans in line with lower birthweights (Yajnik et al., 2003) but crucially,

For all other birth size measurements (head, MUA and abdominal circumferences; subscapular and triceps skinfold thickness) Pakistani origin infants were smaller than White British infants. Unadjusted mean differences were generally similar across generation groups. Adjustment for potential explanatory or mediating factors largely followed similar patterns to those described above for birthweight. One notable exception to this was that adjusting for gestational age had no effect on MUA circumference and subscapular skinfold thickness differences, suggesting that differences in adiposity develop before the final few weeks of pregnancy. Full adjustment reduced mean differences relative to White British infants for head circumference and MUA circumference measurements but had little effect on abdominal circumference and both skinfold measurements. Variation between generation groups was minimal but adjusted mean differences were mostly smallest where both parents were UK born and largest when the mother was South Asian born. Previous studies of generation and birth size in UK South Asians (Dhawan, 1995, Draper et al., 1995, Margetts et al., 2002, Harding et al., 2004, Leon and Moser, 2010) have focused specifically on birthweight thus, it is difficult to compare the additional measures of birth size used here with existing analyses of generational differences in birth size. Such additional measures can provide more insight into what contributes to differences in birthweight. They can also contribute to debate about the underlying mechanisms for these ethnic differences as different patterns (for example, whether Pakistani infants are universally smaller, have a large head and small body, or are small but have a higher percent body fat) would support different hypotheses regarding possible mechanisms. Previous studies have compared such measurements between White British and South Asian populations (Yajnik et al., 2002, Yajnik et al., 2003) and have found significant differences (discussed further in the following section). However, whether these measurements change over generations has to my knowledge, not been reported. The data presented here suggest that Pakistani infants are smaller in all measurements with no indication that this changes depending on whether the parents are born in South Asia or the UK.

7.1.3 Differences in adiposity between White British and Pakistani origin infants

The differences in birth size described above between Pakistani and White British infants may mask greater adiposity in Pakistani origin infants. Therefore, in this thesis I have examined whether Pakistani origin infants are more centrally obese and have a greater proportion of fat mass at a given birthweight than White British babies. I used z-score differences for all measurements (to be able to compare each measure on the same scale and hence explore whether Pakistani infants had larger z-score differences for skinfold thicknesses than overall birthweight, indicating that they were relatively more adipose), subscapular/triceps ratio (to examine regional differences in adiposity) and cord leptin concentration (as a marker of total fat) to explore evidence that South Asian infants, despite being of lower birthweight, were more adipose in general and more centrally adipose specifically.

Mean z-score differences were least for triceps and subscapular measurements and greatest for birthweight. This pattern was mostly maintained across all the generation groups, although where the baby's mother was South Asian born and father UK born, mean z-score differences relative to White British infants for both subscapular and triceps skinfold thickness were notably larger than the equivalent differences for any other group (shown in Table 51). Once differences in birthweight between Pakistani and White British origin infants were accounted for (Table 52), mean z-score differences for all measurements were reduced but remained negative differences for head circumference and abdominal circumference. For mid-upper arm circumference and both skinfold thickness measurements, differences generally became slightly positive thus suggesting that despite being smaller and lighter, Pakistani infants are relatively more adipose than White British origin infants. Looking specifically at generation groups, there was only minimal variation between groups following adjustment for birthweight. These findings are consistent with recent results from the CHASE study (Whincup et al., 2010) which describe greater adiposity in UK South Asian schoolchildren compared with White European children (as indicated by a greater sum of skinfolds in South Asians). They are also similar to results reported by Yajnik (Yajnik et al., 2002) which found little difference in subscapular skinfold thickness between Indian infants born in Pune, India and White British infants born in London, UK once differences in birthweight were accounted for. Thus the findings reported here, along with previous work, all point to the liklihood that the thin-fat insulin resistant phenotype seen in South Asian adults is present at birth and persists in infants of UK born parents.

I found no difference in SS/TR ratio between Pakistani and White British infants both before and after adjustment for birthweight. This suggests that despite greater overall adiposity, Pakistani infants are not more centrally adipose and somewhat contradicts previous findings that pointed to greater adiposity being specifically centrally distributed at birth (Yajnik et al., 2002), although these findings were based on z-score differences in triceps and subscapular skinfold measurements and the SS/TR ratio was not reported. It should be noted that the SS/TR ratio is an indirect measure of central fat patterning and is limited to two skinfold measurements (i.e. excluding abdominal and thigh skinfolds that might further distinguish between central and peripheral fat) (Malina et al., 1988). Furthermore, centrally deposited subcutaneous fat (which is what skinfolds measure) may not be the most toxic form of fat; this could be visceral/liver fat deposition which requires assessment by MRI for example, which would be difficult in a large epidemiological study.

Cord blood leptin (measured on a sub-sample of 1838 infants) was markedly higher among Pakistani infants compared to White British infants. Unadjusted values were on average 11% greater in Pakistani compared to White British infants. Adjustment for maternal height, gestational age, sex and mode of delivery had almost no effect on this association, but adjustment for smoking, parity and living with a partner, each explained (i.e. reduced) some of the difference and maternal BMI masked (i.e. increased) some of the difference. Differences in birthweight between the two ethnic groups had the greatest effect on the difference and following adjustment for all characteristics including birthweight, Pakistani infants had a cord leptin value on average 35% higher than White British infants (ratio of geometric means 1.35 95% CI 1.23, 1.49) (Table 55). It is likely that the explanatory / masking variables found to affect the difference in cord leptin values between Pakistani and White British infants (smoking; parity; living with a partner; maternal BMI), did so through their association with birthweight and the positive correlation between birthweight and cord leptin concentration (discussed in Chapter 2 and Chapter 6). Overall, my findings (positive mean skinfold z-score differences; markedly higher cord leptin concentration) suggest that infants of Pakistani origin have a tendency for greater total body fat than those of White British origin which is consistent with previous findings for adiposity at birth (Yajnik et al., 2002), and also in childhood (Nightingale et al., 2010) and adulthood (McKeigue et al., 1991). My findings add importantly to the one previous study exploring whether the ethnic difference in body fat found in several studies of South Asian and white European origin adults, is present at birth. This study is considerably larger than the previous study and also compares Pakistani origin infants to White British origin infants who were all born in the UK, indeed in the same maternity unit, and so controls for possible differences that may occur between births in a South Asian country and these in the UK.

7.1.4 Differences in explanatory and mediating characteristics between White British and Pakistani origin populations

No previous study of differences in birth size (including generation of migration) between South Asian and White British origin infants has included the wide-ranging explanatory or mediating factors reported in this thesis (gestation; smoking; alcohol; maternal age; parity; maternal size, maternal diabetes, maternal hypertensive disorders; sex; socioeconomic factors). I found noticeable differences in pregnancy, behaviour and socioeconomic characteristics between Pakistani origin and White British origin mothers which, as described above, had varying effects on the associations between ethnicity, generation and birth size. Briefly, Pakistani origin mothers were on average older, shorter and had a lower mean BMI. Pakistani mothers were more likely to be married but less likely to be in employment (Table 38) and it was striking that 36% of Pakistani mothers did not know their household income (compared to 6% of White British mothers) which raises the question of how to accurately measure some socioeconomic markers in this population. Consistent with previous reports (Hawkins et al., 2008, Health Survey for England 2004, 2006) smoking and alcohol consumption were uncommon among Pakistani mothers. There were some differences between generation groups. Most notably, maternal height was on average slightly higher when mothers were UK born (irrespective of where their partner was born) suggesting that there may be some generational shift in maternal height (Table 37). Interestingly, BMI was higher in mothers whose partners were born in South Asia, irrespective of whether the mother herself was born in the UK or South Asia, compared with all other groups, suggesting that partners place of birth (and hence his background culture and extent of acculturation) has an important impact on mothers lifestyle and BMI. I found some evidence for greater acculturation among UK born Pakistani mothers. A higher proportion of UK born Pakistani mothers were in employment and smoked and this was regardless of paternal generation (i.e. the Neither and Dad only groups). In some situations, characteristics differed according to paternal generation for example, there was a tendency for higher household income and lower partiy among UK born mothers with a UK born partner (Neither group) compared to UK born mothers with a South Asian born partner (Dad only group). At this stage, these remain subtle changes and are unlikely to have any significant bearing on ethnic differences in size but they demonstrate that acculturation triggers both improving health (better socioeconomic circumstances) and worsening health behaviours (smoking).

These findings underline the subtle lifestyle differences between these groups which are somewhat hidden when generation is based solely on maternal place of birth. They require further replication in other studies, but if replicated could be important for the development of public health interventions. For example, there are increasing concerns regarding the prevalence of overweight and obesity amongst women of reproductive age. It is possible that in some groups lifestyle advice to counter this might need to include partners as well as the women themselves.

7.1.5 Summary of findings

I have confirmed the marked difference in birthweight between South Asian origin (in this thesis Pakistani origin) and White British origin infants, which persists even after adjustment for a wide range of potential masking and mediating characteristics, that has been previously reported in other studies. My results suggest that important differences exist whether both parents are UK born, one is South Asian born or both are South Asian born, suggesting that at least over two generations, environmental or lifestyle changes amongst parents who have migrated to the UK and spent all of their life here have not had a major impact on these differences. The suggestion that the difference in birth size might be greatest for those whose parents have different places of birth (irrespective of whether this is the mother or father who is South Asian born and the other UK born) compared to those who are either both UK born or both South Asian born is novel, but requires exploration in larger studies as the magnitude of these differences was small in this study and there was no strong statistical evidence that birth size did differ by parental place of birth. I have found evidence that despite their smaller birthweight, South Asian infants have more total body fat than White British infants, which has important implications for any public health interventions aimed at increasing birthweight in South Asian infants, as this could result in greater body fat and ultimately poorer cardiometabolic health.

7.2 Strengths and limitations

The strengths of this study which support the reliability and validity of my results and the limitations that need to be considered when interpreting the findings, are described below.

7.2.1 Strengths

The data presented here were taken from the BiB cohort study data set. BiB achieved a recruitment rate of 87% which is similar to consistent with other local birth cohorts based in a city or small geographical area (Golding, 2004, Plewis, 2007). An evaluation of the representativeness of the cohort (presented in Chapter 5) showed that the study cohort is likely to accurately reflect the population of Bradford. I have shown, with the data currently available, that the sample used in this thesis (n=4221) is representative of the BiB cohort as a whole. Anthropometric measurements were completed on around 75% of infants in the BiB cohort and the data set used here. The maternal questionnaire collected comprehensive ancestry data including paternal generation, which allowed me to go a step further than previous studies by identifying a paternal bearing on acculturation. In addition, detailed information on a large number of potential explanatory and masking factors was obtained. When analyses were completed on maximal subgroups there was no evidence that missing data resulted in any bias in results restricted to those with complete data.

A further strength of this study was that it utilised routinely collected clinical data and on the whole, this was shown to be reliable (reported in Chapter 4). My findings that data good enough for clinical practice are good enough for research, have important implications for future epidemiological research, particularly in terms of avoiding costly duplication of data collection. Key strengths of this study are also its unique contribution to this area of research. As noted earlier, this is the first study to explore generational differences using place of birth of both the mother and father. Indeed, we collected grandparental place of birth information, but found too little variation in this to be able to examine its effect on ethnic differences. I have also been able to adjust for a much wider range of mediating and masking characteristics than in previous studies and to my knowledge, this is the first study to examine whether infants of South Asian origin are more adipose than those of white European origin, in a sample who are all born in the same country and indeed the same hospital. This is also by far the largest study to examine whether the thin-fat (high fat, low weight) South Asian phenotype is present at birth.

7.2.2 Limitations

It was disappointing that only a small number of grandparents were UK born. This meant that the analyses were restricted to two generations rather than three, as had been planned at the start of the study. This likely reflects the persistence of cultural practices within this community, such as a tendency for UK born individuals to marry a partner from South Asia. Indeed, the relatively small proportion of Pakistani origin infants with both parents born in the UK supports this assertion. Whilst this made it impossible for me to explore whether the greater time spent in the UK across generations (i.e. with at least 3 generations UK born) reduced ethnic differences, the collection of grandparental place of birth and the detailed analyses I did to ascertain the proportion of participants in each generational group, is useful for local policy. It suggests that certainly within Bradford, despite a strong presence for many decades, the South Asian population includes a substantial proportion who are new migrants. This is likely to be important for planning of acute health services and public health interventions.

A further limitation of this study was the use of two variables with potentially incomplete data. Analysis for this thesis was undertaken whilst data collection, linking and cleaning for the BiB study as a whole was ongoing. As a result, data for maternal existing or gestational diabetes and maternal hypertension may not have been complete and could potentially have underestimated the number of cases.

Local statistics suggest that around 5% of pregnancies are complicated by gestational diabetes in Bradford (BTHNHST audit data), which is similar to the prevalence (4%) found in this study sample. As noted above, I have used a binary variable (i.e. a clinical diagnosis of diabetes or not) but increases in birthweight as a result of hyperglycaemia, occur on a continuum with no clear cut-off point denoting increased risk (HAPO Study Co-operative Research Group, 2008) thus, here I may not have fully adjusted for hyperglycaemia. However, glucose tolerance tests were obtained on around 94% of BiB participants and whilst at the time of my analysis these data were unavailable, it is anticipated that any future publications arising from this thesis will include GTT results (i.e. a continuous measure of fasting and postload glucose) in the multiregression analyses. In Chapter 5 existing diabetes cases and gestational diabetes cases are presented separately, however due to small numbers of existing cases (less than 1% in both ethnic groups) it was necessary to combine the two for the multiple regression models. Likewise, in Chapter 5 maternal hypertension data is presented in two categories; any hypertension and pre-eclampsia. However, there was some inconsistency across the two categories (some cases of pre-eclampsia were recorded as not having hypertension) and it was not possible to clearly define who had existing hypertension, gestational hypertension, pre-eclampsia and pre-eclampsia superimposed on existing hypertension. Therefore the broad variable of any hypertension was included in the regression analyses, but with a more detailed categorisation it is possible I would have noted ethnic differences in these and adjusting for them may have resulted in some effect on birthweight differences. For example, there is evidence that pre-eclampsia, but not getstaional hypertension, is associated with lower birthweight (Geelhoed et al., 2010).

The absence of birth length as a measure of infant size is a further limitation of this study and limits comparisons with other populations and studies of birth size. Birth length is no longer recorded in the UK during routine physical examinations of the newborn (National Screening Committee 2008) and can be difficult to measure accurately when infants are moving or distressed. As a consequence, paediatricians in Bradford were not willing to record length as an additional measure within the newborn examination. Due to the short postnatal hospital stay of most mothers and the demands of other screening and health checks prior to discharge, it was not considered appropriate for BiB study administrators to record length. However, crown/heel ultrasound measurements will be available for the BiB cohort as a whole once data linkage and cleaning has been completed.

At the time of my analyses, data relating to attendance for antenatal care were not available. There is some evidence of an association between attendance for antenatal care and risk of low birthweight although I could not find any evidence that attendance for antenatal care varies between South Asian and White British women (as discussed in Chapter 2). Thus, my inability to adjust for this characteristic is unlikely to have importantly biased my findings.

This study highlighted how some socioeconomic indicators may be problematic when examining differences between ethnic groups. Differences in levels of missing data by ethnic group and/or important differences by ethnicity in the meaning of some indicators of ethnicity may mean that residual confounding by socioeconomic position is particularly problematic in studies of ethnic differences. In this study, around half of South Asian born mothers did not know their household income (Table 36) which means that using this particular indicator alone could be problematic. Parental educational attainment is also problematic as it is difficult to know whether completion of secondary education in Pakistan is comparable to completion of secondary education in the UK. One way to reduce the potential for residual confounding is to use multiple indicators of socioeconomic position as has been recognised elsewhere (Kelly et al., 2008). The BiB study collected data for a range of socioeconomic markers (maternal and paternal education; housing tenure; receipt of means tested benefits) for which there was little missing data and the amount was similar between different ethnic/generational groups. Therefore, although some residual confounding may remain (for example due to differences in interpretation between different groups), I feel that I have adjusted for socioeconomic position more fully than other studies examining ethnic differences in birth size.

7.4 Contribution to practice

The results reported in this thesis show marked differences in birth size between Pakistani origin and White British origin infants that remain after adjustment for mediating and masking variables and persist in later generations of UK migrants. Whilst the persistence of this difference despite adjustment and across two generations might be interpreted as supporting a genetic basis for this difference, caution is needed with this conclusion. As noted above, there is evidence that the Pakistani community in Bradford have maintained very strong links with Pakistan and UK born Pakistani adults tend to marry South Asian born partners, thus there may have been little change in lifestyles towards that of the UK community and hence lifestyle (environmental) differences could still explain these differences. In relation to this, it is increasingly suggested (although to date with limited evidence) that environmental characteristics, particularly during key stages of development, affect gene expression through DNA methylation and histone modification (epigenetic effects) (Ying Li, et al., 2010), and so lifestyle characteristics may interact with genetic variation to influence birth size differences. The suggestion that non-genetic characteristics explain at least some of the ethnic differences found here is important as genetic variation is currently not modifiable and this is likely to be the case for many decades. That said the characteristics reported here to influence the ethnic difference in size are mostly not modifiable and even where they could be influenced by behaviour change, the change could be detrimental. For example, smoking, parity and living with a partner all masked some of the difference between Pakistani and White British infants and whilst it is clearly advantageous for White British mothers not to smoke (and for Pakistani women not to take it up in larger numbers), this would only increase the difference in birth size between the ethnic groups. Likewise, if more White British women were to live with their partner or have more children, the ethnic difference would increase, although imposing policy aimed at parity and cohabitation would be unacceptable in most societies. Thus, we are left with gestational length, maternal height and BMI, that each explained some of the difference. Consistent with previous studies (Patel et al., 2004), gestation was slightly shorter among Pakistanis in this study and there is an argument for ethnic specific growth charts to account for this (Dua and Schram, 2006, Madan et al., 2002, Kierans et al., 2008). However, whether it can be proven that shorter gestation and consequently smaller size is a normal phenomenon within South Asians or not, the risks arising from smaller birth size still apply (i.e. increased infant mortality and morbidity). Ongoing data collection as part of the BiB Study will investigate this further (in relation to adverse outcomes and future development) but any adaptation of growth charts will only be sanctioned if there is clear evidence to suggest it is appropriate. Maternal height also explained some of the difference in birth size and I found that height was greater among UK born Pakistani mothers than those born in South Asia. This may reflect better diet and living conditions and may over time, translate into increases in birth size in successive generations. However, height is essentially part of the problem, i.e. small babies lead to small height in adulthood and in turn, a small next generation baby. Thus, whilst there may be modest increases in height among successive generations of Pakistani mothers, these are unlikely to result in significant increases in birth size.

In contrast to national data (Health Survey for England, 2004), Pakistani mothers in my sample had on average, a lower BMI than White British mothers. Theoretically, as a higher BMI is associated with greater birth size (Frederick et al., 2008, HAPO Study Cooperative Research Group, 2010), greater BMI among Pakistani mothers would reduce the magnitude of the difference in size between Pakistani and White British infants. However, this requires caution on several counts. First, encouraging greater BMI is clearly contrary to public health advice regarding a healthy lifestyle. Second, my findings show markedly greater adiposity among Pakistani origin infants. If birth size increases but a fat-preserving tendency is maintained, the effect may be to increase relative adiposity further which in turn, may worsen long term health prospects. Indeed, most important among all these considerations is the fact that whilst Pakistani origin babies were smaller in this study, they were also fatter and so any intervention to increase their birthweight and reduce the ethnic difference might have long-term detrimental effects on cadiometabolic health. Therefore, it is essential to further explore ways that could reduce ethnic differences in perinatal mortality related to smaller birth size, but that do not increase adiposity and future risk of type 2 diabetes and cardiovascular disease.

7.5 Further research

As noted earlier, I have been involved with the initiation of the BiB study and data collection in the cohort and have used data from approximately the first 50% of recruited BiB participants for this thesis. This provided a sufficient sample size for me to address my key questions, as well as providing me with the necessary knowledge, skills and experience from study initiation and obtaining ethical approval, collecting data and then completing detailed analysis, to be an epidemiologist. However, having completed this thesis I plan to publish answers to the key questions in peer reviewed journals using the full BiB cohort with some additional data that will become available shortly, for example, data from the glucose tolerance tests. Importantly, having completed the analyses presented here and having been involved in the ongoing follow-up of the BiB participants, I have identified a number of related research questions that I plan to take forward over the coming three years:

1. Should ethnic specific growth curves be developed? I will explore this by comparing birthweight for gestational age categories in South Asian and White British infants with current growth charts and a range of plausible South Asian specific charts in relation to perinatal complications and future offspring outcomes, including IQ and educational attainment.

2. Do the differences that I have found here with respect to greater total fat in Pakistani origin infants relative to White British infants, continue through childhood? And related to this, are there characteristics that increase or decrease these ethnic differences across childhood? I will examine this with further follow-up of the BiB cohort, including further assessment of skinfold thickness and biomarkers of adiposity such as leptin, and if further funding allows, detailed analysis of visceral adiposity in the two groups.

3. Do the subtle differences in some behaviours and possibly in birthweight by generational groups replicate other studies? I am aware that funding has been secured for the next national birth cohort and that this will recruit 90,000 participants with detailed birth size measurements and will oversample minority ethnic groups. There are possibilities for add-on studies to this cohort that I will explore to see if I can address this question.

4. Is the continued marriage of UK born South Asian adults to South Asian born adults found here in the BiB cohort, similar in other areas of the UK? If not is it possible to examine birth size over three generations elsewhere in the UK? I will explore the possibility of this using ONS data and also the new national birth cohort.

7.6 Summary

In this chapter I have summarised my findings in the context of what was already known about ethnic differences in birth size and adiposity (described in Chapter 2) and have described the contribution of my results to policy and further research. My findings suggest that despite being born smaller and lighter, Pakistani infants are relatively more adipose than White British origin infants. I have tried to highlight possible modifiable factors that could reduce differences in birth size between Pakistani and White British origin infants, but both the persistence of differences in multivariable models adjusting for a wide range of characteristics and across two generations, together with the concern that any interventions that increase birth weight in Pakistani infants may increase their body fat and hence their risk of future cardiometabolic ill health, have led me to be cautious about the feasibility and desirability of doing this. Finally, I draw attention to the need to consider the role of fathers in generational analyses and the need for robust outcome data to resolve the question of ethnic specific growth charts.

References

ABBA, K. (2001) Black and minority ethnic health service provision in Liverpool Primary Care Trusts. Liverpool, UK, Liverpool John Moores University.

AGYEMANG, C. & BHOPAL, R. (2002) Is the blood pressure of South Asian adults in the UK higher or lower than that of European white adults? A review of cross-sectional data. *Journal of Human Hypertension*, 16, 739-751.

ALBERMAN, E. (1991) Are our babies becoming bigger? *Journal of the Royal Society of Medicine*, 84, 257-260.

ALEXANDER, G. R., WINGATE, M. S., MOR, J. & BOULET, S. (2007) Birth outcomes of Asian-Indian-Americans. *International Journal of Gynecology & Obstetrics*, 97, 215-20.

ASHWORTH, A. (1998) Effects of intrauterine growth retardation on mortality and morbidity in infants and young children. *European Journal of Clinical Nutrition*, 52, 534-541.

ASSOCIATION OF PUBLIC HEALTH OBSERVATORIES, D. O. H. (2008) Health Profiles, Bradford. APHO.

BALCHIN, I., WHITTAKER, J. C., PATEL, R. & AL, E. (2007) Racial variation in te association between gestational age and perinatal mortality: prospective study. *BMJ*, 334, 807-812.

BAMBANG, S., SPENCER, N. J., LOGAN, S. & GILL, L. (2000) Cause specific death rates, birth weight and deprivation in te West Midlands 1991-1995. *Child Care & Health Development*, 26, 73-82.

BARKER, D. J. P. (1992) *Fetal and infant origins of adult disease*, London, BMJ Publications Group.

BATESON, P., BARKER, D., CLUTTON-BROCK, T., DEB, D. & D'UDINE, B. E. A. (2004) Developmental plasticity and human health. *Nature*, 430, 419-421.

BHOPAL, R., HAYES, L., WHITE, M., UNWIN, N., HARLAND, J., AYIS, S. & ALBERTI, G. (2002) Ethnic and socio-economic inequalities in coronary heart disease, diabetes and risk factors in Europeans and South Asians. *Journal of Public Health Medicine*, 24, 95-105.

BHOPAL, R. S., PHILLIMORE, P. & KOHLI, H. S. (1991) Inappropriate use of the term 'Asian': an obstacle to ethnicity and health research. *Journal of Public Health Medicine*, 13, 244-246.

BLAND, J.R. & ALTMAN, D.G. (1986) Statistical methods for assessing agreement between 2 methods of clinical measurement. *Lancet*, (i) 307-310

BLONDEL, B. & MARSHALL, B. (1998) Poor antenatal care in 20 French districts: risk factors and pregnancy outcome. *Journal of Epidemiology & Community Health*, 52, 501-506.

BRADFORD DISTRICT INFANT MORTALITY COMMISSION (2006) The Report. *Available from* www.ebm.bradford.nhs.uk/BDIMC/TheReport.aspx *Accessed on 25.11.2010.*

BRADFORD DISTRICT METROPOLITAN COUNCIL (2008) About Bradford. Bradford, BDMC.

BRADFORD TEACHING HOSPITALS NHS FOUNDATION TRUST (2005) Guidelines for Obstetric Ultrasound.

CANN, B., HORGEN, D. M. & MARGEN, S. E. A. (1987) Benefits associated with WIC supplemental feeding during the inter-pregnancy interval. *American Journal of Clinical Nutrition,* 45, 29-41.

CATALANO, P. M., THOMAS, A., HUSTON-PRESLEY, L. & AMINI, S. B. (2003) Increased fetal adiposity: a very sensitive marker of abnormal inutero development. *American Journal of Obstetrics & Gynecology,* 189, 1698-704.

CATALANO, P. M., TYZBIR, E. D., ALLEN, S. R. & AL, E. (1992) Evaluation of fetal growth by estimation of neonatal body composition. *Obstetrics & Gynecology,* 79, 46-50.

CETIN, I., MORPURGO, M. S., RADELLI, T. & AL, E. (2000) Fetal plasma leptin concentrations: relationship with different intrauterine growth patternsfrom 19 weeks to term. *Pediatric Research,* 48, 646-651.

CHAN, J. C. N., MALIK, V., JIA, W., KADOWAKI, T., YAJNIK, C. S., YOON, K. H. & HU, F. B. (2009) Diabetes in Asia: epidemiology, risk factors and pathophysiology. *JAMA,* 301, 2129-2140.

CHATURVEDI, N. (2001) Ethnicity as an epidemiological determinant -crudely racist or crucially important? *International Journal of Epidemiology,* 30, 925-927.

CHETCUTI, P., SINHA, S. H., LEVENE, M. I., CHETCUTI, P., SINHA, S. H. & LEVENE, M. I. (1985) Birth size in Indian ethnic subgroups born in Britain. *Archives of Disease in Childhood,* 60, 868-70.

CHIKE-OBI, U., DAVID, R. J., COUTNHO, R. & WU, S.-Y. (1996) Birth weight has increased over a generation. *American Journal of Epidemiology,* 144, 563-569.

CHOWDHURY, S., AMMARI, F., BURDEN, A. C. & GREGORY, R. (2000) Secular trend in birth weight in native white and immigrant South Asian populations in leicester, UK: possible implications for incidence of Type 2 diabetes in the future. *Practical Diabetes International,* 17, 104-108.

CHUMLEA, W. C., GUO, S., KUCZMARSKI, R. J. & AL, E. (1990) Reliability for anthropometric measurements in the Hispanic Health and Nutrition Examination Survey (HHANES 1982-1984). *American Journal of Clinical Nutrition,* 51, 902S-7S.

COSSIDINE, R. V., SINHA, M. K., HEIMAN, M. L. & AL, E. (1996) Serum immunoreactive leptin concentrations in normal weight and obese humans. *NEJM,* 334, 292-295.

DAVEY-SMITH, G. (2008) Assessing intrauterine influences on off-spring health outcomes: Can epidemiological studies yield robust findings? *Basic & Clinical Pharmacology & Toxicology,* 102, 245-256.

DEURENBERG-YAP, M., CHEW, S. K. & DUERENBERG, P. (2002) Elevated body fat percentage and cardiovascular risks at low body mass index levels among Singaporean Chinese, Malays and Indians. *Obesity Reviews*, 3, 209-215.

DH (2002) The health of minority ethnic groups, Health Survey for England 1999. IN HEALTH, D. O. (Ed.), The Stationary Office.

DHAWAN, S. (1995) Birth weights of infants of first generation Asian women in Britain compared with second generation Asian women. *BMJ*, 311, 86-88.

DORNHURST, A., PATESON, E. M., NICHOLLS, J. S. D. & AL, E. (1992) High prevalence of gestational diabetes mellitus in women from ethnic minority groups. *Diabetes Medicine*, 9, 820-825.

DRAPER, E. S., ABRAMS, K. R. & CLARKE, M. (1995) Fall in birth weight of third generation Asian infants. *BMJ*, 311, 876.

DUA, A. & SCHRAM, C. (2006) An investigation into the applicability of customised charts for the assessment of fetal growth in antenatal population at Blackburn, Lancashire, UK. *Journal Obstetrics & Gynaecology*, 26, 411-413.

ESKENAZI, B., GLADSTONE, E. A., BERKOWITZ, G. S., DREW, C. H., FAUSTMAN, E. M., HOLLAND, N. T. & AL, E. (2005) Methodological and logistic issues in conducting longitudinal birth cohort studies: Lessons learned from the Centres for Children's Environmental Health & Disease Prevention Research. *Environmental Health Perspectives*, 13, 1419-1429.

FIRDOUS, R. & BHOPAL, R. (1989) Reproductive health of Asian women: a comparative study with hospital and community perspectives. *Public Health*, 103, 307-315.

FREDERICK, I. O., WILLIAMS, M. A., SALES, A. E. & AL, E. (2008) Pre-pregnancy BMI, gestational weight gain and other maternal characteristics in relation to infant birthweight. *Maternal & Child Health Journal*, 12, 557-567.

FUENTES-AFFLICK, E. & HESSOL, N. (1997) Impact of Asian ethnicity and national origin on infant birth weight. *American Journal of Epidemiology*, 145, 148-155.

GEELHOED, J. J., FRASER, A., TILLING, K., BENFIELD, L., DAVEY SMITH, G., SATTAR, N., NELSON, S. M. & LAWLOR, D. A. (2010) pre-eclampsia and gestational hypertension are associated with childhood blood pressure independently of family adiposity measures: the Avon Longitudinal Study of Parents & Children. *Circulation*, 122, 1192-1199.

GIANNI, M. L., ROGGERO, P., TARONI, F. & AL, E. (2009) Adiposity in small for gestational age preterm infants assessed at term equivalent age. *Archives of Disease in Childhood Fetal Neonatal Edition*, 94, F368-F372.

GILLMAN, M. W., RIFAS-SHIMAN, S. L., BERKEY, C. S. & AL, E. (2003) Maternal gestational diabetes, birth weight and adolescent obesity. *Pediatrics*, 111, 221-226.

GJESSING, H. K. & LIE, R. T. (2008) Biometric modelling in genetics are complex traits too complex? . *Statistical Methods in Medical Research*, 17, 75-96.

GLUCKMAN, P. D. & HANSON, M. A. (2004) The development of origins of the metabolic syndrome. *Trends in Endocrinology and Metabolism,* 15, 183-187.

GOLDING, J. (2004) The Avon Longitudinal Study of Parents and Children (ALSPAC) - study design collaborative opportunities. *European Journal of Endocrinology,* 151, U119-U123.

GOTO, R. & MASCIE-TAYLOR, C. G. N. (2007) Precision of measurement as a component of human variation. *Journal of Physical Anthropometry,* 26, 253-256.

GOULD, J. B., MADAN, A., QIN, C. & CHAVEZ, G. (2003) Perinatal outcomes in two dissimilar immigrant populations in the united States: a dual epidemiologic paradox. *Pediatrics,* 111, 676-82.

GULMEZOGLU, M., ONIS, M. & VILLAR, J. (1997) Effectiveness of interventions to prevent or treat impaired fetal growth. *Obstetric & Gynaecological Survey,* 52, 139-149.

HALILEH, S., N., A.-R., WATT, G., SPENCER, N. & GORDON, N. (2008) Determinants of birth weight; Gender based analysis. *Maternal and Child Health, 12, 606-612.*

HAPO STUDY CO-OPERATIVE RESEARCH GROUP (2008) Hyperglycaemia and adverse pregnancy outcomes. *NEJM,* 358, 1991-2002.

HAPO STUDY COOPERATIVE RESEARCH GROUP (2010) Hyperglycaemia and adverse pregnancy outcome (HAPO) Study: associations with maternal body mass index. *British Journal of Obstetrics & Gynaecology,* 117, 575-84.

HARDING, S., ROSATO, M. G., CRUICKSHANK, J. K., HARDING, S., ROSATO, M. G. & CRUICKSHANK, J. K. (2004) Lack of change in birthweights of infants by generational status among Indian, Pakistani, Bangladeshi, Black Caribbean, and Black African mothers in a British cohort study. *International Journal of Epidemiology,* 33, 1279-85.

HASSINK, S. G., SHESLOW, D. V., DE LANCEY, E. & AL, E. (1996) Serum leptin in children with obesity: relationship to gender and development. *Pediatrics,* 98, 201-203.

HATTERSLEY, A. T. & TOOKE, J. E. (1999) The fetal insulin hypothesis: an alternative explanantion of the association of low birth weight with diabetes and vascular disease. *Lancet,* 353, 1789-92.

HAWKINS, S., LAMB, K., COLE, T. & LAW, C. (2008) Influence of moving to the UK on maternal health behaviours: prospective cohort study. *BMJ,* 336, 1052-5.

HAYES, D. K., LUKACS, S. L. & SCHOENDORF, K. C. (2008) Heterogeneity within Asian sub-groups: a comparison of birthweight between infants of US and non-US born Asian Indian and Chinese mothers. *Maternal and Child Health,* 12, 549-556.

HEALTH SURVEY FOR ENGLAND 2004 (2006) The health of ethnic minority groups. London, The Information Centre.

HEALTH SURVEY FOR ENGLAND (2004) *Risk factors for cardiovascular disease,* London, Joint Health Surveys Unit.

HEDIGER, M. L., OVERPECK, M. D., RUAN, W. J. & AL, E. (2002) Birth weight and gestational age effects on motor and social development. *Paediatric & Perinatal Epidemiology,* 16, 33-46.

HERNAN, M.A., HERNANDEZ-DIAZ, S., WERLER, M.M., MITCHEL, A.A. (2002) Causal knowledge as a prerequisite for confounding evaluation. *American Journal of Epidemiology*, 155, 176-184.

HIMES, J. H. (2009) Challenges of accurately measuring and using BMI and other indicators of obesity in children. *Pediatrics*, 124, S3-S18.

HOWE, H. D., TILLING, K. & LAWLOR, D. A. (2009) Accuracy of height and weight data from child health records. *Journal of Epidemiology & Community Health, 63, 79.*

HUGHES, K., TAN, N. R. & LUN, K. C. (1986) Ethnic group differences in low birthweight of live singletons in Singapore 1981-3. *Journal of Epidemiology & Community Health,* 40, 262-266.

HUMPHREY, M. D. & KEATING, S. M. (2004) Lack of antenatal care in far north Queensland. *Australian & New Zealand Journal of Obstetrics & Gynaecology,* 44, 10-13.

HUXLEY, R., NEIL, A. & COLLINS, R. (2002) Unravelling the fetal origins hypothesis: is there really an inverse association between birthweight and subsequent blood pressure. *Lancet,* 360, 659-65.

HUXLEY, R., OWEN, C. G., WHINCUP, P. H., COOK, D. G., RICH-EDWARDS, J., SMITH, G. D., COLLINS, R., HUXLEY, R., OWEN, C. G., WHINCUP, P. H., COOK, D. G., RICH-EDWARDS, J., SMITH, G. D. & COLLINS, R. (2007) Is birth weight a risk factor for ischemic heart disease in later life? *American Journal of Clinical Nutrition,* 85, 1244-50.

JACKSON, D. J., BATISTE, E. & RENDELL-MKOSI, K. (2007) Effect of smoking and alcohol use during pregnancy on the occurance of low birthweight in a farming region in South Africa. *Paediatric & Perinatal Epidemiology*, 21, 432-440.

JADDOE, V. W. V., BAKKER, R., HOFMAN, A. & AL, E. (2007) Moderate alcohol consumption during pregnancy and teh risk of low birth weight and preterm birth. The Generation R Study. *Annals of Epidemiology*, 17, 834-840.

JOHNSON, T. S. & ENGSTROM, J. L. (2002) State of the science in measurement of infant size at birth. *Newborn & Infant Nursing Reviews*, 2, 150-158.

JOHNSON, T. S., ENGSTROM, J. L. & GELHAR, D. K. (1997) Intra and interexaminer reliability of anthropometric measurements of term infants. *Journal of Pediatric Gastroenterology & Nutrition,* 24, 497-505.

JOHNSON, W., CAMERON, N., EMSLEY, S. & AL, E. (2009) A reliability asssessment of routine anthropometric data collected by health workers: A cross-sectional study. *International Journal of Nursing Studies*, 46, 310-6.

JOSHI, M. D., KULKARNI, S. R., YAJNIK, C. S. & AL, E. (2005) Increasing maternal parity predicts neonatal adiposity: Pune Nutrition Study. *American Journal of Obstetrics & Gynecology*, 193, 783-789.

KAPLAN, J. B. & BENNETT, T. (2003) Use of race and ethnicity in biomedical publication. *JAMA,* 289, 2709-2716.

KARAKOSTA, P., CHATZI, L., PLANA, E., MARGIORIS. A., CASTANAS, E. & KOGEVINAS, M. (2010) Leptin levels in cord blood and anthropometric measures at birth: a systematic review and meta-analysis *Paediatric & Perinatal Epidemiology,* 25, 150-163.

KAWACHI, I., DANIELS, N., ROBINSON, D. (2005) Health disparities by race and class: why both matter. *Health Affairs,* 24, 343-352.

KELLY, Y., PANICO, L., BARTLEY, M., MARMOT, M., NAZROO, J. & SACKER, A. (2008) Why does birthweight vary among ethnic groups in the UK? Findings from the Millenium Cohort Study. *Journal of Public Health. 31, 131-137.*

KIERANS, W. J., JOSEPH, K. S., ZHONG-CHENG, L. & AL, E. (2008) Does one size fit all? The case for ethnic specific standards of fetal growth. *BMC Pregnancy & childbirth, 8, 1.*

KINARE, A. S., CHNICHWADKAR, M. C., NATEKAR, A. S., COYAJI, K. J., WILLS, A. K., JOGLEKAR, C. V. & AL, E. (2010) Patterns of fetal growth in a rural Indian cohort and comparison with a western European population. *Journal of Ultrasound Medicine,* 29, 215-223.

KLEBANOFF, M. A., SCHULSINGER, C., MEDNICK, B. R. & AL, E. (1997) Preterm and small for gestational age birth across generations. *American Journal of Obstetrics & Gynecology,* 176, 521-6.

KNIGHT, B., SHIELDS, B. M., TURNER, M., POWELL, R. J. & AL, E. (2005) Evidence of genetic regulation of fetal longitudinal growth. *Early Human Development,* 81, 823-831.

KRAMER, M. S. (1987) Determinants of low birth weight: methodological assessment and meta-analysis. *Bulletin of the World Health Organisation,* 65, 663-737.

KRAMER, M. S. & SEGUIN, L. (2000) Socio-economic disparities in pregnancy outcome-Why do the poor fair so poorly? *Paediatric & Perinatal Epidemiology,* 14, 194-210.

KRISHNAVENI, G. V., HILL, J. C., VEENA, S. R., LAERY, S. D., SAPERIA, J., CHACHYAMMA, K. J., KARAT, S. C. & FALL, C. H. (2005) Truncal adiposity is present at birth and in early childhood in South Indian children. *Indian Paediatrics,* 42, 527-538.

KUZAWA, C. W. (2004) Modelling fetal adaptation to nutrition restriction: testing the fetal origins hypothesis with a supply-demand model. *The Journal of Nutrition,* 134, 194-200.

KUZAWA, C. W., QUINN, E. A. & ADAIR, L. S. (2007) Leptin in a lean population of Filipino adolescents. *American Journal of Physical Anthropology,* 132, 642-649.

LAWLOR, D. A., BENFIELD, L., LOGUE, J., TILLING, K., HOWE, L. D., FRASER, A., CHERRY, L. & AL, E. (2010) Association between general and central adiposity in childhood, and change in these, with cardiovascular risk factors in adolescence: prospective cohort study. *BMJ,* 341, 6224.

LAWLOR, D. A., DAVEY SMITH, G. & EBRAHIM, S. (2003) Life course influences on insulin resistance: findings from the Women's British Heart and Health Study. *Diabetes Care,* 26, 97-103.

LAWLOR, D. A., LEARY, S. & DAVEY SMITH, G. (2009) Theoretical underpinning for the use of intergenerational studies in life course epidemiology. IN LAWLOR, D. A. & MISHRA, G. D. (Eds.) *Family Matters: designing, analysing and understanding family-based studies in life course epidemiology.* Oxford, Oxford University Press.

LAWLOR, D. A., MORTENSEN, L. & ANDERSON, A.-M. N. (2011) The association of maternal age with offspring birth weight and gestational age: a sibling study of 548601 Danish women and their firstborn offspring. *International Journal of Epidemiology,* (Published online 12 July 2011).

LAWLOR, D. A., OWEN, C. G., DAVIES, A. A., WHINCUP, P. H., EBRAHIM, S., COOK, D. G. & DAVEY-SMITH, G. (2006) Sex differences in the association between birthweight and total cholesterol, a meta-analysis. *Annals of Epidemiology,* 16, 19-25.

LEARY' S., FALL, C., OSMOND, C. & AL, E. (2006a) Geographical variation in neonatal phenotype. *Acta Obstetricia et Gynecologica Scandinavica,* 85, 1080-1089.

LEARY, S., FALL, C., OSMOND, C., LOVEL, H., CAMPBELL, D., ERIKSSON, J. & AL, E. (2006b) Geographical variation in relationships between parental body size and offspring phenotype at birth. *Acta Obstetricia et Gynecologica Scandinavica,* 85, 1066-1079.

LEON, D. A. (2004) Biological theories, evidence and epidemiology. *International Journal of Epidemiology,* 33, 1167-1171.

LEON, D. A. & MOSER, K. (2010) Low birth weight persists in South Asian babies born in England & Wales regardless of maternal country of birth. Slow pace of acculteration, physiological constraint or both? Analysis of routine data. *Journal of Epidemiology & Community Health,* (Published online 30 Nov 2010).

LINDLEY, J., DALE, A. & DEX, S. (2004) Ethnic differences in women's demographic, family caracteristics and economic activity profiles, 1992-2002. *Labour Market Trends,* 112, 153-165.

LIRA, P. I., ASHWORTH, A. & MORRIS, S. (1996) Low birth weight and morbidity from diarrhea and respiratory infection in northeast Brazil. *Journal of Pediatrics,* 128, 497-504.

LUQUE, V., MENDEZ, G., CAPDEVILA, F. & AL, E. (2009) Subcutaneous fat stores related to weight in full term neonates. *Annuls of Human Biology,* 36, 88-97.

MADAN, A., HOLLAND, S., HUMBERT, J. E. & BENITZ, W. E. (2002) Racial differences in birth weight of term infants in a northern California population. *Journal of Perinatology,* 22, 230-235.

MALINA, R. M., BOUCHARD, C. & BUENEN, G. (1988) Human growth: selected aspects of research on well-nourished children. *Annual Reviews of Anthropology,* 17, 187-219.

MARCHINI, G., FRIED, G., OSTLUND, E. & HAGENAS, L. (1998) Plasma leptin in infants: Relations to birthweights and weight loss. *Pediatrics*, 101, 429-432.

MARGETTS, B. M., MOHD YUSOF, S., AL DALLAL, Z., JACKSON, A. A., MARGETTS, B. M., MOHD YUSOF, S., AL DALLAL, Z. & JACKSON, A. A. (2002) Persistence of lower birth weight in second generation South Asian babies born in the United Kingdom. *Journal of Epidemiology & Community Health*, 56, 684-7.

MARKS, G. M., HABICHT, J. P. & MUELLER, W. H. (1989) Reliability, dependability and precision of anthropometric measurements. *American Journal of Epidemiology*, 130, 578-587.

MATSUDA, J., YOKOTA, I., IIDA, M., MURAKAMI, T., NAITO, E., ITO, M. & AL, E. (1997) Serum leptin concentration in cord blood: relationship to birthweight and gender. *Journal of Clinical Endocrinology & Metabolism*, 82, 1642-1644.

MCCLEOD, S. & KIELTY, J. L. (1988) The effects of maternal age and parity on birth weight: a population study in New York. *International Journal of Gynecology & Obstetrics*, 26, 11-19.

MCCOWAN, L., STEWART, A. W., FRANCIS, A. & GARDOSI, J. (2004) A customised birthweight centile calculator developed for a New Zealand population. *Australian & New Zealand Journal of Obstetrics & Gynaecology*, 44, 428-431.

MCFADYEN, I. R., CAMPBELL-BROWN, M., ABRAHAM, R., NORTH, W. R. & HAINES, A. P. (1984) Factors affecting birthweights in Hindus, Moslems and Europeans. *Britisn Journal Obstetrics & Gynaecology*, 91, 968-72.

MCKEIGUE, P. (1999) Diabetes and insulin action. IN KUH, D. (Ed.) *A life course approach to chronic disease epidemiology*. Oxford, Oxford Medical Publications.

MCKEIGUE, P. M., FERRIE, J. E., PIERPOINT, T. & MARMOT, M. G. (1993) Association of early onset coronary heart disease in south Asian men with glucose intolerance and hyperinsulinaemia. *Circulation*, 87, 152-161.

MCKEIGUE, P. M., SHAH, B., MARMOT, M. G., MCKEIGUE, P. M., SHAH, B. & MARMOT, M. G. (1991) Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians.[see comment]. *Lancet*, 337, 382-6.

MENTE, A., RAZAK, F., BLANKENBURG, S., VUKSAN, V., DAVIS, A. D., MILLER, R. & AL, E. (2010) Ethnic variation in adiponectin and leptin levels and their association with adiposity and insulin resistance. *Diabetes Care (Published online 22 April 2010)*.

MESSECAR, D. C. (2001) Smoking cessation interventions for pregnant women to prevent low birth weight: what does the evidence show? *Journal of the American Academy of Nurse Practitioners*, 13, 171-177.

MODI, N., THOMAS, E. L., UTHAYA, S. N. & AL, E. (2009) Whole body magnetic resonance imaging of healthy newborn infants demonstrates increased central adiposity in Asian Indians. *Pediatric Research*, 65, 584-587.

MOSER, K., STANFIELD, K. & LEON, D. A. (2008) Birthweight and gestational age by ethnic group, England and Wales 2005: introducing new data on births. *Health Statistics Quarterly,* 39, 22-31.

MUTHAYA, S., DWARKANATH, P., THOMAS, T., VAZ, M., MHASKAR, A., MHASKAR, R., THOMAS, A., BHAT, S., KURPAD, A., MUTHAYYA, S., DWARKANATH, P., THOMAS, T., VAZ, M., MHASKAR, A., MHASKAR, R., THOMAS, A., BHAT, S. & KURPAD, A. (2006) Anthropometry and body composition of south Indian babies at birth. *Public Health Nutrition,* 9, 896-903.

NANDA, S., SAVVIDOU, M., SYNGELAKI, A., AKOLEKAR, R. & NICHOLAIDES, K. H. (2011) Prediction of gestational diabetes mellitus by maternal factors and biomarkers at 11 to 13 weeks. *Prenatal Diagnosis, 31, 135-141.*

NATIONAL SCREENING COMMITTEE (2008) Newborn and infant physical examination: standards and competencies. Available from www.screening.nhs.uk accessed on 31.3.2008.

NAZROO, J. (2001) *Ethnicity, class and health,* London, Policy Studies Institute.

NESS, A. R. & SIBAI, B. M. (2006) Shared and disparate components of the pathophysiologies of fetal growth restriction and pre-eclampsia. *American Journal of Obstetrics & Gynecology,* 195, 40-49.

NHS BRADFORD & AIREDALE (2010). Health Informatics Service.

NIGHTINGALE, C. M., RUDNICKA, A. R., OWEN, C. G., COOK, D. G. & WHINCUP, P. H. (2010) Patterns of body size and adiposity among UK children of South Asian, black African-Caribbean and white European origin: Child Heart And health Study in England (CHASE Study). *International Journal of Epidemiology (Advance access published Nov 1 2010).*

OLDFIELD, M. D., DONLEY, P., WALWYN, L. & AL, E. (2007) Long term prognosis of women with gestational diabetes in a multiethnic population. *Postgraduate Medical Journal,* 83, 426-430.

OVANOVIC, L. & PETTITT, D. J. (2001) Gestational diabetes mellitus. *JAMA,* 286, 2516-2518.

OWEN, C. G., WHINCUP, P. H., ODOKI, K., GILG, J. A., COOK, D. G., OWEN, C. G., WHINCUP, P. H., ODOKI, K., GILG, J. A. & COOK, D. G. (2003) Birth weight and blood cholesterol level: a study in adolescents and systematic review. *Pediatrics,* 111, 1081-9.

PATEL, R., STEER, P. J., DOYLE, P., LITTLE, M. P. & ELLIOTT, P. (2004) Does gestation vary by ethnic group? A London-based study of over 122,000 pregnancies with spontaneous onset of labour. *International Journal of Epidemiology,* 33, 107-13.

PAZ, I., GALE, R., LAOR, A. & AL, E. (1995) The cognitive outcome of full term small for gestational age infants at late adolescence. *Obstetrics & Gynecology,* 85, 452-456.

PHILLIPS, D. (2001) The changing geography of South Asians in Bradford. Available from www.bradford2020.com/pride/docs/section5.doc Accessed on 12.6.2009.

PICKETT, K., SHAW, R. J., ATKIN, K., KIERNEN, K. & WILKINSON, R. G. (2009) Ethnic density effects on maternal and infant health in the Millenium Cohort Study. *Social Science & Medicine,* 69, 1476-1483.

PLEWIS, I. (2007) The Millenium Cohort Study: Technical report on sampling (4th Ed). London, Institute of Education, University of London.

POON, L. C. Y., KAMETAS, N. A., CHELEMAN, T., LEAL, A. & NICOLAIDES, K. H. (2010) Maternal risk factors for hypertensive disorders in pregnancy: a multivariate approach. *Journal of Human Hypertension,* 24, 104-110.

PRADA, J. A. & TSANG, R. C. (1996) Biological mechanisms of environmentally induced causes of IUGR. *European Journal of Clinical Nutrition,* 52, S21-S28.

PRINGLE, P. J., GEARY, M. P., RODECK, C. H., KINGDOM, J. C., KAYAMBA-KAYS, S. & HINDMARSH, P. C. (2005) The influence of cigarette smoking on antenatal growth, birth size and insulin-like growth factor axis. *Journal of Clinical Endocrinology & Metabolism,* 90, 2556-62.

RAFNSSON, S. B. & BHOPAL, R. (2009) Large scale epidemiological data on cardiovascular disease and diabetes in migrant and ethnic minority groups in Europe. *European Journal of Public Health,* 19, 484-491.

RAO, S., YAJNIK, C. S., KANADE, A., FALL, C. H. D. & AL, E. (2001) Intake of micronutrient rich foods in rural Indian mothers is associated with the size of theri babies at birth: Pune Maternal Nutrition Study. *Journal of Nutrition,* 131, 1217-1224.

RAYNOR, P. (2008) Born in Bradford, a cohort study of babies born in Bradford, and their parents: Protocol for the recruitment phase. *BMC Public Health, 8, 327.*

REES, G. A., DOYLE, W., SRIVASTAVA, A. & AL, E. (2005) The nutrient intakes of mothers of low birth weight babies - A comparison of ethnic groups in East London, UK. *Maternal & Child Nutrition,* 1, 91-99.

RODRIGUEZ, G., SAMPER, M. P., OLIVARES, J. L. & AL, E. (2005) Skinfold measurements at birth: sex and anthropometric influence. *Archives of Disease in Childhood Fetal & Neonatal Edition,* 90, F273-F275.

ROGERS, I. S., NESS, A. R., STEER, C. D., WELLS, J., EMMOTT, P. M., REILY, J. R. & AL, E. (2006) Association of size at birth and dual energy x-ray absorptiometry measures of lean and fat mass at 9 to 10 years of age. *American Journal of Clinical Nutrition,* 84, 739-747.

ROSENBERG, T. J., RAGGIO, T. P. & CHIASSON, M. A. (2005) A further examination of the "Epidemiologic Paradox": birth outcomes among latinas. *JAMA,* 97, 550-557.

SALMI, I. A., HOY, W. E., KONDALSAMY-CHENNAKESAVAN, S., WANG, Z., GOBE, G. C. & AL, E. (2008) Disorders of glucose regulation in adults and birth weight. *Cardiovascular and Metabolic Risk,* 31, 159-164.

SAYLAN, F., KOKEN, G., COSAR, E., KOKEN, T., SAYLAN, A., ARIOZ, D. T. & AL, E. (2010) Maternal and fetal leptin and ghrelin levels: relationship with fetal growth. *Archives of Gynecology & Obstetrics (Online publication 10 Sept 2010).*

SCHUBRING, C., SIEBLER, T., KRATSCH, J., ENGLARO, P., BLUM, W. F., TRIEP, K. & KIESS, W. (1999) Leptin serum concentrations in healthy neonates within the first week of life: relation to insulin and growth hormone levels, skinfold thickness, body mass index and weight. *Clinical Endocrinology,* 51, 199-204.

SHEKHAWAT, P. S., GARLAND, J. S., SHIVPURI, C. & AL, E. (1998) Neonatal cord blood leptin: its relationship to birthweight, body mass index, maternal diabetes and steroids. *Pediatric Research,* 43, 338-43.

SHIELDS, B. M., KNIGHT, B., POWELL, R. J. & AL, E. (2006) Assessing newborn body composition using principal components analysis: differences in the determinants of fat and skeletal size. *BMC Pediatrics,* 6, 23.

SPENCER, N. J. & LOGAN, S. (2002) Social influences on birth weight. *Journal of Epidemiology & Community Health,* 56, 326-327.

SPENCER, N. J., LOGAN, S. & GILL, L. (1999) Trends and social apetterning of birth weight in Sheffield, 1985-94. *Archives of Disease in Childhood Fetal & Neonatal Edition,* 81, F138-F140.

STEER, P. J., LITTLE, M. P., KOLD-JENSON, T. & AL, E. (2004) Maternal blood pressure in pregnancy, birth weight and perinatal mortality in first births: prospective study. *BMJ,* 329, 1312.

STEIJN, L. V., KARAMALI, N. S., KANHAI, H. H. H., ARIENS, G. A. M., FALL, C. H. D., YAJNIK, C. S. & AL, E. (2009) Neonatal anthropometry: thin-fat phenotype in fourth to fifth generation South Asian neonates in Surinam. *International Journal of Obesity,* 33, 1326-1329.

STEIN, A. D., ZYBERT, P. A., VAN DE BOR, M. & LUMEY, L. H. (2004) Intrauterine famine exposure and body proportions at birth: the Dutch Hunger Winter. *International Journal of Epidemiology* 33, 831-836.

STENHOUSE, E., WRIGHT, D. E., HATTERSLEY, A. T. & MILLWARD, A. (2004) The accuracy of birth weight. *Clinical Nursing,* 13, 767-768.

TAYLOR, D. J. & HOWLE, P. W. (1989) Fetal growth achievement and neuro-developmental disability. *British Journal of Obstetrics & Gynaecology,* 96, 789-794.

THOMAS, J. (2002) Nutrition intervention in minority etnic groups. *Proceedings of the Nutrition Society,* (Nov), 559-567.

TU, Y.-K., WEST, R., ELLISON, G. T. H. & GILTHORPE, M. S. (2005) Why evidence for the fetal origins of adult disease might be a statistical artefact: the reversal paradox for the relation between birthweight and blood pressure in later life. *American Journal of Epidemiology,* 161, 27-32.

ULIJASZEK, S. J. & KERR, D. A. (1999) Anthropometric measurement error and the assessment of nutritional status. *British Journal of Nutrition,* 82, 165-177.

UNITED NATIONS CHILDREN'S FUND, W. H. O. (2004) Low birthweight: country, regional and global estimates. New York, Geneva, UNICEF, WHO.

VALUNIENE, M., VERKAUSKIENE, R., BOGUSZEWSKI, M., DAHLGREN, J., LASIENE, D., LASAS, L. & WIKLAND, K. A. (2007) Leptin levels at birth and in early postnatal life in small and appropriate for getstaional age infants. *Medicina,* 43, 784-91.

VANGEN, S., STOLTENBERG, C., SKJAERVEN, R., MAGNUS, P., HARRIS, J. R., STRAY-PEDERSEN, B., VANGEN, S., STOLTENBERG, C., SKJAERVEN, R., MAGNUS, P., HARRIS, J. R. & STRAY-PEDERSEN, B. (2002) The heavier the better? Birthweight and perinatal mortality in different ethnic groups. *International Journal of Epidemiology,* 31, 654-60.

VYAS, A., GRENHALGH, A., CADE, J. & AL, E. (2003) Nutrient intakes of an adult Pakistani, European and African Caribbean community in inner city Britain. *Journal of Human Nutrition & Dietetics* 16, 327-337.

WATERLAND, R. A. & MICHELAS, K. B. (2007) Epigenetic epidemiology of teh developmental origins hypothesis. *Annals & Reviews in Nutrition,* 27, 363-88.

WHINCUP, P. H., GILG, J. A., PAPACOSTA, A., SEYMOUR, C. & AL, E. (2002) Early evidence of ethnic differences in cardiovascular risk: cross sectional comparison of British south Asian and white children. *BMJ,* 324, 635.

WHINCUP, P. H., KAYE, S.J., OWEN, C.G., HUXLEY, R. ET AL (2008) Birth weight and risk of type 2 diabetes. *JAMA,* 300, 2886-2897.

WHINCUP, P. H., NIGHTINGALE, C. M., OWEN, C. G., RUDNICKA, A. R., GIBB, I., MCKAY, C. M. & AL, E. (2010) Early emergence of ethnic differences in Type 2 diabetes precursors in the UK: The Child Heart & Health Study in England (CHASE). *PLoS Medicine,* 7 (4):e1000263.

WHO (2006) Reliability of anthropometric measurements in the WHO Multi-centre Growth Reference Study. *Acta Paediatrica,* suppl 450, 38-46.

WHO EXPERT CONSULTATION (2004) Appropriate BMI for Asian populations and its implications for policy and intervention strategies. *Lancet,* 363, 157-63.

WHO, U. N. C. F. (2004) Low birthweight. Country, regional and global estimates. New York, UNICEF.

WILCOX, A. J. (2001) On the importance and unimportance of birthweight. *International Journal of Epidemiology,* 30, 1233-1241.

WILCOX, A. J., CHANG, A. & JOHNSON, I. (1996) The effects of parity on birthweight using successive pregnancies. *Acta Obstetricia et Gynecologica Scandinavica,* 75, 459-463.

WITHERSPOON, D., WOODING, S., ROGERS, A. R. & AL, E. (2007) Genetic similarities within and between human populations. *Genetics,* 176, 351-359.

WOLLMANN, H. A. (2009) Children born small for gestational age. IN KIESS, W., CHERNAUSEK, S.D., HOKKEN-KOELEGA, A.C.S. (Ed.) *Small for gestational age: causes and consequences.* Basel, Karger Publishers.

WORLD HEALTH ORGANISATION (2005) World Health Statistics 2005.

YAJNIK C. S., FALL, C. H., COYAJI, K. J., HIRVE, S. S., RAO, S., BARKER, D. J., JOGLEKAR, C., KELLINGRAY, S., YAJNIK, C. S., FALL, C. H. D., COYAJI, K. J., HIRVE, S. S., RAO, S., BARKER, D. J. P., JOGLEKAR, C. & KELLINGRAY, S. (2003) Neonatal anthropometry: the thin-fat Indian baby. The Pune Maternal Nutrition Study. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity,* 27, 173-80.

YAJNIK C. S., LUBREE, H. G., REGE, S. S., NAIK, S. S., DESHPANDE, J. A., DESHPANDE, S. S., JOGLEKAR, C. V., YUDKIN, J. S., YAJNIK, C. S., LUBREE, H. G., REGE, S. S., NAIK, S. S., DESHPANDE, J. A., DESHPANDE, S. S., JOGLEKAR, C. V. & YUDKIN, J. S. (2002) Adiposity and hyperinsulinemia in Indians are present at birth. *Journal of Clinical Endocrinology & Metabolism,* 87, 5575-80.

YAJNIK, C. S. (2004) Obesity epidemic in India: intrauterine origins. *Proceedings of the Nutrition Society,* 63, 387-396.

YASMIN, S., OSRIN, D., PAUL, E. & COSTELLO, A. (2001) Neonatal mortality of low birth weight infants in Bangladesh. *Bulletin of WHO,* 79, 608-614.

YING LI, C.C., MALONEY, C.A., CROPLEY, J.E., SUTER, C.M. (2010) Epigenetic programming by maternal nutrition: shaping future generations. *Epigenomics*, 2(4), 539-549.

YOSHIMITSU, N., DOUCHI, T., KAMIO, M. & NAGATA, Y. (2000) Differences in umbilical venous and arterial leptin levels by mode of delivery. *Obstetrics Gynecology,* 96, 158-9.

ZHANG, Y., PROENCA, R., MAFFAI, M. & AL, E. (1994) Positional cloning of the mouse obese gene and its human homologue. *Nature,* 372, 425-432.

Appendix A

Search Strategy

The search strategy used in this thesis was developed from an initial subject heading, this was then supplemented by introducing key words to the strategy. Truncation and wildcard options were included as appropriate.

Ethnic differences in birth weight

1.differences in birth size and anthropometry between Pakistani and white babies

2.birth size.mp.

3.birth weight.mp.

4.small date$.ti,ab.

5.small gestation$.ti,ab

6.iugr.ti.ab.

7.retard$ growth or growth retard$

8.birth anthropometr$

9.skinfold thickness.mp.

10. pakistan$.mp.

11. south asian.mp.

12. asia$.mp.

13. (india$ or bangladesh$).mp.

Generational differences in birth weight

1.generational differences in birth weight.mp.

2.transgeneration$ birth weight

3.offspring.mp.

4.pakistan$.mp.

5.south asian.mp.

6.asia$.mp.

7.(india$ or bangladesh$).mp.

8.or/ 1-3

9.or 4-7

10. 8 and 9

Fat /thin insulin resistant phenotype

1.insulin resistant phenotype.mp.

2.development$ plasticity.mp.

3.thrifty phenotype.mp.

4.fetal programming.mp.

5.cord blood leptin.mp.

6.central adiposity.mp.

7.central obesity.mp.

8.birth size.mp.

9.birth weight.mp.

10. small date$.ti,ab.

11. small gestation$.ti,ab

12. iugr.ti.ab.

13. retard$ growth or growth retard$

14. birth anthropometr$

15. skinfold thickness.mp.

16. pakistan$.mp.

17. south asian.mp.

18. asia$.mp.

19. (india$ or bangladesh$).mp.

20. or/ 1-7

21. or/ 8-15
22. or/ 16-19
23. 20 and 21
24. 23 and 22

Search filters used:

.mp.	indicates a free text search for a term
ti.	word in title
ab.	word contained in abstract
/	sub-heading
$	indicates the term has been truncated

Appendix B

Mothers' questionnaire

Draft

Study ID [ ][ ][ ][ ][ ] [P][ ]

Born in Bradford - Mothers' Questionnaire

To be completed by interviewer:

Interviewer's Number [ ][ ] - [ ][ ] *(2 initials - 2 numbers e.g. AN 01)*

1. Date Completing this questionnaire?

[ ][ ] / [ ][ ] / [2][0][ ][ ]
d d m m y y y y

***2. What language(s) was used for administering the questionnaire?**

☐ English ☐ Mirpuri/Punjabi ☐ Urdu

Any other language (please write in)

***3. Was an Interpreter used?**

☐ No ☐ Hospital/Study Interpreter ☐ Family Member/Friend

(To be measured by interviewer)

4. Height (Cms) [ ][ ][ ] . [ ] **5. Weight** [ ][ ][ ] . [ ][ ] (Kilos) (Grms)

***6. Triceps** (Cms) [ ][ ] . [ ] ☐ Not able to take

***7. Arm circumference** (Cms) [ ][ ] . [ ] ☐ Not able to take

8. How old were you when you had your first period?

[ ][ ] [ ][ ] ☐ Don't Know
y y m m

1 2 3 4 5

Draft

Draft

9. Will this be your first child? ☐ Yes ☐ No

9a) If no:- what month and year were each of your previous children born in ?
- starting with the eldest:

	Month	Year
First child		
Second child		
Third child		
Fourth child		
Fifth child		
(add birth dates of all other children)		

1 2 3 4 5

Draft

Draft

Section A - Where you live

These questions relate to where you are living at present.

***A1. How long have you lived at your current address?** ☐☐ ☐☐

Y Y m m

***A2. In which of these ways does your household occupy this address?**
(Cross ONE box ONLY)

If answers yes to any of the three * questions, please go to A2a). If not go to A3

- ☐ Buying it with the help of a mortgage or loan
- ☐ Owns outright
- ☐ *Rents it
- ☐ *Lives here rent free (including rent free in relatives/friends property excluding squatting)
- ☐ *Pays part rent and part mortgage (shared ownership)
- ☐ Don't know
- ☐ Squatting

***A2a) If A2 was answered - Rents it: Lives rent free or pays part rent and part mortgage - ask who is your landlord?**
(Cross ONE box ONLY)

- ☐ Private Landlord or Letting Agency, Another individual
- ☐ Housing Association, Housing Co-operative, Charitable Trust
- ☐ Local Authority/Council
- ☐ Relative or friend (before you lived here) of a household member
- ☐ Employer (individual) of a household member
- ☐ Employer (organisation) of a household member
- ☐ Another Organisation
- ☐ Don't Know

A3) How many bedrooms does your household have, including bedsitting rooms and spare bedrooms?

Enter number of bedrooms ☐☐

1 2 3 4 5

Draft

Draft

Section B - Who you live with?

B1. What ages are those, including yourself, who live in your household or accommodation? [If age not known, please give best estimate]

Is there anybody:-

Age	**Number of males**	**Number of females**
Under 2 years	☐☐	☐☐
between 2 -15 years	☐☐	☐☐
between 16 - 17 years	☐☐	☐☐
between 18 - 64 years	☐☐	☐☐
65 years and over	☐☐	☐☐

B2. Are you: (Cross ONE box ONLY)

☐ Married (first marriage)

☐ Re-married

☐ Single (never married)

☐ Separated (but still legally married)

☐ Divorced

☐ Widowed

B3. Are you: (Cross ONE box ONLY)

☐ Living with baby's father

☐ Living with another partner

☐ Not living with a partner – but in a relationship (eg. partner living abroad or in another propery)

☐ Not living with a partner and not in a relationship

Draft

Section C - About you, your family and your baby's father and his family

C1. What country were you and your baby's father born in?

(Cross ONE box ONLY in each column).

Country	You
England	☐
Northern Ireland	☐
Scotland	☐
Wales	☐
Channel Islands	☐
Isle of Man	☐
Republic of Ireland	☐
Czech Republic	☐
Poland	☐
Slovakia	☐
Bangladesh	☐
India	☐
Pakistan	☐
Sri Lanka	☐
Philippines	☐
Don't know	☐

Country	Baby's father
England	☐
Northern Ireland	☐
Scotland	☐
Wales	☐
Channel Islands	☐
Isle of Man	☐
Republic of Ireland	☐
Czech Republic	☐
Poland	☐
Slovakia	☐
Bangladesh	☐
India	☐
Pakistan	☐
Sri Lanka	☐
Philippines	☐
Don't know	☐

You - Other (Please write in)

Baby's father - Other (Please write in)

Draft

***C2. To be asked if not born in the UK**
How old were you when you moved to the UK?

Age in Years ☐☐ ☐☐
y y m m

If answered Pakistan for you and/or baby's father in C1 go to C3.
If not Pakistan for either person then go to C4.

C3) Were you and/or baby's father born in Mirpur District?
(Cross ONE box ONLY in each row)

You	☐ Yes	☐ No	☐ Don't Know
Baby's father	☐ Yes	☐ No	☐ Don't Know

***C3a) If yes, which town or village?**

You (Please write in) ☐ Don't Know

Baby's father (Please write in) ☐ Don't Know

***C3b) Do you know the name of your's and baby's father's Biraderi?**
(Interviewer - consult list of Biraderi if necessary).

You (Please write in) ☐ Don't Know

Baby's father (Please write in) ☐ Don't Know

1 2 3 4 5

Draft

Draft

***C4. What country were your mother and father born in?**
(Cross ONE box ONLY in each column).

Country	Your Mother	Country	Your Father
England	☐	England	☐
Northern Ireland	☐	Northern Ireland	☐
Scotland	☐	Scotland	☐
Wales	☐	Wales	☐
Channel Islands	☐	Channel Islands	☐
Isle of Man	☐	Isle of Man	☐
Republic of Ireland	☐	Republic of Ireland	☐
Czech Republic	☐	Czech Republic	☐
Poland	☐	Poland	☐
Slovakia	☐	Slovakia	☐
Bangladesh	☐	Bangladesh	☐
India	☐	India	☐
Pakistan	☐	Pakistan	☐
Sri Lanka	☐	Sri Lanka	☐
Philippines	☐	Philippines	☐
Don't know	☐	Don't know	☐

Your mother - Other (Please write in)

Your father - Other (Please write in)

If answered Pakistan for your mother or father in C4 go to C5 if not Pakistan then go to C6

C5) Were your mother and father born in Mirpur district?
(Cross ONE box ONLY)

Your mother	☐ Yes	☐ No	☐ Don't Know
Your father	☐ Yes	☐ No	☐ Don't Know

1 2 3 4 5

Draft

Draft

C5a) If yes, which town or village?

Your mother - (Please write in) ☐ Don't Know

Your father - (Please write in) ☐ Don't Know

C5b) Do you know the name of your mother's and father's Biraderi?

Your mother - (Please write in) ☐ Don't Know

Your father - (Please write in) ☐ Don't Know

1 2 3 4 5

Draft

Draft

C6 What country were your grandparents born in?

(Cross ONE box ONLY in each column).

Country	Your mother's mother	Your mother's father	Your father's mother	Your father's father
England	☐	☐	☐	☐
Northern Ireland	☐	☐	☐	☐
Scotland	☐	☐	☐	☐
Wales	☐	☐	☐	☐
Channel Islands	☐	☐	☐	☐
Isle of Man	☐	☐	☐	☐
Republic of Ireland	☐	☐	☐	☐
Czech Republic	☐	☐	☐	☐
Poland	☐	☐	☐	☐
Slovakia	☐	☐	☐	☐
Bangladesh	☐	☐	☐	☐
India	☐	☐	☐	☐
Pakistan	☐	☐	☐	☐
Sri Lanka	☐	☐	☐	☐
Philippines	☐	☐	☐	☐
Don't know	☐	☐	☐	☐

Your mother's mother - Other (Please write in)

Your mother's father - Other (Please write

Your father's mother - Other (Please write in)

Your father's father - Other (Please write in)

1 2 3 4 5

Draft

Draft

If answered Pakistan in C6 for where any of your grandparents were born ask C7:
If not go to C8.

Answer this if your grandparents were born in Pakistan If not go to C8.

C7. Were your grandparents born in Mirpur district? (Cross ONE box ONLY in each row)

Your mothers mother	☐ Yes	☐ No	☐ Don't Know
Your mother's father	☐ Yes	☐ No	☐ Don't Know
Your father's mother	☐ Yes	☐ No	☐ Don't Know
Your father's father	☐ Yes	☐ No	☐ Don't Know

C7a) If yes, which town or village ?

Your mother's mother - (Please write in) ☐ Don't Know

Your mother's father - (Please write in) ☐ Don't Know

Your father's mother - (Please write in) ☐ Don't Know

Your father's father - (Please write in) ☐ Don't Know

C7b) Do you know the name of your grandparent's Biraderies?

Your mothers mother - (Please write in) ☐ Don't Know

Your mothers father - (Please write in) ☐ Don't Know

Your fathers mother - (Please write in) ☐ Don't Know

Your fathers father - (Please write in) ☐ Don't Know

Draft

C8. What country were the parents of your baby's father born in?
(Cross ONE box ONLY in each column).

Country	Mother of baby's father	Country	Father of baby's father
England	☐	England	☐
Northern Ireland	☐	Northern Ireland	☐
Scotland	☐	Scotland	☐
Wales	☐	Wales	☐
Channel Islands	☐	Channel Islands	☐
Isle of Man	☐	Isle of Man	☐
Republic of Ireland	☐	Republic of Ireland	☐
Czech Republic	☐	Czech Republic	☐
Poland	☐	Poland	☐
Slovakia	☐	Slovakia	☐
Bangladesh	☐	Bangladesh	☐
India	☐	India	☐
Pakistan	☐	Pakistan	☐
Sri Lanka	☐	Sri Lanka	☐
Philippines	☐	Philippines	☐
Don't know	☐	Don't know	☐

Mother of baby's father - Other (Please write in)

Father of baby's father - Other (Please write in)

1 2 3 4 5

Draft

Draft

If answered Pakistan in C8 for where the mother of the baby's father or father of the baby's father was born ask C9: If not then go to C10.

Answer this if the mother of the baby's father or father of the baby's father was born in Pakistan

C9. Was the mother of the baby's father / father of the baby's father born in Mirpur ? (Cross ONE box ONLY in each row)

Mother of baby's father	☐ Yes	☐ No	☐ Don't Know
Father of baby's father	☐ Yes	☐ No	☐ Don't Know

C9a) If yes, which town or village ?

Mother of baby's father - (Please write in) ☐ Don't Know

Father of baby's father - (Please write in) ☐ Don't Know

C9b) Do you know the name of your baby's father's parents' Biraderies?

Mother of baby's father - (Please write in) ☐ Don't Know

Father of baby's father - (Please write in) ☐ Don't Know

Returning to you;

C10. To which of these groups do you consider you belong? (Cross ONE box ONLY)

☐ White ☐ Asian or Asian British

☐ Mixed ethnic group ☐ Chinese

☐ Black or Black British ☐ Other

C10a) If Answered C10 as White what do you consider your cultural background? (Cross ONE box ONLY)

☐ British ☐ Irish

Any other white background (please write in)

1 2 3 4 5

Draft

Draft

C10b) If Answered C10 as Mixed ethnic group what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ White and Black Caribbean
- ☐ White and Black African
- ☐ White and Indian
- ☐ White and Pakistani
- ☐ White and Bangladeshi
- ☐ White and Indian Caribbean
- ☐ White and African-Indian

Any other mixed background (please write in)

C10c) If answered C10 as Black or Black British what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ Caribbean
- ☐ African

Any other Black background (please write in)

C10d) If answered C10 as Asian or Asian British what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ Indian
- ☐ Pakistani
- ☐ Bangladeshi
- ☐ Indian Caribbean
- ☐ African-Indian

Any other Asian background (please write in)

C10e) If answered C10 as Chinese what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ Chinese
- ☐ Japanese
- ☐ Filipino
- ☐ Vietnamese

Any Chinese or other background (please write in)

C10f) If answered C10 as Other what do you consider your cultural background?
(please write in)

Draft

Section D - Your Family

These questions are about you and your family and about baby's father and his family.

D1. Are you related to the father of your baby other than by marriage? For example are you cousins? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

D1a) If yes, how are you related to the father of your baby? e.g. 1st cousin, 2nd cousin (Cross ONE box ONLY)

☐ 1st Cousin
☐ 1st Cousin, once removed
☐ Second Cousin
☐ Other related by blood
☐ Other related by marriage
☐ Don't know

D2. Were your parents related? For example were they cousins? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

D2a) If yes, how were your parents related? (Cross ONE box ONLY)

☐ 1st Cousins
☐ 1st Cousins, once removed
☐ Second Cousins
☐ Other related by blood
☐ Other related by marriage
☐ Don't know

D3. Were the parents of the father of your baby related? For example were they cousins? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

D3a) If yes, how were they related? (Cross ONE box ONLY)

☐ 1st Cousins
☐ 1st Cousins, once removed
☐ Second Cousins
☐ Other related by blood
☐ Other related by marriage
☐ Don't know

Interviewer: If answered yes in D1, please complete a family tree (on a separate form after you have completed this section. Do not change questions D1 to D3 after the family tree is completed).

D4. Was a family tree completed? ☐ Yes ☐ No

1 2 3 4 5

Draft

Draft

Section E Education

E1. What is the highest educational qualification you have? (Cross ONE box ONLY)

- ☐ 1 + 0 levels/CSEs/GCEs (any grades)
- ☐ 5 + 0 levels, 5+ CSEs (grade 1) 5 + GCSEs (grades A-C), School Certificate
- ☐ 1 + A levels/AS levels
- ☐ 2 + A levels, 4 + AS levels, Higher School Certificate
- ☐ NVQ Level 1, Foundation GNVQ
- ☐ NVQ Level 2,Intermediate GNVQ
- ☐ NVQ Level 3, Advanced GNVQ
- ☐ NVQ Levels 4-5, HNC, HND
- ☐ First Degree (e.g. BA, BSc)
- ☐ Higher Degree (e.g. MA, PhD, PGCE Post-graduate certificates/diplomas)
- ☐ Other qualifications (e.g. City and Guilds, RSA/OCR, BTEC/Edexcel)
- ☐ Overseas qualification *(If obtained in Pakistan go to E1a, If obtained in another country go to E1b)*
- ☐ No Qualifications
- ☐ Don't know

E1a) If your highest educational qualification was obtained in Pakistan please indicate: (Cross ONE box ONLY)

- ☐ Second School Certificate (SSC) Matriculation (Metric)
- ☐ Diploma in Commerce
- ☐ Higher Secondary (HSC) Cert/Intermediate Humanities, Pre-Eng or Pre-Medical/Science Streams
- ☐ Certificate from Board of Technical Education
- ☐ Diploma from Board of Technical Education
- ☐ Final Apprenticeship Certificate/Grade 2 Skilled
- ☐ Vocational Institute Diploma/Grade 3 Skilled Worker Certificate
- ☐ Batchelor Degree (4 year) in generally professional fields (excluding Bachelor of Education)
- ☐ Batchelor of Arts/Commerce/Engineering/Science/Technology (Pass and Honours)
- ☐ Postgraduate Eg Masters degree/PhD
- ☐ Don't know

1 2 3 4 5

Draft

Draft

E1b) If your highest educational qualification was not obtained in the UK or in Pakistan, please specify what that qualification was and which country it was obtained in.

Qualification

Country

E2. What is baby's father's highest educational qualification? (Cross ONE box ONLY)

- ☐ 1 + 0 levels/CSEs/GCEs (any grades)
- ☐ 5 + 0 levels, 5+ CSEs (grade 1) 5 + GCSEs (grades A-C), School Certificate
- ☐ 1 + A levels/AS levels
- ☐ 2 + A levels, 4 + AS levels, Higher School Certificate
- ☐ NVQ Level 1, Foundation GNVQ
- ☐ NVQ Level 2,Intermediate GNVQ
- ☐ NVQ Level 3, Advanced GNVQ
- ☐ NVQ Levels 4-5, HNC, HND
- ☐ First Degree (e.g. BA, BSc)
- ☐ Higher Degree (e.g. MA, PhD, PGCE Post-graduate certificates/diplomas)
- ☐ Other qualifications (e.g. City and Guilds, RSA/OCR, BTEC/Edexcel)
- ☐ Overseas qualification ***(If obtained in Pakistan go to E2a, If obtained in another country go to E2b)***
- ☐ No Qualifications
- ☐ Don't know

1 2 3 4 5

Draft

Draft

E2a) If his highest educational qualification was obtained in Pakistan please indicate (Cross ONE box ONLY)

- ☐ Second School Certificate (SSC) Matriculation (Metric)
- ☐ Diploma in Commerce
- ☐ Higher Secondary (HSC) Cert/Intermediate Humanities, Pre-Eng or Pre-Medical/Science Streams
- ☐ Certificate from Board of Technical Education
- ☐ Diploma from Board of Technical Education
- ☐ Final Apprenticeship Certificate/Grade 2 Skilled
- ☐ Vocational Institute Diploma/Grade 3 Skilled Worker Certificate
- ☐ Batchelor Degree (4 year) in generally professional fields (excluding Bachelor of Education)
- ☐ Batchelor of Arts/Commerce/Engineering/Science/Technology (Pass and Honours)
- ☐ Postgraduate Eg Masters degree/PhD
- ☐ Don't know

E2b) If his highest educational qualification was not obtained in the UK or Pakistan, please specify what the qualification was and which country it was obtained in.

Qualification

Country

Draft

Section F Your Current Employment

F1. Are you currently a full time student? ☐ Yes ☐ No

F2. Are you currently working? ☐ Yes ☐ No (If Yes, go to F3)

F2a) If No - Have you ever worked? ☐ Yes ☐ No (If No, go to F12)

F2b) If yes to F2a - how long ago did you stop working?

Years ☐☐ Months ☐☐

If stopped less than one month ago record weeks - (round up to nearest week) Weeks ☐☐

F3. Are you currently on Maternity/Sick Leave? ☐ Yes ☐ No

F4. Were/are you self employed? ☐ Yes ☐ No

F4a) If no to F4 - If an employee, what type of industry/company do/did you work for?

F5. What was/is your job title?

F5b) How many people work at the place that you usually work?

☐ 1-2 ☐ 3-24 ☐ 25-499 ☐ 500+ (Cross ONE box ONLY)

F5c) Are/were you a: (Cross ONE box ONLY)

☐ Manager ☐ Supervisor ☐ Other Employee

F6. Please list the 2 or 3 main tasks you perform/performed at work?

F7. How many hours do/did you work in a typical week?

Indicate number of hours ☐☐.☐

1 2 3 4 5

Draft

Draft

Only answer F8-F11 if currently working or stopped working less than one year ago.

F8. How long have/had you done this job?

Years ☐☐ Months ☐☐

F9. Where is/was your main place of work? (Cross ONE box ONLY)

☐ Work mainly at or from home ☐ No regular place of work

If neither of the above ask 10 and 10a. Everyone should be asked F11.

F10. What is/was your main place of work?

Street

Town

Postcode

F10a. How do/did you usually travel to work?

Cross ONE box ONLY indicating what is/was the longest part, by distance, of your usual journey to work.

- ☐ Work mainly at or from home
- ☐ Train
- ☐ Bus, minibus or coach
- ☐ Motor cycle, scooter or moped
- ☐ Driving a car or van
- ☐ Passenger in a car or van
- ☐ Taxi
- ☐ Bicycle
- ☐ On foot
- ☐ Other

Other - (please write in)

F11. How many days in a typical week do/did you go to work?

(Enter 0 if works mainly at or from home)

Days ☐☐

1 2 3 4 5

Draft

Draft

About baby's father

***F12. Which best describes the sort of work the baby's father does?**

If not in work now, please cross **ONE box ONLY** to show what work he did in his last main job.

- ☐ Modern professional occupations
- ☐ Clerical and intermediate occupations
- ☐ Senior managers or administrators
- ☐ Technical and craft occupations
- ☐ Semi-routine manual and service occupations
- ☐ Routine manual and service occupations
- ☐ Middle or junior managers
- ☐ Traditional professional occupations
- ☐ Self Employed
- ☐ Student/in training
- ☐ Does not work – long term unemployed/ill health (one year or over).
- ☐ Don't know

Draft

*F13. **Can you tell me which of these credits/allowances/benefits you and your husband/partner receive?**
(Please cross ALL that apply)

- ☐ Child Benefit
- ☐ Child Tax Credit
- ☐ Working Tax Credit (Formerly Working Family Tax Credit and Disabled Person's Tax Credit)
- ☐ Income Support
- ☐ Disability Living Allowance (including Disabled Person's Tax Credit)
- ☐ Income tested Job Seekers Allowance (Unemployment)
- ☐ Housing Benefit/Rent Rebate/Council Tax Benefit
- ☐ Incapacity Benefit (Replaces Invalidity and NI Sickness Benefit)
- ☐ Pension Credit
- ☐ Carer's allowance (was Invalid Care Allowance)
- ☐ None
- ☐ Don't know
- ☐ Does not wish to answer

Any Other State Benefit Please specify below

1 2 3 4 5

Draft

Draft

***F14. This table shows income in weekly, monthly and annual amounts.**
Which of the amounts on this list represents you and your husband/partner's, total income from all jobs, (full and part time), all tax credits, all benefits and all other sources and earnings after tax when all income is added together. (Cross ONE box ONLY)

Weekly Income after Tax	Monthly Income after tax	Annual Income after Tax	
Less than £25	Less than £108	less than £1,299	☐
£25 - £39	£109 - £175	£1,300 - £2,099	☐
£40 - £59	£176 - £259	£2,100 - £3,099	☐
£60 - £79	£260 - £350	£3,100 - £4,199	☐
£80 - £99	£351 - £433	£4,200 - £5,199	☐
£100 - £124	£434 - £542	£5,200 - £6,499	☐
£125 - £149	£543 - £650	£6,500 - £7,799	☐
£150 - £179	£651 - £775	£7,800 - £9,299	☐
£180 - £209	£776 - £917	£9,300 - £10,999	☐
£210 - £259	£918 - £1,125	£11,000 - £13,499	☐
£260 - £299	£1,126 - £1,333	£13,500 - £15,999	☐
£300 - £379	£1,334 - £1,667	£16,000 - £19,999	☐
£380 - £479	£1,668 - £2,083	£20,000 - £24,999	☐
£480 - £577	£2,084 - £2,500	£25,000 – £29,999	☐
£578 - £769	£2,501 - £3,333	£30,000 - £39,999	☐
£770 - £962	£3,334 - £4,167	£40,000 - £49,999	☐
£963 - £1,154	£4,168 - £5,000	£50,000 - £59,999	☐
£1,155 - £1,346	£5,001 - £5,833	£60,000 - £69,999	☐
£1,347 - £1,538	£5,834 - £6,667	£70,000 - £79,999	☐
£1,539 or more	£6,668 or more	£80,000 or more	☐
Does not wish to answer ☐		Don't know	☐

1 2 3 4 5

Draft

Draft

The next few questions are about the sorts of things that some people have but which many people have difficulty finding the money for.

***F15. Do you or you and your husband/partner have?**
(Cross ONE box ONLY in each row)

	Yes	I/we would like this but can't afford it at this moment	I/we do not want/need this at the moment	Does not wish to answer	Don't know
a) A holiday from home for at least one week once a year (not including staying with relatives in their home)	☐	☐	☐	☐	☐
b) Friends or family who call for a drink or meal at your house at least once a month	☐	☐	☐	☐	☐
c) Two pairs of all weather shoes	☐	☐	☐	☐	☐
d) Enough money to keep your home in a decent state of decoration	☐	☐	☐	☐	☐
e) Household contents Insurance	☐	☐	☐	☐	☐
f) Money to make regular savings of £10 a month or more for rainy days or retirement	☐	☐	☐	☐	☐
g) Money to replace any worn out furniture	☐	☐	☐	☐	☐
h) Money to replace or repair major electrical goods such as a refrigerator or a washing machine when broken	☐	☐	☐	☐	☐
i) A small amount of money to spend each week on yourself (not on your family)	☐	☐	☐	☐	☐
j) A hobby or leisure activity	☐	☐	☐	☐	☐
k) In winter are you able to keep your home warm enough	☐	☐	☐	☐	☐

***F16. Sometimes people are not able to pay every bill when it falls due. May I ask, are you up to date with the bills on this list or are you behind with any of them?**

Interviewer: Show card with list of bills

F16a) Are you up to date with all these bills? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know ☐ Does not wish to answer

1 2 3 4 5

Draft

Draft

F16b) If no, which ones are you behind with? (Cross ALL that apply)

- ☐ Electricity Bill
- ☐ Gas
- ☐ Other fuel bills like coal or oil
- ☐ Council tax
- ☐ Insurance Policies
- ☐ Telephone Bill
- ☐ Television/video/DVD rental or hire purchase
- ☐ Other hire purchase payments
- ☐ Water rates

***F17. These questions apply if you have any children living in your household now.** (Cross ONE box ONLY in each row)

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
a) Are there enough bedrooms for every child of 10 or over of a different sex to have their own bedroom.	☐	☐	☐	☐

The following questions apply to your children living with you

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
b) Does your child/children have leisure equipment or a bicycle	☐	☐	☐	☐
c) Does your child/children have celebrations on special occasions such as birthdays, or religious festivals	☐	☐	☐	☐
d) Does your child/do your children go swimming at least once a month	☐	☐	☐	☐
e) Does your child/children do A hobby or leisure activity	☐	☐	☐	☐
f) Does your child/children have friends round for tea or a snack once a fortnight	☐	☐	☐	☐

F18. If you have any children age under 6 who are not in School

(Cross ONE box ONLY)

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
Does your child/children go to a toddler group/nursery/playgroup at least once a week	☐	☐	☐	☐

F19. If your child/children is/are over age 6 or in school.

(Cross ONE box ONLY)

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
Does your child/children go on school trips	☐	☐	☐	☐

1 2 3 4 5

Draft

Draft

F20. For children of all ages (Cross ONE box ONLY)

	Yes	No	Does not apply
Does your child/children have an outdoor space or facilities nearby where they can play safely	☐	☐	☐

F21. How well would you say you or you and your husband/partner are managing financially these days. Would you say you are? (Cross ONE box ONLY)

☐ Living comfortably
☐ Doing alright
☐ Just about getting by
☐ Finding it quite difficult
☐ Finding it very difficult
☐ Does not wish to answer

F22. Compared to a year ago, how would you say you and your husband/partner are doing financially now? (Cross ONE box ONLY)

☐ Better off
☐ Worse off
☐ About the same
☐ Does not wish to answer

Draft

Section G - Smoking/Alcohol/Drug Use

We apologise if any questions in this section cause offence - we are asking everyone the same questions but we realise some religions do not permit certain things.

SMOKING

G1. Have you ever regularly smoked cigarettes; that is at least one cigarette a day? (Cross ONE box ONLY)

☐ Yes for more than 1 year ☐ Yes for less than 1 year ☐ No

If NO, go to question G4

G1a) How old were you when you started smoking cigarettes?

Age: ☐☐ Years old ☐ Don't Remember

G2. Do you smoke cigarettes nowadays? ☐ Yes ☐ No (Cross ONE box ONLY)

G2a) If no, when did you stop smoking?

Age: ☐☐ Years old ☐ Don't Remember

G3. How many cigarettes do/did you smoke during pregnancy, or in the three months before pregnancy? (Cross ONE box ONLY in each row)

	None	1-5 a day	6-10 a day	11-20 a day	Over 20 a day
a) 3 months before	☐	☐	☐	☐	☐
b) First 3 months of pregnancy	☐	☐	☐	☐	☐
c) Since the beginning of 4th month	☐	☐	☐	☐	☐

G4. During pregnancy have you been exposed to other peoples' cigarette smoke at work or at home and if Yes, for how many hours per day approx?
(Cross ONE box ONLY)

☐ Yes ☐ No ☐ Less than 1 hour per day/occasionally

If yes - Hours ☐☐

1 2 3 4 5

Draft

Draft

G5. Have you used any other tobacco products like Paan during pregnancy, or in the 3 months before pregnancy? Interviewer: please show list of possible products.
(Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know — If No, Don't Know or you don't remember go to question G6

***G5a) If yes please identify which ones and how many you smoke/chew etc., (relevant to point in pregnancy)**

3 Months before pregnancy	Daily	Weekly	Monthly	Rarely	If 1+ per week, how many per week
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	

First 3 months of pregnancy	Daily	Weekly	Monthly	Rarely	If 1+ per week, how many per week
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	

From beginning of 4th month to now	Daily	Weekly	Monthly	Rarely	If 1+ per week, how many per week
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	

G6. Have you used any drugs like marijuana or ecstasy during pregnancy or in the three months before pregnancy? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know — If No, Don't Know or you don't remember go to question G7

Draft

*G6a) If yes please identify which ones and how often you have taken them (relevant to point in pregnancy)

	Daily	Weekly	Monthly	Rarely	If 1+ per week, how many per week
3 Months before pregnancy					
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
First 3 months of pregnancy					
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
From beginning of 4th month to now					
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐
☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	☐	☐	☐	☐	☐☐

ALCOHOL

G7. Did you drink any alcohol during your pregnancy or in the 3 months before? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Remember If NO or don't remember go to Section H

G7a) Did you drink any alcohol in the 3 months before pregnancy?
(Cross ONE box ONLY)

☐ Yes, Once per week or more ☐ Yes, occasionally ☐ No ☐ Don't remember

Draft

1 2 3 4 5

Draft

If NO or don't remember go to question G7d)

G7b) If once per week or more, what is the weekly average and maximum number of units in a week?

	Average number of units per week	Maximum units at one time
Beer/Lager	☐☐	☐☐
Wine	☐☐	☐☐
Spirits	☐☐	☐☐
Other	☐☐	☐☐
Don't remember	☐	☐

G7c) In the 3 months before pregnancy how often did you consume 5 or more units of alcohol on one occasion? (Cross ONE box ONLY)

☐ Everyday ☐ 1-3 times a month

☐ Nearly every day ☐ Rarely

☐ 1-4 times/week ☐ Never

G7d) Did you drink any alcohol in the first 3 months of pregnancy?
(Cross ONE box ONLY)

☐ Yes, Once per week or more ☐ Yes, occasionally ☐ No ☐ Don't remember

If NO or don't remember go to section G7g)

G7e) If once per week or more, what is the average and maximum number of units in a week?

	Average number of units per week	Maximum units at one time
Beer/Lager	☐☐	☐☐
Wine	☐☐	☐☐
Spirits	☐☐	☐☐
Other	☐☐	☐☐
Don't remember	☐	☐

1 2 3 4 5

Draft

Draft

G7f) In the first 3 months of pregnancy how often did you consume 5 or more units of alcohol on one occasion? (Cross ONE box ONLY)

☐ Every day or more often ☐ 1-3 times a month

☐ Nearly every day ☐ Rarely

☐ 1-4 times/week ☐ Never

G7g) Did you drink any alcohol from the beginning of the 4th month until now of your pregnancy? (Cross ONE box ONLY)

☐ Yes, Once per week or more ☐ Yes, occasionally ☐ No ☐ Don't remember

If NO or don't remember go to section H

G7h) If once per week or more, what is the average and maximum number of units in a week?

	Average number of units per week	Maximum units at one time
Beer/Lager	☐☐	☐☐
Wine	☐☐	☐☐
Spirits	☐☐	☐☐
Other	☐☐	☐☐
Don't remember	☐	☐

G7i) Since the beginning of the 4th month of your pregnancy how often did you consume 5 or more units of alcohol on one occasion?
(Cross ONE box ONLY)

☐ Every day or more often ☐ 1-3 times a month

☐ Nearly every day ☐ Rarely

☐ 1-4 times/week ☐ Never

1 2 3 4 5

Draft

Draft

Section H Your diet

BREADS AND BREAD PRODUCTS

H1. During the last 4 weeks, on average how many slices/pieces of the following did you eat per week?

	Total Slices/Pieces	No. eaten as toast
a) White bread incl baguette	☐☐	☐☐
b) Brown bread incl granary, multiseed, best of both, 50/50.	☐☐	☐☐
c) Baps/rolls/teacake	☐☐	☐☐
d) Crumpets	☐☐	☐☐
e) Pizza (1 slice)	☐☐	
f) Roti/Chappatis	☐☐	
g) Naan, pitta bread, bagel	☐☐	☐☐
h) Paratha	☐☐	
Other bread products e.g. wraps, croissants, pancakes, flatbreads, English muffin	☐☐	☐☐

Other please write in

1 2 3 4 5

Draft

Draft

CAFFEINATED DRINKS

H2. During the last 4 weeks of pregnancy, on average, how many cups or mugs of the following drinks would you have per day or per week?
(Glass is 200 ml Cup is 200 ml 1 Mug = 2 cups.
If less than 1 per day enter weekly average)

How many cups of: ?	Per day	Per Week
a) Instant coffee (Caffeinated)	☐☐	☐☐
b) Instant coffee (De-caffeinated)	☐☐	☐☐
c) Filter/cafetiere coffee (Caffeinated)	☐☐	☐☐
d) Filter/cafetiere coffee (De-caffeinated)	☐☐	☐☐
e) Tea (Caffeinated)	☐☐	☐☐
f) Tea (De-caffeinated)	☐☐	☐☐
g) Kashmiri tea (Caffeinated)	☐☐	☐☐
h) Kashmiri tea (De-caffeinated)	☐☐	☐☐
i) Herbal/fruit teas (Caffeinated)	☐☐	☐☐
j) Herbal/fruit teas (De-caffeinated)	☐☐	☐☐
k) Cola (regular, with sugar Caffeinated)	☐☐	☐☐
l) Cola (regular, with sugar De-caffeinated)	☐☐	☐☐
m) Diet or sugar free cola (Caffeinated)	☐☐	☐☐
n) Diet or sugar-free cola (De-caffeinated)	☐☐	☐☐

1 2 3 4 5

Draft

Draft

SUPPLEMENTS/VITAMINS

H3. Have you taken any dietary supplements including vitamins or iron tablets in the last 4 weeks of pregnancy? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Remember

H3a) If Yes, which:

	Daily	5-6 per week	2-4 per week	Once a week	Less Often
Vitamin C	☐	☐	☐	☐	☐
Vitamin D	☐	☐	☐	☐	☐
Vitamin E	☐	☐	☐	☐	☐
Iron	☐	☐	☐	☐	☐

Other vitamins and dietary supplements, please write in below:

Don't Know ☐

If multivitamins:

Pregnacare	☐	☐	☐	☐	☐
Sanatogen prenatal	☐	☐	☐	☐	☐

Other multivitamins, please write in below:

Don't Know ☐

Draft

Section I Water Consumption

***I1. On a typical day how much of the following do you drink?**

	At home	At work/study	Elsewhere
a) Tap water	Glasses per day: ☐☐	Glasses per day: ☐☐	Glasses per day: ☐☐
b) Bottled water (Includes water cooler)	Glasses per day: ☐☐	Glasses per day: ☐☐	Glasses per day: ☐☐
c) Tea (any sort)	Cups per day: ☐☐	Cups per day: ☐☐	Cups per day: ☐☐
d) Coffee	Cups per day: ☐☐	Cups per day: ☐☐	Cups per day: ☐☐
e) Squash (Including any other drinks made with tap water)	Glasses per day: ☐☐	Glasses per day: ☐☐	Glasses per day: ☐☐

I2. Do you filter the water you drink at home? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

I3. Do you filter the water you drink at work? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know ☐ N/A

I4. In a typical week while you have been pregnant how often and for how long do you undertake the following?
(if you do not do any then fill in 0)

	Times per week	Minutes each time
Shower	☐☐	☐☐☐
Bath	☐☐	☐☐☐
Swim	☐☐	☐☐☐

1 2 3 4 5

Draft

Draft

Study ID [ ][ ][ ][ ][ ] [P][ ]

Section J General Health

Interviewer to give questionnaire for this section to be self-completed.

We should like to know if you have had any medical complaints and how your health has been in general, over the past few weeks. Please answer ALL the questions on the following pages simply by putting a cross by the answer which you think most nearly applies to you. Remember that we want to know about present and recent complaints, not those that you had in the past. It is important that you try to answer ALL the questions.

Cross ONE box ONLY for each question - have you:

J1a. Been feeling perfectly well and in good health?
☐ Better than usual ☐ Same as usual ☐ Worse than usual ☐ Much worse than usual

J1b. Been feeling in need of a good tonic?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1c. Been feeling run down and out of sorts?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1d. Felt that you are ill?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1e. Been getting any pains in your head?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1f. Been getting a feeling of tightness or pressure in your head?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1g. Been having hot or cold spells?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2a. Lost much sleep over worry?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2b. Had difficulty in staying asleep once you are off?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2c. Felt constantly under strain?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2d. Been getting edgy and bad- tempered?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2e. Been getting scared or panicky for no good reason?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

1 2 3 4 5

Draft

Draft

J2f. Found everything getting on top of you?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2g. Been feeling nervous and strung-up all the time?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J3a. Been managing to keep yourself busy and occupied?
☐ More so than usual ☐ Same as usual ☐ Rather less than usual ☐ Much less than usual

J3b. Been taking longer over the things you do?
☐ Quicker than usual ☐ Same as usual ☐ Longer than usual ☐ Much longer than usual

J3c. Felt on the whole you were doing things well?
☐ Better than usual ☐ About the same as usual ☐ Less well than usual ☐ Much less well

J3d. Been satisfied with the way you've carried out your tasks?
☐ More satisfied ☐ About the same as usual ☐ Less satisfied than usual ☐ Much less satisfied

J3e. Felt that you are playing a useful part in things?
☐ More so than usual ☐ Same as usual ☐ Less useful than usual ☐ Much less than usual

J3f. Felt capable of making decisions about things?
☐ More so than usual ☐ Same as usual ☐ Rather less so than usual ☐ Much less capable

J3g. Been able to enjoy your normal day-to-day activities?
☐ More so than usual ☐ Same as usual ☐ Less so than usual ☐ Much less than usual

J4a. Been thinking of yourself as a worthless person?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4b. Felt that life is entirely hopeless?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4c. Felt that life isn't worth living?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4d. Thought of the possibility that you might make away with yourself?
☐ Definitely not ☐ I don't think so ☐ Has crossed my mind ☐ Definitely have

J4e. Found at times you couldn't do anything because your nerves were too bad?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4f. Found yourself wishing you were dead and away from it all?
☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4g. Found that the idea of taking your own life kept coming into your mind?
☐ Definitely not ☐ I don't think so ☐ Has crossed my mind ☐ Definitely has

1 2 3 4 5

Draft

Draft

Study ID ☐☐☐☐☐ P☐

Section K Exercise

Interviewer to give questionnaire for this section to be self-completed

K1. Please tell us about the type and amount of physical activity involved in your paid work. (Cross ONE box ONLY)

☐ I am not in paid employment

☐ I spend most of my time at work sitting (such as in an office)

☐ I spend most of my time at work standing or walking. However my work does not require much intense physical effort (e.g. shop assistant; hairdresser; childminder)

☐ My work involves definite physical effort including handling of heavy objects and use of tools (e.g. cleaner; hospital nurse; gardener, postal delivery worker)

☐ My work involves vigorous physical activity including handling of very heavy objects.

K2. During the last week how many hours did you spend on each of the following activities? (Cross only one box in each row)

	None	Some but less than one hour	1 hour but less than 3 hours	3 hours or more
a) Physical exercise such as swimming, jogging, aerobics, tennis, gym workout etc	☐	☐	☐	☐
b) Cycling, including cycling to work and during leisure time	☐	☐	☐	☐
c) Walking, including walking to work, shopping, for pleasure etc	☐	☐	☐	☐
d) Housework/childcare	☐	☐	☐	☐
e) Gardening/DIY (Do it Yourself)	☐	☐	☐	☐

K3. How would you describe your usual walking pace?

☐ Slow pace ☐ Steady average pace

☐ Brisk pace ☐ Fast pace

Please return to the interviewer' - 'Thank you for completing this questionnaire

1 2 3 4 5

Draft

Draft

Section Interviewer's feedback

L1. Was anyone present with Mother during the interview? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Part of interview

L1a) If yes or part of interview: who was present? (Cross ALL that apply)

☐ Baby's father ☐ Mother's friend

☐ Mother's mother ☐ Relative

☐ Mother's father ☐ Child

Other (please write in)

L2 Was a transliteration used to administer the questionnaire? ☐ Yes ☐ No ☐ Partially
(Cross ONE box ONLY)

L3 Were there any problems in completing this interview? ☐ Yes ☐ No

L3a) If yes, what were the problems

L4 Do you feel confident with the answers provided? ☐ Yes ☐ No

L4a) If no, why are you not confident?

COMPLETED QUESTIONNAIRE - CHECKED BY STUDY ADMINISTRATOR ☐ Yes

ALSO CHECKED: ☐ M Diet ☐ J General Health ☐ K Exercise

Interviewer Number
(if applicable)

BY: Name

1 2 3 4 5

Draft

Draft

Study ID | | | | | | P | |

Section M Your diet

Questionnaire about your diet

This short questionnaire asks you about the food you have eaten over the last four weeks of your pregnancy. You may not eat all the foods given or you may find that some of the foods you eat are not included – please do not worry but complete all of the question asked.

Please do not leave any of the lines blank and answer every question even if you are uncertain.

INSTRUCTIONS ABOUT HOW TO COMPLETE THE QUESTIONS

Please put a cross in each box to show how often you have eaten each food item. E.g. if you eat 4 slices of white bread a day – cross the box as shown below

FOOD ITEM	HOW OFTEN HAVE YOU EATEN THIS IN THE LAST 4 WEEKS?							
	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ a Day
White bread	0	1	2	3	4	5	X 6	7

If you make a mistake and cross the wrong box, just cross out and enter the cross in the correct box.
E.g. If you cross you had fruit juice 3 times a day when you meant 3 times a week just cross out the '3-4 times a day' answer and cross the '2-3 times a week' box.

FOOD ITEM	HOW OFTEN HAVE YOU EATEN THIS IN THE LAST 4 WEEKS?							
	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ a Day
Fruit juice (not cordial or squash)	0	1	2	X 3	4	5	~~X~~	7

1 2 3 4 5

Draft

Draft

M1. The following questions ask about some food and drinks you might have consumed during the last 4 weeks of your pregnancy. Do not be concerned if some things you eat or drink are not mentioned.

Please cross how often you eat at least ONE portion of the following foods & drinks: (a portion includes: a packet of crisps, a serving of chips, one bowl of cereal). **(Please cross ONE box ONLY, but answer EVERY line even if you don't eat that food)**

	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ Times a Day
a) Chips	☐	☐	☐	☐	☐	☐	☐	☐
b) Roast or fried potatoes, hash browns or potato waffles	☐	☐	☐	☐	☐	☐	☐	☐
c) Fibre or bran-rich wheat breakfast cereal, like Weetabix, Fruit 'n Fibre, Bran flakes	☐	☐	☐	☐	☐	☐	☐	☐
d) Oat cereals including muesli, porridge, crunchy oats, instant hot oats	☐	☐	☐	☐	☐	☐	☐	☐
e) Other breakfast cereals like cornflakes, rice krispies, Cheerios	☐	☐	☐	☐	☐	☐	☐	☐
f) Crispbread, like Ryvita	☐	☐	☐	☐	☐	☐	☐	☐
g) Pasta or noodles (also pot noodles, tinned spaghetti)	☐	☐	☐	☐	☐	☐	☐	☐
h) Savouries like Yorkshire puddings, dumplings, pakoras or bhajia	☐	☐	☐	☐	☐	☐	☐	☐
i) Potato crisps	☐	☐	☐	☐	☐	☐	☐	☐
j) Other salted savoury snacks like tortilla chips, Wotsits, Quavers, Bombay mix	☐	☐	☐	☐	☐	☐	☐	☐
k) Cakes, buns, gateaux, doughnuts, muffins	☐	☐	☐	☐	☐	☐	☐	☐
l) Sweet pastries like fruit pies, Danish pastries, custard/curd tarts, croissants	☐	☐	☐	☐	☐	☐	☐	☐
m) Chocolate bars and chocolate coated biscuits e.g. Twix, Kit-Kat, Dairy milk bar	☐	☐	☐	☐	☐	☐	☐	☐
n) Sweet biscuits like digestive, custard creams, gingernut, shortbread	☐	☐	☐	☐	☐	☐	☐	☐

1 2 3 4 5

Draft

Draft

M2. **The following questions ask about types of meat and fish you might have consumed over the last 4 weeks of your pregnancy.** Please cross how often you eat at least ONE portion of the following:

	Rarely or never	Less than 1 a Week	2-3 times a Week	4-6 times a Week	7+ times a week
Whole meats					
a) Beef - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐
b) Pork - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐
c) Lamb, mutton or goat	☐	☐	☐	☐	☐
d) Chicken or Turkey - steaks, roasts, joints, portions (not in batter, sauce or breadcrumbs)	☐	☐	☐	☐	☐
Processed meats/meat					
e) Meat sausages e.g. Walls or chipolata	☐	☐	☐	☐	☐
f) Beef burgers, either home cooked or takeaway	☐	☐	☐	☐	☐
g) Kebabs	☐	☐	☐	☐	☐
h) Hot dog, frankfurter or saveloy	☐	☐	☐	☐	☐
i) Bacon rashers	☐	☐	☐	☐	☐
j) Meat pies and pastries (sausage roll, pasties, meat samosa, steak/meat pie)	☐	☐	☐	☐	☐
k) Chicken/turkey nuggets, Kiev, turkey or chicken burgers, chicken pies, or in batter or breadcrumbs	☐	☐	☐	☐	☐
l) Ham	☐	☐	☐	☐	☐
m) Cured/dried sausage e.g. Chorizo, Salami	☐	☐	☐	☐	☐
Meat dishes					
n) Chicken or turkey with sauce e.g. curry, stir-fry, casserole	☐	☐	☐	☐	☐
o) Beef, lamb or goat in sauce e.g. curry, stew, Shepherd's pie, Bolognese sauce, Chilli con carne, Lasagne	☐	☐	☐	☐	☐
p) Pork in sauce e.g. stew, casserole or stir-fry	☐	☐	☐	☐	☐
q) Gravy made with pan or meat juices (not instant)	☐	☐	☐	☐	☐
Fish					
r) White fish in batter or breadcrumbs, like 'fish 'n chips'	☐	☐	☐	☐	☐
s) White fish not in batter or breadcrumbs e.g. cod in parsley sauce, fish curry (marsala fish), fish pie	☐	☐	☐	☐	☐
t) Tinned tuna	☐	☐	☐	☐	☐
u) Fresh or tinned oily fish like sardines, mackerel, salmon, trout (not tuna)	☐	☐	☐	☐	☐
v) Smoked fish, like smoked mackerel, kippers or smoked salmon	☐	☐	☐	☐	☐
w) Salted/dried fish e.g. 'Bombay duck'/bummalo	☐	☐	☐	☐	☐

1 2 3 4 5

Draft

Draft

M3. If eaten in the last 4 weeks of pregnancy how did you mainly cook the following?
Please enter only one cross on each line for cooking method. Cross yes if mainly eaten very well done, crispy or heavily browned as shown.

	Did not eat	Don't know or take-away	Grill	Fry	Roast	BBQ	Well done? Yes	No
a) Beef - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐	☐	☐	☐
b) Beef burgers, either home cooked or takeaway	☐	☐	☐	☐	☐	☐	☐	☐
c) Pork - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐	☐	☐	☐
d) Lamb, mutton or goat - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐	☐	☐	☐
e) Chicken or Turkey-steaks, roasts, joints, portions (not in batter, sauce or breadcrumbs)	☐	☐	☐	☐	☐	☐	☐	☐
f) Meat Sausages e.g. Walls or chipolata	☐	☐	☐	☐	☐	☐	☐	☐
g) Bacon rashers, chops or bacon ribs	☐	☐	☐	☐	☐	☐	☐	☐
h) White fish fillets or steaks e.g. cod or haddock NOT in batter	☐	☐	☐	☐	☐	☐	☐	☐
i) Oily fish fillets or steaks e.g. salmon, mackerel, trout	☐	☐	☐	☐	☐	☐	☐	☐

M4. a. Are you familiar with the "5 a day" recommendations for fruit and vegetables?

☐ Yes ☐ No

b. Do you consume 5 portions of fruit and vegetables per day?
(Please place a CROSS in ONE box ONLY)

☐ Always ☐ Sometimes ☐ Never

(Please place a CROSS in ONE box ONLY)
M5. Where does most of your advice about healthy eating during pregnancy come from?

☐ Family members ☐ GPs/Doctors

☐ Friends ☐ Midwife/Health Visitor

☐ Magazines/Newspapers ☐ Other

☐ Books

Thank you for completing this questionnaire - please leave it in the place indicated.

1 2 3 4 5

Draft

Appendix C

Neonatal Measurement Protocol

Version 1~27.6.07

This document provides clear guidance on how to collect baby measurements for Born in Bradford. It is important that you follow the same procedures every time you take a measurement, and that we all use the same techniques. By following these guidelines errors will be reduced and the results will be more accurate.

Main points:

- When measuring babies it is important to familiarise the mothers with the equipment you are using and talk them through the procedure
- To measure accurately you will need to remove the baby's clothing
- Arm and skinfold measurements should always be taken on the left side of the body
- Record each measurement to the last completed unit
- If you are unhappy with the measurement take it again. The acceptable differences between recordings are given for each measurement

It is vital that you adhere to current infection control guidelines. In particular:

- Perform hand hygiene before and after contact with each baby
- Tape measures are to be used once only, use a new measure for each baby. Dispose of the lasso-o measures in the bags provided on each ward
- Skinfold callipers must be cleaned with alcohol wipes after use on each baby
- Cover any broken skin with waterproof dressings
- Avoid sitting on patient's beds
- Remove all jewellery – the only exception is a plain wedding ring
- Remove wrist watches or bracelets
- Wear short sleeves or roll up long sleeves
- Keep nails short and do not wear nail varnish

Head circumference

Equipment – Lasso-o tape

Acceptable difference between measurements – 0.5cm

- Lay the baby flat in the cot
- Place the tape around the head
- Using the index fingers on each hand position the tape so that it crosses the most anterior part of the head (midway between eyebrows and the hair line) and most posterior part of the head (occipital prominence)
- Pull the tape tight to record the measurement

Abdominal circumference

Equipment – lasso-o tape

Acceptable difference between measurement – 0.5cm

- Lay the baby flat in the cot
- Pass the tape around the body
- Ensure that the measurement is taken at the level of the umbilicus, with tape just above umbilicus when measurement taken.
- Make sure the tape is horizontal and not compressing soft tissue
- Record the measurement

Arm circumference

Equipment – lasso-o tape

Acceptable difference between measurement – 0.5cm

- Where possible the baby's arm should be relaxed
- Locate the point midway between the elbow and the shoulder
- Pass the tape around the arm

- Make sure the tape is horizontal and not compressing soft tissue
- Record the measurement

Skinfold measurements

- Skinfold measurements record a measure of subcutaneous fat
- The thumb and index finger are used to sweep together the fold whilst the right hand operates the calliper
- The aim is to apply the calliper to the 'neck' of the fold just below your thumb and index finger
- After applying the calliper count to three and then record the measurement
- Either record the measurement whilst the baby is laying in the cot or ask the mother to hold the baby with the baby's left side facing away from her
- Reassure the mother that the calliper will not cause pain

Triceps skinfold

Equipment - caliper

Acceptable difference between measurements – 0.5mm

- With the arm bent at a right angle locate the midpoint between the elbow and shoulder
- Sweep together the fold of fat at the back of the arm i.e. triceps skinfold
- Still holding the arm, straighten the arm and take the measurement

Subscapular skinfold

Equipment - caliper

Acceptable difference – 1mm

- Locate the lowest part of the shoulder blade (inferior angle of the scapular)
- You will notice that the fold of fat runs diagonally downwards and outwards
- Sweep together the fold, apply the calliper and record the measurement

Appendix D

BORNINBRADFORD
For a Healthy Future

Standard Operating Procedure for Blood Collection and Sample Reception

Born in Bradford Study Cord Blood Leptin Samples

Collection to begin on 6.10.08

Version 1~June2008/LC

1 Collection of cord blood at delivery using syringe.

2 Collected blood is expelled into EDTA tubes as soon as possible.

3 Mix blood in EDTA tubes by gentle inversion several times.

4 Refridgerate EDTA cord blood samples on Delivery Suite (at 4° C) until collected by laboratory staff.

5 EDTA blood samples should be spun at 4°C, 3000rpm for 10-15 mins.

6 Label Apex tubes with barcode stickers (with patient ID, date, sample type, study name) and attach matching sticker to pink cord blood sample form.

7 Complete the rest of the pink form and file in the BiB cord blood sample LEPTIN folder.

8 Aliquot 0.5ml of EDTA plasma into apex tubes.

9 Freeze all aliquots in a -80°C freezer.

10 Store aliquots in blue BiB study trays labelled with study name, investigators, and box number.

11 Batches of 1000 samples should be sent to Naveed Sattar/Lynne Cherry in Glasgow.