What factors influence the proportion of underweight children in Cardiff local authority: A review of the evidence and analysis of data from the Child Measurement Programme

Author: Dr E Rachel Andrew, Specialty Registrar in Public Health, Public Health Wales, Dr Linda Bailey, Consultant in Public Health / Health Intelligence, Public Health Wales, Holly Walsh, Advanced Public Health Intelligence Analyst, Public Health Wales and Mari Ann Jones, Senior Public Health Intelligence Analyst, Public Health Wales

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Purpose and Summary of Document:

This piece of work was undertaken to investigate why a higher proportion of children in Cardiff local authority were underweight, than compared to their peers across Wales. This report describes the methods used, the results, conclusions and recommendations.

Work Plan reference:

Public Health Wales Strategic Plan 2015 – 2018: Section 8.3.2

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Abbreviations

AGA	Appropriate for Gestational Age
ALSPAC	Avon Longitudinal Study of Parents and Children
AMED	Allied & Complementary Medicine Database
%BF	Body fat percentage
BMI	Body Mass Index
CDC 200	US Centres for Disease Control and Prevention 2000 growth reference
CI	Confidence Interval
CMP	Child Measurement Programme
CWI	Child well-being index
DOH	Department of Health
EU	European Union
FSM	Free school meals
g	Grams
HMIC	Health Management Information Consortium
IMD	Index of Multiple Deprivation
IOTF	International Obesity Task Force
LA	Local Authority
LSOA	Lower Super Output Area
MCS	Millennium Cohort Study
MGRS	Multicentre Growth Reference Study
n	Number of children
NCHS	National Centre for Health Statistics
NCMP	National Child Measurement Programme
NHANES I	National Health and Nutrition Examination survey
NICE	National Institute for Health and Care Excellence
ONS	Office for National Statistics
ONS-AC	Office for National Statistics Area Classification
OR	Odds Ratio
p	P value (calculated probability)
PCT	Primary Care Trust
PHE	Public Health England
PHW	Public Health Wales
PICO	Population, Intervention, Comparison and Outcome
RCPCH	Royal College of Paediatric and Child Health
RRR	Relative risk ratio
Sacn	Scientific Advisory Committee on Nutrition
SD	Standard Deviation
SDS	Standard Deviation Score
SGA	Small for Gestational Age
SIGN	Scottish Intercollegiate Guidelines Network
UK	United Kingdom
UK90	British 1990 growth reference
WG	Welsh Government
WHO	World Health Organisation
WIMD	Welsh Index of Multiple Deprivation

Executive summary

Underweight in childhood is an important Public Health issue, as being underweight can have adverse effects on a child's health, some of which can persist into adulthood and may even effect future generations. In children, the term underweight (a low weight-for-age), reflects the BMI relative to the persons age and is affected by both the height (height-for-age) and weight (weight-for-height) of an individual. A low weight-for-height can reflect the long term health and nutritional status of that individual.

The findings from the Child Measurement Programme (2011/12, 2012/13 and 2013/14) suggested that, a higher proportion of children in Cardiff Local Authority (LA) were underweight, than compared to children in other areas of Wales. This project describes the methods used to investigate this finding. Methods included a comprehensive literature review and univariate and multivariate analysis of aggregated Child Measurement Programme data.

The key findings of the literature review include:

- There was evidence that in recent years, there has been a declining trend in the prevalence of underweight children, both in the UK and in other countries;
- The evidence in this literature review suggests that, the prevalence of underweight children, was associated with gender; and that younger boys are at increased risk of being underweight than compared to girls;
- There was evidence that the prevalence of underweight children varies between ethnic groups; with a higher proportion of children from non-White ethnic groups being underweight, than compared to children from White ethnic groups;
- There was inconclusive evidence in this literature review to say whether there is any association between the prevalence of underweight children and socioeconomic deprivation;
- There was inconclusive evidence in this literature review, to say whether there is any association between area of residence and being underweight;
- The literature review identified a number of parental factors that were associated with being underweight in childhood, including: level of maternal education; maternal underweight pre-pregnancy; older maternal age; drinking in pregnancy and maternal stress;
- The literature review identified a number of infant and/or child factors associated with being underweight in childhood, including prematurity; low birth weight and rates of growth in infancy.

Key findings from the data analysis include:

Univariate analysis:

- In Cardiff LA, a significantly higher proportion of children aged 4-5 years were underweight, than compared to their peers across Wales (Cardiff 1.47%, *95%CI 1.25 to 1.71* and Wales 0.67%, *95%CI 0.62 to 0.73*);
- Across Wales, a significantly higher proportion of boys aged 4 to 5 years were underweight, than compared to girls (Boys 0.82%, *95%CI 0.75 to 0.91* and Girls 0.51%, *95%CI 0.45 to 0.58*);
- In Cardiff LA, a higher proportion of boys aged 4 to 5 years were underweight, than compared to girls (Boys 1.75%, *95%CI 1.43 to 2.13* and Girls 1.17%, *95%CI 0.91 to*

1.50); however, this difference was not statistically significant;
- Across Wales and Cardiff LA, the ethnic group with the highest proportion of underweight children was the Asian ethnic group;
- The proportion of children aged 4 to 5 years from the Asian ethnic group who were underweight, did not differ significantly between Wales and Cardiff LA (Wales 3.41%, *95%CI 2.54 to 4.58* and Cardiff 4.24%, *95%CI 2.91 to 6.14*);
- Across Wales, a significantly higher proportion of children aged 4 to 5 years from the Asian ethnic group were underweight, than compared to children from the White ethnic group (3.41%, *95%CI 2.54 to 4.58* vs. 0.58%, *95%CI 0.52 to 0.65*);
- In Cardiff LA, a significantly higher proportion of children aged 4 to 5 years from the Asian ethnic group were underweight, than compared to children from the White ethnic group (4.24%, *95%CI 2.91 to 6.14* vs. 1.24%, *95%CI 0.96 to 1.61*);
- In Cardiff LA, a significantly higher proportion of children aged 4 to 5 years from the White ethnic group were classed as underweight, than compared to children from the White ethnic group across Wales (Cardiff 1.24%, *95%CI 0.96 to 1.61* and Wales 0.58%, *95%CI 0.52 to 0.65*);
- Across Wales, a significantly higher proportion of all children (all weight categories) aged 4 to 5 years resided in the two most deprived quintiles (25.22% in the most deprived quintile and 21.03% in the next most deprived quintile), than compared to other quintiles;
- In Cardiff LA, a significantly higher proportion of all children (all weight categories) aged 4 to 5 years resided in the most deprived quintile (41.11%), than compared to other quintiles;
- A significantly higher proportion of all children (all weight categories), aged 4 to 5 years, from Cardiff LA, resided in the most deprived quintile, than compared to all children (all weight categories), who resided in the most deprived quintile in Wales (Cardiff 41.11%, *95%CI 40.2 to 42.1* and Wales 25.22%, *95%CI 24.9 to 25.5*);
- For both Wales and Cardiff LA, there was no significant difference in the proportion of children, who resided in the least deprived quintile who were underweight, than compared to the proportion who resided in the most deprived quintile of deprivation;
- In Wales, the proportion of all children who resided in the least deprived quintile who were underweight was 0.65% (*95%CI 0.5 to 0.8*), while in the most deprived quintile the proportion was 0.73% (*95%CI 0.6 to 0.9*);
- In Cardiff LA, the proportion of all children who resided in the least deprived quintile and were underweight was 1.24% (*95%CI 0.9 to 1.8*), while in the most deprived quintile the proportion was 1.43% (*95%CI 1.1 to 1.8*);
- Across Wales, a significantly higher proportion of all children, aged 4 to 5 years, who resided in an urban area, were underweight (0.54%, *95%CI 0.5 to 0.6*), than compared to all children, aged 4 to 5 years, who resided in either a 'less sparse' rural area (0.08%, *95%CI 0.1 to 0.1*) or a 'sparse' rural area of residence (0.04%, *95%CI 0.0 to 0.1*);

Census data:
- 92.82% of children, aged 15 years and under, in Cardiff were born in the UK;
- Cardiff had a lower proportion of the usual resident population (adults & children), who were born in the UK, than compared to Wales (86.72% vs. 94.52%);
- In Cardiff a higher proportion of usual resident population (adults & children), were born outside of the EU, than compared to Wales (9.41% vs. 3.28%);
- In Cardiff a lower proportion of children, aged 7 years and under, were from the White ethnic group, than compared to Wales (73.05% vs. 92.30%);
- In Cardiff, a lower proportion of the usual resident population (adult & children), described themselves as being from a White ethnic group, than compared to Wales (84.69% vs. 95.59%);
- The second most populated ethnic group in Cardiff and Wales was the Asian/Asian British ethnic group (8.06% and 2.29% respectively);
- Cardiff has a lower proportion of households (90.47% vs. 96.73%) where the household has English (or Welsh) as a main language and a higher proportion of

households where they do not have any person (adult or child) who has English (or Welsh) as a main language (5.20% vs. 1.67%), than compared to Wales;

Logistic regression:

- The logistic regression model included all children aged 4 to 5 years in Wales, who participated in the Child Measurement Programme in 2012/13 and 2013/14 (n=59,904);
- The logistic regression model identified that children from non-White ethnic groups, were at increased risk of being underweight, than compared to children from the White ethnic group;
- Children from the Asian ethnic group were over five times more likely to be underweight, than compared to children from the White ethnic group (OR 5.45, *p-value 0.000, 95%CI 3.91 to 7.60);*
- Female gender and living in a rural area of residence were protective factors against being underweight in childhood;
- The socioeconomic deprivation variable, showed a small association with being underweight in the univariate analysis. However, when the variable was included in the multivariate analysis there was no discernible difference to the output of the final model (may have been due to the small sample size of underweight children). Therefore socioeconomic deprivation was not included in the final model;
- The logistic regression model had a good 'goodness of fit' indicating that from the (limited) variables available in the data set, the three explanatory variables used in the final model (gender, ethnicity and area of residence) were the best at explaining why children were underweight. However, the final model had poor discrimination, and suggests that the final model has a low predictive power to say that those three explanatory variables alone, can predict underweight in children.
- Explanations for the goodness of fit and the poor predictive power of the final model are the small sample size of underweight children in the sample and that there were insufficient explanatory variables in the Child Measurement Programme data set to predict underweight in children.

Conclusion

Cardiff LA is an urban area and is more ethnically diverse than other areas of Wales. These two factors may have contributed to the higher proportion of underweight children, aged 4 to 5 years, in Cardiff LA. However , the reason why there is variation between urban and rural areas and the reason why a higher proportion of children from non-White ethnic groups are underweight are not evident from the literature review and from the data analysis in this report. Therefore further work and research are recommended.

Recommendations:

- The findings of this report will be shared with colleagues in the Cardiff and Vale Local Public Health Team and wider stakeholders; their expertise and local knowledge will be essential in interpreting and adding context to the evidence and data presented in this report.
- Further work is recommended, to understand why there is variation in the proportion of underweight children, both within and between different ethnic groups, in Cardiff LA, and across Wales.
- Analysis of aggregated Child Measurement Programme data should be considered in the future, as a larger data set would increase the power

of the study and the predictive power of the logistic regression analysis. Associations which have not been identified in this report e.g. socioeconomic deprivation and underweight in childhood may then be detected.

- Analysis of trends in the Child Measurement Programme data should be considered in the future, when a larger, data set is available.

1 Introduction

The term underweight has a different meaning for adults than compared to children. In 1995 the World Health Organisation (WHO) suggested that for adults underweight or thinness means an adult with a low Body Mass Index (BMI). In children they have separate meanings with underweight indicating a low weight-for-age and wasting indicating a low weight-for-height (WHO, 1995). Cole et al (2007) developed this further by suggesting that the term thinness in children means a low BMI-for-age.

Underweight in children (a low weight-for-age), reflects the BMI relative to the persons age and is affected by both the height (height-for-age) and weight (weight-for-height) of an individual. A low weight-for-height can reflect the long term health and nutritional status of that individual (UNICEF, WHO and The World Bank, 2015 and WHO, 1995). However, it should not be assumed that a low weight-for-age (or other growth parameter) is due to nutrient or energy deficiencies (lack of food) as an increased rate of use of nutrients (as in infectious diseases) and impaired absorption can also play a role. It is also important to consider all factors which influence a child's weight-for-height (or other growth parameter) and the socioeconomic status of the population being studied (WHO, 1995).

Underweight in childhood is an important Public Health issue, as being underweight can have adverse effects on a child's health, some of which can persist into adulthood and may even effect future generations (Victoria et al, 2008). In middle and low income countries, there is evidence that undernutrition is strongly associated with shorter adult height; lower offspring birth weight (for women) and lower educational and economic attainment. In addition there is evidence that lower birth weight and undernutrition are risk factors for a number of cardiovascular risk factors such as high blood pressure or raised glucose levels. It has been postulated that this is due to the rapid postnatal weight gain, especially after infancy (Victoria et al, 2008).

Despite the importance of understanding why children are underweight, there is a paucity of published evidence on the factors which are associated with the prevalence of underweight in childhood in developed countries.

The Child Measurement Programme (CMP) in Wales is a surveillance programme which collects the weight and height of Reception aged children (aged 4-5 years) across Wales. The programme has been running for three years (2011/12, 2012/13 and 2013/14) (Public Health Wales, 2015). Over this time period, the Child Measurement Programme identified that, a higher proportion of children in Cardiff Local Authority (LA) were underweight, than compared to children in other areas of Wales (Public Health Wales, 2013, Public Health Wales, 2014 and Public Health

Wales, 2015). The reason for this variation was not clear; therefore a piece of work was undertaken to understand what factors are associated with the prevalence of being underweight in childhood and whether these factors influenced the proportion of underweight children in Cardiff LA.

This project comprised of two parts; a comprehensive literature review and analysis of aggregated Child Measurement Programme data. This report describes the methods used to review the evidence base, the findings of the literature review and data analysis and the recommendations drawn from the results.

2 Aim and objectives

The aim of this piece of work was to identify what factors influence the proportion of underweight children in Cardiff LA.

In order to achieve this aim the following objectives were developed:

- To undertake a comprehensive literature review; in order to understand what factors influence the prevalence of underweight children in the United Kingdom (UK);
- To analyse aggregated Child Measurement Programme data including the use of multivariate logistic regression; to identify which factors are associated with the proportion of underweight children in Cardiff and Wales;
- To formulate recommendations and share findings of this report with Public Health colleagues and key stakeholders.

3 Methods

3.1 Literature Review

A comprehensive literature review was undertaken, in September 2015. The research question used to search the literature was:

What factors influence the prevalence of underweight children in the UK?

The OVID databases searched, included: Medline, Embase, Health Management Information Consortium (HMIC) and Allied & Complementary Medicine Database (AMED). Search terms and keywords were identified for each Population, Intervention, Comparison and Outcome (PICO) area and were used to search the databases.

Each database used slightly different search terms, therefore keywords were also utilised. The search terms within each PICO area (columns in table 1) were used to search each database. All articles identified by using each search term / keyword in a PICO area were combined using the

Boolean term OR e.g. Child* OR Pre-school OR Infant OR Early years. Initially a search was completed excluding the risk factor search terms to ensure key papers were not missed (broad search). Then, the four PICO areas were combined using the Boolean term AND (narrow search). Limitations applied to the search included: English language papers; human subjects; papers from 2005 to current date; children from birth to 23 months and children aged 2 to 5 years of age.

Table 1: Summary of search terms and keywords by PICO area

Population (P)	Intervention (I) (Risk factors)	Comparison (C) (Area)	Outcome (O)
Child*	Socioeconomic factors	Great Britain	Thinness
Pre-school	Poverty	United Kingdom	Underweight
Infant	Low income	Europe	malnutrition
Early years	Food deprivation		Body weight
	Ethnic groups		Child* nutrition
	Cultural groups		Child* development
			Body Mass Index

A total of 1247 papers were identified (broad search=1021, narrow search=226). All papers were reviewed by title for suitability to the research question using the inclusion and exclusion criteria.

Table 2: Inclusion and exclusion criteria

Inclusion criteria	**Exclusion criteria**
Child or adolescent subjects	Adult subjects
UK, European countries or Australia	Research from developing countries
Primary outcome: Thinness or underweight	Primary outcome: Overweight and obesity

A total of 135 papers were selected and reviewed by their abstract. Three papers were identified as duplicates and 45 were identified as being potentially relevant to the research question. These papers were retrieved and read in full. In addition, the references of included papers were reviewed, which identified a further 13 papers. Out of a total of 58 papers which were read in full, 35 were relevant and included in the review, 23 papers were excluded (the majority focused on obesity). A summary of the literature search is displayed in figure one.

Figure 1: Flow chart of literature search

In addition to undertaking a literature review of scientific journals, other sources of evidence were also reviewed. This involved a web based search of public bodies and third sector organisations for relevant publications using key words (underweight and thinness). Sites searched included: Welsh Government (WG), Public Health Wales, Public Health Network Cymru, Department of Health (DOH), The England National Child Measurement Programme (NCMP), Public Health England (PHE), Royal College of Paediatric and Child Health (RCPCH), Scottish Intercollegiate Guidelines Network (SIGN), National Institute for Health and Care Excellence (NICE) and the Children in Wales charity.

3.2 Data analysis

Analysis of Child Measurement Programme data was undertaken to determine if a higher proportion of children in Cardiff LA were underweight, than compared to children from other areas in Wales. In addition, this project aimed to identify any association between being underweight and the risk factors identified in the literature review.

Due to the relatively small number of underweight children in Wales, Child Measurement Programme data was aggregated; increasing the size of the data set, provided greater power to the study; thereby, allowing a more detailed analysis of the associations between identified risk factors and risk of being underweight. Three years of aggregated Child Measurement Programme data (2011/12, 2012/13 and 2013/14) were analysed. The exception being when Child Measurement Programme data was analysed by ethnic group; only two years of data (2012/13 and 2013/14), were aggregated, as in 2011/12 Child Measurement Programme data was not analysed by ethnic group.

Logistic regression analysis was undertaken using two years of aggregated Child Measurement Programme data (2012/13 and 2013/14). The data on all children aged 4 to 5 years (all weight categories), who participated in the Child Measurement Programme, in Wales, during this time period, were included in the model. Data on 59,904 children was included, of these only 427 were classed as underweight, which equates to 0.71%. The primary outcome was to identify which explanatory variables were significantly associated with being underweight in childhood.

Caveats to data analysis

The Child Measurement Programme define underweight as, a BMI less than but not including the second centile (BMI<2^{nd} centile) of the British 1990 growth reference (UK90) curves. Deprivation is assessed using the Welsh Index of Multiple Deprivation (WIMD) (Public Health Wales, 2015). The Child Measurement Programme uses the most recent WIMD; therefore the findings for the school year 2013/14 were based on WIMD 2014, while previous reports were based on WIMD 2011.

Findings from the NCMP in England have been used in this report, in order to compare the prevalence of underweight children in England with the proportion of underweight children in Cardiff LA and across Wales. However, in England, the NCMP collects the weight and height of both Reception (4-5 years) and year six (10-11 years) children (Public Health England, 2014b). Therefore, only NCMP data from Reception children has been included in this report (where possible). It should also be noted that the NCMP define underweight as, a BMI less than or equal to the 2nd centile (UK90, BMI≤2^{nd} centile) and deprivation is based on the 2010 Index of Multiple Deprivation (IMD) (Public Health England, 2014b). These differences should be considered when comparing the prevalence rates for the different populations.

4 Results

4.1 Literature review

A comprehensive review of the literature identified 35 relevant papers (22 cross sectional studies and 13 cohort studies). A description of each study included in this review can be found in Appendix A, table 17. In addition, to the 35 papers, three reports based on NCMP data were also reviewed. Two reports included findings from the most recent NCMP data collections (2013/14 and 2014/15) and one report described the trends in NCMP data. Despite, underweight being an important public health issue, there was a paucity of evidence on the subject. This is evident by the number of papers excluded from this review, because they primarily focused on overweight or obesity.

A variety of different growth reference populations and definitions for growth parameters such as underweight or thinness have been used by the studies in this review. These have been summarised in Appendix B.

This review identified that a number of factors (variables) are associated with the prevalence of underweight in children. However, not all studies agreed on the significance of the associations, or the direction of effect that each factor had on prevalence rates.

Key findings of literature review:

- There was evidence that in recent years, there has been a declining trend in the prevalence of underweight children, both in the UK and in other countries;
- The evidence in this literature review suggests that, the prevalence of underweight children, was associated with gender; and that younger boys are at increased risk of being underweight than compared to girls;
- There was evidence that the prevalence of underweight children varies between ethnic groups; with a higher proportion of children from non-White ethnic groups being underweight, than compared to children from White ethnic groups;
- There was inconclusive evidence in this literature review to say whether there is any association between the prevalence of underweight children and socioeconomic deprivation;
- There was inconclusive evidence in this literature review, to say whether there is any association between area of residence and being underweight;
- The literature review identified a number of parental factors that were associated with being underweight in childhood, including: level of maternal education; maternal underweight pre-pregnancy; older maternal age; drinking in pregnancy and maternal stress;
- The literature review identified a number of infant and/or child factors associated with being underweight in childhood, including prematurity; low birth weight and rates of growth in infancy.

4.1.1 Prevalence rates

The prevalence rate of underweight children varied according to the growth reference population and cut-offs used. Martínez-Vizcaíno et al (2008) reported that the overall prevalence of thinness varied depending on the growth reference used with the highest prevalence of thinness being measured with the International Obesity Task Force (IOTF) growth reference. The prevalence was approximately double that obtained by the National Health and Nutrition Examination survey (NHANES I) and The United States (US), Centres for Disease Control and Prevention (CDC) 2000 growth reference. Therefore direct comparisons of prevalence rates between studies using different growth reference and definitions cannot be made.

Studies which analysed UK based surveys / cohorts, reported a range of prevalence rates for underweight children (Public Health Wales, 2015, Public Health England, 2015a, Smith et al, 2013, Whitaker et al, 2011 and Boddy, Hackett and Stratton, 2008). These prevalence rates varied considerably, depending on whether the UK90 growth reference or the IOTF growth reference was used.

Table 3: Comparison of prevalence rates for underweight children, by reference population, UK

Study / publication	UK90 growth reference	IOTF growth reference
Child Measurement Programme 2013/14*	0.8% (BMI<2ndcentile)	-
NCMP 2013/14**	0.95% (BMI≤2ndcentile)	-
Whitaker et al (2011)	-	5.7% (all grades)
Smith et al (2013) (children born in 2006)	1.2% (BMI<2ndcentile)	4.8% (grade I)
Boddy, Hackett and Stratton (2008)	-	6.9% (Boys all grades) 7.5% (Girls all grades)

Source:
*Public Health Wales. 2015. *Child Measurement Programme for Wales 2013/2014*.
**Public Health England. 2015a. *Changes in children's body mass index between 2006/07 and 2013/14: National Child Measurement Programme.*
- No data

4.1.2 Trends in Prevalence rates

A number of studies compared the prevalence rate of underweight children at ≥2 points in time, thereby providing evidence on the trend in prevalence rate in that study population. There was some evidence from the literature that the prevalence of underweight children had declined in recent years (Public Health England, 2015a, Wang, Monterio and Popkin, 2002 and Schönbeck et al, 2014). However, some of the studies found that the declining trend was not always significant across every population group or country being studied (Smith et al, 2013, Wang, Monterio and Popkin, 2002, Schönbeck et al, 2014 and Lazzeri et al, 2008). While, one study did not identify a significant trend in the prevalence of thinness (IOTF, all grades) (Whitaker et al, 2011) and one study identified an increasing trend in prevalence rate (Martínez-Vizcaíno et al, 2008).

Public Health England (2015a) undertook analysis of a large database of NCMP data (2006/07 to 2013/14). The authors reported that overall there had been a significant downward trend in the total proportion of underweight children (aged 4-5) over this period. This downward trend was significant for both boys and girls. The authors also reported a significant decline in the proportion of underweight Reception boys in two ethnic groups (Black Caribbean and White British). No other trends were significant. There was also a significant downward linear trend in the proportion of underweight Reception girls in three ethnic groups (Pakistani, Black African and White British). Other ethnic groups also showed downward trends in the prevalence of underweight in Reception girls, but these were not significant (Public Health England, 2015a).

In addition, an international study analysed data from cross sectional studies from four countries between 1970 and 1998. The authors reported that two of the four countries, had a significant decline in the prevalence of underweight children and adolescents (Brazil 14.8% to 8.6% and the US 5.1% to 3.3%) (Wang, Monterio and Popkin, 2002). While, a study involving 54,814 children (aged 2-18) from three cross sectional surveys in The Netherlands estimated the prevalence and trends of thinness (IOTF, grade I, II & III) in children of Dutch, Moroccan and Turkish origin. The authors reported, a significant downward trend in the prevalence of thinness (grade I & grade II) for children of Dutch origin and a significant downward trend in the prevalence of thinness (all grades) for children of Moroccan origin (Schönbeck et al, 2014).

Five studies reported that the declining trend was not always significant across every population group or country being studied (Smith et al, 2013, Boddy, Hackett and Stratton, 2008, Wang, Monterio and Popkin, 2002, Schönbeck et al, 2014 and Lazzeri et al, 2008). This included a cross sectional study of children in North East Scotland. The authors reported a declining trend in the prevalence of thinness (IOTF, grade I and ≥II) between children born in 1970 and those born in 2006. However, the prevalence of grade I thinness varied considerably during this time and there was no significant overall decline during this period. In contrast there was a significant decline in the prevalence of grade ≥II thinness over the same period (Smith et al, 2013). In addition, a cross sectional study in Liverpool reported that the prevalence of total underweight (IOTF, grade I, II & III) (boys and girls) fell between 1998 and 2006; however the authors failed to provide information on whether the downward trend was significant. The authors reported that the prevalence of underweight boys declined from 10.3% to 6.9%, while the prevalence of underweight girls fell from 10.8% to 7.5%. However, the prevalence of grade II underweight for boys remained similar over the time period; while the prevalence of grade II underweight for girls fell. No details were provided by the authors, as to whether the downward trends were statistically significant (Boddy, Hackett and Stratton, 2008).

As already described, Wang, Monterio and Popkin, (2002) reported a significant decline in the prevalence of underweight children in two countries (Brazil and US). However, they also found a non-significant decline in the third country being studied (China, 14.5% to 13.1%). In addition, they reported a non-significant increase in prevalence rate in the fourth country (Russia, 6.9% to 8.1%). Schönbeck et al (2014) did not identify a significant decline in the prevalence rate of grade III thinness in children of Dutch origin and reported that the downward trend in prevalence of thinness was not evident for children of Turkish origin. The fifth study was a cross sectional survey undertaken in Tuscany (2002, 2004 and 2006). The authors identified a declining trend in the prevalence of thinness (IOTF all grades) for children aged 9 to 15 years. However, the downward trend failed to reach a significant level (Lazzeri et al, 2008).

Not all studies reported a declining trend in prevalence rate, a study analysing data from the Health Survey for England between 2001 and 2006 did not identify a significant trend in the prevalence of thinness (IOTF, all grades) (Whitaker et al, 2011). While, one study identified an increasing trend in prevalence rates of thinness (IOTF, grade I, II & III) in Spanish children (aged 9-10), between 1992 and 2004 (Martínez-Vizcaíno et al, 2008). The authors reported that for all children (boys and girls) there was a significant increase in prevalence of thinness from 2.7% to 9.2% during this time period. However when analysed by gender, the authors reported that the increasing trend in prevalence of thinness was only significant for girls.

The evidence in this literature review suggests that, there has been a declining trend in the prevalence of underweight children, both in the UK and in other countries. Although, it is not clear why, no trend in prevalence was identified in the data from the Health Survey for England. In addition, the reason why some countries (Russia and Spain), had an increasing trend in prevalence rate, was also not clearly identified.

4.1.3 Gender

There was evidence from this review that the prevalence of underweight children, varied by gender; with boys being at greater risk of being underweight than girls. However, the prevalence of moderate/severe thinness was found to be similar for boys and girls (Pearce, Rougeaux and Law, 2015). There was some evidence that this association with gender may reverse with increasing age; with older girls /adolescents having a higher prevalence of underweight than their male peers (Public Health England, 2015b, Yngve et al, 2007 and Antal et al, 2009). In contrast, four studies reported that there was no significant difference in the prevalence of underweight children by gender (Schönbeck et al, 2014, Whitaker et al, 2011, Savva et al, 2005 and Kherkheulidze et al, 2010). However, two of these studies included a wide age range of children and therefore, differences in prevalence rates, at different ages, may have been masked (Schönbeck et al, 2014 and Whitaker et al, 2011). The remaining two studies had small sample sizes and therefore may have been of inadequate power to detect a real difference in prevalence rates (Savva et al, 2005 and Kherkheulidze et al, 2010).

Analysis of a large database of NCMP data from 2007/08 to 2011/12 (2,620,422 Reception children), reported that, the total prevalence of thinness (IOTF, grade I, II & III) for Reception boys was significantly higher (5.88%, *95% Confidence Interval (CI) 5.85 to 5.93*) than for Reception girls (5.2%, *95%CI 5.16 to 5.24*). Boys were more likely to be mildly thin than girls; although the prevalence of moderate/severe thinness, was similar for boys and girls (Pearce, Rougeaux and Law, 2015). In addition The NCMP data from the 2014/15 school year reported that overall the prevalence of underweight children in Reception class was 1.0% (*95%CI 0.9 to 1.0*). The prevalence was significantly higher for boys (1.2%, *95%CI 1.2 to 1.3*) than compared to girls (0.7%, *95%CI 0.7 to 0.7*). However, in year six (aged 10-11) the overall prevalence of underweight was significantly higher at 1.4% (*95%CI 1.4 to 1.5*), and girls had a significantly higher prevalence rate (1.6%, *95%CI 1.6 to 1.7*) than compared to boys (1.2%, *95%CI 1.2 to 1.3*) (Public Health England, 2015b). This may suggest that for younger children, boys are more likely to be thinner and for older children / adolescents, girls are more likely to be thinner.

This theory may be supported by the findings of two studies which reported that, girls had a significantly higher prevalence of being underweight, than compared to boys; both studies included data from older children (Yngve et al, 2007 and Antal et al, 2009). Yngve et al (2007) undertook analysis of an international study involving 8,089 children (aged 11). The authors reported that across all nine European countries (Austria, Belgium, Denmark, Iceland, The Netherlands, Norway, Portugal, Spain and Sweden) girls had a significantly higher prevalence of underweight (7.2%, *95%CI 6.5 to 8.1*) than compared to boys (5.4%, *95%CI 4.7 to 6.2*). It should be noted that the heights and weights of children were self reported by parents and recorded by questionnaire. Antal et al (2009) reported that a cross sectional study in Hungary including 1,928 children (aged 7-14) found that the prevalence of underweight girls (6.8%) was higher than compared to boys (5.1%). However, the authors did not provide details on whether this difference was statistically significant. It should be noted that, both studies defined underweight as, a BMI<5th centile, this would lead to a higher prevalence rate being recorded for both boys and girls than compared to studies which use a lower cut-off.

Four studies, one in the UK and three across Europe, reported no significant difference in the prevalence of underweight by gender (Schönbeck et al, 2014, Whitaker et al, 2011, Savva et al, 2005 and Kherkheulidze et al, 2010). The UK based study analysed data from the Health Survey for England (70,782 children aged 2-15) and reported no significant difference in prevalence of thinness by gender (Whitaker et al, 2011). Another large study (54,814 children aged 2-18), in The Netherlands, looked at the prevalence of thinness of children of Dutch, Moroccan and Turkish origin. The authors reported (across all three groups) that, no significant difference in prevalence rates between boys and girls was found (Schönbeck et al, 2014). These are two large studies which should have adequate power to detect a real difference in prevalence rates. However, the age range of children included in these studies was very wide and therefore differences in prevalence rates at different ages may have been masked. The two remaining studies (Savva et al, 2005 and Kherkheulidze et al, 2010), included analysis of data from a cross sectional survey of pre-school children in Cyprus. The authors reported, no significant differences in prevalence of underweight, stunting and wasting by gender (Savva et al, 2005). While, a cross sectional study of 754 children (aged 5-6) in Tbilisi in Georgia, also reported no significant difference in the prevalence of low weight by gender (Kherkheulidze et al, 2010). These studies included data on younger children, however, the sample size of both studies was small, and therefore, the studies may have had inadequate power to detect a real difference in prevalence rates.

Another study analysed data from the Generation R cohort study in The Netherlands. The authors reported that at age 6, girls had higher fat mass index and abdominal body fat measures than boys (Gishti et al, 2014). However, the results of this study are not directly comparable to the aforementioned studies as the outcomes being measured are different.

The evidence in this literature review suggests that, the prevalence of underweight children, is associated with gender; and that younger boys are at increased risk of being underweight than compared to girls. However, this association may reverse with increasing age; with older girls /adolescents being at increased risk of being underweight than compared to their male peers.

4.1.4 Age

The association between age and prevalence of underweight in children and adolescents is not clearly evident from this review. Two studies suggest that older children (>10 years) have a higher prevalence of underweight than compared to younger children (Public Health England, 2015b and Wang, Monterio and Popkin, 2002). However, two studies contradict this and suggest that younger children (<6 years) had a higher prevalence of underweight than compared to older children / adolescents (Whitaker et al's, 2011 and Schönbeck et al, 2014). Further research is therefore required to determine if there is an association between age and prevalence of underweight in children.

There is limited evidence from the literature that older children / adolescents have a higher prevalence of underweight than younger children (Public Health England, 2015b and Wang, Monterio and Popkin, 2002). Analysis of NCMP data from the 2014/15 school year, reported that, the prevalence of underweight children (boys and girls) was significantly higher for children in year six (aged 10-11) at 1.4% (*95%CI*

1.4 to 1.5), than compared to those in Reception class (aged 4-5) at 1.0% (*95%CI 0.9 to 1.0*) (Public Health England, 2015b). A similar finding was found in an international study which analysed data from cross sectional studies in four countries between 1970 and 1998. The authors reported that in all countries except the US, the prevalence of underweight was lower in children (aged 6-9) than for adolescents (aged 10-18) (Wang, Monterio and Popkin, 2002).

In contrast, two studies reported that younger children had a higher prevalence of underweight than compared to older children / adolescents (Whitaker et al's, 2011 and Schönbeck et al,2014). Whitaker et al's (2011) analysis of data from the Health Survey for England found that younger children had a higher prevalence of thinness (8.1%, aged 2-5), than compared to older children (4.9%, aged 6-10) and adolescents (4.7%, aged 11-15); however, the Odds Ratio (OR) of thinness by age group, did not reach a significant level. A similar finding was reported by Schönbeck et al (2014), who reported analysis of data from 54,814 children (aged 2-18) in The Netherlands. They found that the prevalence of thinness of children of Dutch, Moroccan and Turkish origin was more prevalent in children aged <6 years.

The evidence in this literature review does not clearly identify if there is any association between prevalence of underweight and age.

4.1.5 Ethnic group

Seven studies in this review, explored the relationship between prevalence of underweight children and ethnic group (Whitaker et al, 2011, Joosten et al, 2010, Taylor et al, 2005, Yngve et al, 2007, Malenfant, 2009, Loka, Nossar and Bauman, 1994 and Renzaho et al, 2009). However, the studies looked at the associations from different perspectives. Three studies compared prevalence rates of underweight children between different ethnic groups in the same country (Whitaker et al, 2011, Joosten et al, 2010 and Taylor et al, 2005). Two studies compared the difference in prevalence rates of underweight children from a specific ethnic group who were born in different countries (Loka, Nossar and Bauman, 1994 and Malenfant, 2009). One study compared the prevalence rates of underweight children in different countries rather than by ethnic group (Yngve et al, 2007) and another study looked at the association between prevalence of underweight children and their parents' country of birth (Renzaho et al, 2009).

Whitaker et al (2011), Joosten et al (2010) and Taylor et al (2005) all reported a significant difference in the prevalence rates of underweight children / adolescents by ethnic group. The studies reported that, children from Asian ethnic groups (Whitaker et al, 2011 and Taylor et al, 2005), Black ethnic groups (Whitaker et al, 2011) and non-White ethnic groups (Joosten et al, 2010) had a higher prevalence of underweight, than compared to children from White ethnic groups. Whitaker et al's (2011) findings from the Health Survey for England found that, the prevalence of thinness was higher in children and adolescents from non-White ethnic groups (11.4%), than compared to children from White ethnic groups (4.2%). In addition, they found that children from the Black ethnic group (OR 2.28, *95%CI 1.22 to 4.26*) and children from the Asian ethnic group (OR 3.65, *95%CI 2.76 to 4.83*) were at an increased risk of underweight than compared to children from the White ethnic group.

Joosten et al (2010) reported that the prevalence of chronic malnutrition on admission to hospital was significantly higher in children from non-white ethnic groups than compared to children from white ethnic groups (19% vs. 7%). When analysis was undertaken to adjust for age, underlying disease, ethnicity and surgery the relationship between chronic malnutrition and children from non-white ethnic groups remained significant (OR 2.8, *95%CI 1.2 to 6.6*). However, this was a relatively small study. The third study of adolescents from East London, reported a significant difference in the prevalence of underweight between adolescent boys from the Bangladeshi ethnic group (OR 3.13, *95%CI 1.33 to 7.14*), the Indian ethnic group (OR 3.03, *95%CI 1.16 to 8.33*) and Pakistani ethnic group (OR 5.88, *95%CI 2.94 to 12.50*), than compared to adolescent boys from the White British ethnic group. However, the differences in prevalence rates were not consistent for every group being studied; with no significant difference found in the prevalence of underweight girls from the White British ethnic group, than compared to, girls from any of the other ethnic groups (Taylor et al, 2005).

Two studies which compared the prevalence of underweight children from a specific ethnic group, who were born in different countries (Loka, Nossar and Bauman, 1994 and Malenfant, 2009) included a study by Loka, Nossar and Bauman (1994). They reported a significant difference in the height and weight of children of South-East Asian origin, who were born overseas than compared to children of South-East Asian origin, who were born in Australia. While in contrast Malenfant (2009) reported that children of Tamil origin who were born in France had a higher prevalence of thinness than compared to children who lived in South India. However, they did not report if these differences were statistically significant.

Yngve et al (2007) compared the prevalence of underweight children between different countries in Europe. The authors reported a significant difference in prevalence of underweight children (boys and girls) between the nine countries; with Belgium reporting the highest prevalence rates. However, the authors did not discuss the reasons why there was a difference in prevalence rates between the different countries in the study. It should be noted that the heights and weights of children were self reported by parents and recorded by questionnaire, which may have biased the results. In contrast, Renzaho et al (2009) studied the relationship between prevalence of thinness in children and the parents' country of birth. The authors reported that, children (boys and girls) whose primary carer's birthplace was in Asia, had a significantly higher prevalence of thinness than compared to those whose primary carer's birthplace was in Australia. They also reported a significant relationship between the prevalence of thinness and the language spoken at home. Boys who used English at home were less likely to be thin than compared to those who spoke a different language at home (OR 0.27, *95%CI 0.12 to 0.62*). However, this relationship was not evident for the girls in the study.

In addition to looking for an association between prevalence of underweight and ethnicity, four studies raised the question of whether the body composition of children varied by ethnic group (West et al, 2013) and whether this contributed to the variation in prevalence rates (Nightingale et al, 2011, Taylor et al, 2005 and De Wilde et al, 2013).

West et al (2013) looked at the differences in body composition of children from different ethnic groups using data from the Born in Bradford study. The authors reported that, infants of South-Asian origin had a lower birth weight than infants of White British origin. However, cord leptin levels were higher in infants of Asian origin, and therefore, levels of fat mass were higher, than compared to infants of White British origin. The results remained significant after adjusting for birth weight. Three studies suggested that BMI can be a misleading comparison of levels of adiposity, between children of different ethnic groups, due to the differences in their body composition and the differences in height between populations (Nightingale et al, 2011, Taylor et al, 2005 and De Wilde et al, 2013). Nightingale et al (2011) suggested that levels of adiposity in children of South-Asian origin may be underestimated while levels of adiposity in children of Black African-Caribbean origin may be overestimated. Taylor et al (2005) concluded that in their study, BMI and height were positively associated, and therefore, there was a risk that the study overestimated the prevalence of underweight in groups who were shorter than the general population and underestimated the prevalence of underweight in taller groups. De Wilde et al (2013) reported an 'unusually' high prevalence of severe thinness, in a cohort of Surinamese South-Asian children who lived in The Netherlands. The authors concluded that this may be due an expression of body characteristics of South-Asian children (thin-fat body composition). The authors suggested that the current universal BMI cut-offs may therefore have overestimated the prevalence of thinness in this study population.

The evidence in this literature review suggests that, the prevalence of underweight children does vary between ethnic groups. The evidence suggests that children from non-White ethnic groups had a higher prevalence of underweight, than compared to children from White ethnic groups. However, the studies included in this review did not provide evidence on the reasons why there is a difference in prevalence rates.

4.1.6 Socioeconomic factors

There was insufficient evidence in this literature review to say whether there is any association between the prevalence of underweight children and socioeconomic factors. Three studies found an association between the prevalence of underweight children and socioeconomic factors; reporting that, a significantly higher proportion of children from socioeconomically disadvantaged areas, were underweight, than compared to their peers who lived in more affluent areas (Armstrong et al, 2003, Pearce, Rougeaux and Law, 2015 and Wang, Monterio and Popkin, 2002). In addition, one study reported a difference in prevalence rates, but the authors did not report if the difference was significant (Smith et al, 2013). However, in contrast, four studies reported, no significant difference in the prevalence of underweight children by socioeconomic group (Whitaker et al, 2011, Schönbeck et al, 2014, Taylor et al, 2005 and Bhandari et al, 2002).

The three studies reported a significantly positive association between prevalence of underweight children and socioeconomic deprivation, including a large retrospective cross sectional study in Scotland (74,500 children, aged 3-4). The authors reported that children from more deprived areas had a significantly higher prevalence of undernutrition, than compared to children from the least deprived areas. Children in the most deprived areas also had a significantly increased risk of undernutrition, than compared to their peers in the least deprived areas (OR 1.29, *95%CI 1.03 to 1.62*) (after adjusting for birth weight of the children) (Armstrong et al, 2003). A similar finding was reported from an international study which analysed data from four countries. The authors reported that in all but one survey, a lower prevalence of underweight was identified in more affluent groups than compared to those who were less affluent (Wang, Monterio and Popkin, 2002). The third study by Pearce, Rougeaux and Law (2015) analysed two data sets; NCMP data (2007/08 to 2011/12) and Millennium Cohort Study data (involving 16,715 children aged 3, 5 and 7). The authors reported that, children in the more deprived IMD deciles in England, had a higher relative risk ratio (RRR) for thinness (all grades), than compared to children living in the least deprived areas. The authors identified a number of factors which were significantly associated with an elevated RRR of thinness namely:

- Socioeconomically disadvantaged groups;
- Low birth weight;
- Maternal pre-pregnancy underweight;
- Pre-term birth;
- Older maternal age;
- Drinking in pregnancy.

When Pearce, Rougeaux and Law (2015) adjusted their analysis for these factors, the increased RRR for thinness remained significant in the most disadvantaged groups. The authors therefore concluded that, the aforementioned factors were not the cause of the difference in prevalence rates seen between the most and least socioeconomic disadvantaged groups.

The fourth study by Smith et al (2013), reported that children born in Scotland, between 1970 and 1976, who lived in more socioeconomically deprived areas, had a higher prevalence of grade ≥II thinness than their peers in less deprived areas (7.2% vs. 4.7%). However, the authors did not report whether this difference was significant. In addition, the difference in prevalence of underweight children from different socioeconomic groups was not evident for children born between 2000 and 2006 (1.6% vs. 1.5%). It is not clear if this was due to a decline in prevalence rates across all socioeconomic groups (between the 1970's and 2000's) or due to other factors. The theory of a downward trend in prevalence rates of underweight children, across all socioeconomic groups over time, may be supported by the findings of another study which analysed NCMP data (2006/07 to 2013/14) (Public Health England, 2015a). The authors of the NCMP report, found a significant decline in the proportion of underweight children (boys and girls) across all five quintiles of deprivation (IMD) in England. However, there was no consistent pattern, with the greatest decline seen in the most deprived quintile and the smallest decline observed in the third IMD quintile (Public Health England, 2015a). It should be noted that, the NCMP report looked at trends of prevalence rates by socioeconomic group and not the difference in prevalence rates between socioeconomic groups.

In contrast to the aforementioned studies, four studies reported no significant difference in the prevalence of underweight children between socioeconomic groups (Whitaker et al, 2011, Schönbeck et al, 2014, Taylor et al, 2005 and Bhandari et al, 2002). Whitaker et al's (2011) analysis of the Health Survey for England found no significant difference in prevalence of thinness when analysed by socio-economic status of the household (Whitaker et al, 2011). Similarly, the study by Schönbeck et al (2014) in The Netherlands, found no significant difference in the prevalence of thinness, for children of Dutch origin, across different socio-economic groups (defined by parental educational level). The authors did not provide data on the prevalence of thinness by socio-economic group for children of Moroccan and Turkish origin. The study by Taylor et al (2005) reported that BMI was generally not associated with socio-economic status (% with car, % eligible for free school meals, % overcrowded and % no employed parent); the only exception being, an association between car ownership and BMI in girls. The fourth study included children from affluent areas of South Delhi, which aimed to see whether the affluent population in India had a growth performance similar to that found in developed countries (using the National Centre for Health Statistics (NCHS) /WHO reference population). The authors reported that, no socioeconomic factors were significantly associated with either a low weight-for-age (underweight) or low weight-for-length (wasting) (Bhandari et al, 2002).

In addition, one study looked at the relationship between socioeconomic deprivation and children's mean BMI z-scores (Townsend, Rutter and Foster, 2012). The authors used NCMP data from 2007/08 (788,525 children in Reception and year six), and analysed the data by individual-level, area of residence (child well-being index (CWI)), school-level (eligibility for free school meals (FSM)) and Primary Care Trust-level (PCT). The authors reported that over 95% of the variance in BMI z-score was found at the individual-level (student). However, there was also a significant positive association between BMI z-score and area of residence (CWI) and school-level deprivation measures (FSM); with children (Reception and year six) from more deprived areas having a higher mean BMI z-score. The authors also reported that a larger proportion of the variation in BMI z-scores was explained by CWI than by FSM. Therefore, the authors concluded that, the link between deprivation and BMI was not only due to financial deprivation but also linked to other inequalities related to deprivation, such as education and housing. The findings of this study may not be relevant to this review, as the authors used mean BMI z-scores and not prevalence of underweight children; therefore the factors influencing mean BMI z-score may not be applicable.

There was inconclusive evidence in this literature review to say whether there is any association between the prevalence of underweight children and socioeconomic deprivation. The three studies reporting a significant association included large samples of children. Therefore, the large sample size may have given the studies adequate power to identify a real difference. However, two of the studies that reported no significant difference also had a large sample size. The reason why Smith et al's findings did not reach a significant level is also unclear.

4.1.7 Infant and Child factors

A number of infant and child factors were found to be associated with prevalence of underweight in childhood including: Low birth weight (Pearce, Rougeaux and Law, 2015 and Savva et al, 2005); prematurity (Pearce, Rougeaux and Law, 2015); Rates of growth in infancy (Fairley et al, 2013 and Gishti et al, 2014); Infant weaning and feeding practices (Imai et al, 2014) and Medical conditions (Joosten et al, 2010 and Meyer et al, 2013).

Low birth weight / prematurity

This review found some evidence that Prematurity and / or low birth weight is associated with an increased risk of being underweight / thinness in childhood (Pearce, Rougeaux and Law, 2015 and Savva et al, 2005), and with increased risk of stunting in childhood (Knops et al, 2005).

Pearce, Rougeaux and Law (2015) reported that being born prematurely and / or having a low birth weight were significantly associated with an elevated RRR of thinness in childhood. While Savva et al's (2005) study of pre-school children in Cyprus reported that after adjusting for age, gender, gestational age, fathers height and weight and mothers height and weight that all three growth parameters (underweight, stunting and wasting) were significantly associated with a history of a low birth weight (<2500 grams (g)). The OR of being underweight was 4.09 (*95%CI 1.37 to 12.24*), the OR of being stunted was 5.15 (*95%CI 1.14 to 23.31*) and OR of being wasted was 4.22 (*95%CI 1.25 to 14.27*). However, unlike Pearce, Rougeaux and Law (2015), Savva et al (2005) did not find a significant difference in prevalence of underweight, stunting and wasting with gestational age at birth.

In addition, a study analysing data from a prospective cohort study of premature (<32 weeks) and/or low birth weight (<1500g) children, in The Netherlands, reported that despite catch-up growth, the children with small for gestational age (SGA) (both <32 & ≥32 weeks) demonstrated a higher prevalence of short stature (stunting) (defined as a height<10^{th}centile) at age 10 years. The children who had an appropriate weight for gestational age (AGA) (AGA <32 weeks), showed little or no stunting and no catch-up growth at age 10 years (Knops et al, 2005).

This review also found evidence that, the birth weight of infants varied between ethnic groups (West et al, 2013 and Fairley et al, 2013). Analysis of data from the Born in Bradford cohort study reported that children (boys and girls) from the Pakistani ethnic group were lighter and had a shorter predicted mean length at birth than compared to children from the White British ethnic group (Fairley et al, 2013). Another UK study reported that infants of South-Asian origin had a lower birth weight than infants of White British origin. The authors also reported that infants of South-Asian origin had higher cord leptin levels, and therefore, levels of fat mass were higher, than compared to infants of White British origin. These results remained significant after adjusting for birth weight (West et al, 2013). However, the authors did not discuss whether having a low birth weight or a high cord leptin influenced growth parameters in childhood.

Rates of growth in infancy

In addition to birth weight, there was some evidence from cohort studies that childhood growth parameters were influenced by rates of growth in infancy (Fairley et al, 2013 and Gishti et al, 2014). Fairley et al's (2013) results from the Born in Bradford cohort study suggest that, infants from the Pakistani ethnic group were lighter and had a shorter predicted mean length at birth than compared to children from the White British ethnic group. In addition, the authors reported that, children (boys and girls) from the Pakistani ethnic group gained more length per month in the first four months of life and gained more weight per month after nine months of age than compared to children from the White British ethnic group. The authors found that, measurements at two years showed that, the two ethnic groups had similar weights but children (boys and girls) from the Pakistani ethnic group were taller. The authors found that differences in maternal height explained some of the differences in weight and height, however, adjustment for maternal height, smoking during pregnancy and gestational age, did not explain all of the differences in postnatal growth rates described. In addition, Gishti et al (2014) reported the findings from the Generation R cohort study in The Netherlands, which suggested that the BMI of school aged children was associated with their growth in foetal life and through infancy. The authors reported that length gain in late infancy was positively associated with BMI and that estimated foetal weight and abdominal growth in the second and third trimester and weight gain in early, mid and late infancy were all positively associated with childhood BMI.

A number of studies in this review, also looked at weight faltering in infancy (Emond et al, 2007, Wright, Parkinson and Drewett, 2006 and Wright, Stone and Parkinson, 2010); however, the studies did not report on childhood growth parameters, therefore no conclusions can be made as to whether weight faltering in infancy is associated with being underweight in childhood.

Infant weaning and feeding practices

Imai et al (2014) reported that growth rates of infants and childhood BMI were also shown to be associated with infant weaning and feeding practices (cross sectional study of children in Iceland). The authors reported that infants who were formula fed and had solids introduced at five months of age grew quicker and had a higher BMI at age six years than exclusively breast fed children.

Medical conditions

Some of the studies included in this review excluded children with a medical condition or those on medication affecting growth (Schönbeck et al, 2014 and Bhandari et al, 2002). However, two studies suggested that medical conditions (Joosten et al, 2010) including food allergies (Meyer et al, 2013) may be associated with prevalence of underweight in childhood. Joosten et al (2010) looked at rates of malnutrition in children (424) admitted to a hospital in The Netherlands over a 3 day period. The authors reported that the prevalence of overall malnutrition was 19% (11% acute and 9% chronic); of these, 44% were identified as having an underlying disease. The relationship between overall malnutrition (OR 2.2, *95%CI 1.3 to 3.9*) and chronic malnutrition (OR 3.7, *95%CI 1.7 to 7.8*) with underlying disease, remained significant even after adjusting for: age; underlying disease; ethnicity and surgery. The authors did not identify any significant factors associated with the prevalence of acute malnutrition.

Another study by Meyer et al (2013) looked at the association between children with food allergies and growth parameters. The authors reported that children who excluded ≥3 food groups had a significantly higher prevalence of a low weight-for-age (z-score<-2 Standard Deviation (SD)), than compared to those with ≤2 food groups (10% vs. 7.8%). No significant differences in the growth parameters of children were identified between those cared for in primary, secondary or tertiary care and no difference was identified between those who had an IgE-mediated, a non IgE-mediated or a mixed allergic reaction.

There is some evidence in this literature review that a number of infant and/or child factors are associated with being underweight in childhood. Factors included prematurity; low birth weight and rates of growth in infancy. In addition, it should be considered that, the birth weight of infants, varied between ethnic groups and that children from different ethnic groups may also grow at different rates.

4.1.8 Parental factors

This review identified a number of parental factors that were associated with being underweight in childhood, including: level of maternal education (Lakshman et al, 2013 and Janevic et al, 2010); a mother who was underweight pre-pregnancy (Pearce, Rougeaux and Law, 2015); a mother of older maternal age (Pearce, Rougeaux and Law, 2015); drinking in pregnancy (Pearce, Rougeaux and Law, 2015); a mother with a positive SPSQ (stress) score (OR 3.08, *95%CI 1.64 to 5.81*) (Stenhammar et al, 2010) and a mother with a preoccupied attachment style (OR 4.26, *95%CI 1.67 to 10.86*) (Stenhammar et al, 2010).

Two studies reported that levels of maternal education were associated with prevalence of underweight in childhood (Lakshman et al, 2013 and Janevic et al, 2010). Lakshman et al (2013) reported that maternal education was associated with stunting in the UK, and that in China, where the prevalence of stunting and underweight were more common, there was evidence of a strong inverse association with level of maternal education. While a study of Romani children in Serbia, reported that a low level of maternal literacy was a significant factor associated with wasting in this population (Janevic et al, 2010).

However, level of maternal education had conflicting evidence (Lakshman et al, 2013 and Savva et al, 2005). In the UK study population, Lakshman et al (2013) reported that, there was evidence that the level of maternal education was not associated with prevalence of underweight or thinness. In addition, a study of pre-school children in Cyprus also reported, no significant difference in the prevalence of underweight, stunting and wasting by parental educational level (Savva et al, 2005).

Howe et al (2011) reported from the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort study in England, that boys (aged 7-10), had a significantly lower BMI if their mother was degree-educated than compared to A-levels only. The BMI of girls whose mother was degree-educated was also lower than for other educational categories; however, the finding was not statistically significant. In addition, Whitaker et al (2011) reported from the Health Survey for England, that children with parents in the thinner spectrum of healthy weight (BMI<50% centile) were more likely to be thin (OR 1.86, *95%CI 0.97-3.55*) than compared to children with two parents in the upper spectrum of healthy weight. However, this finding did not reach a significant level. It should be noted that neither study reported on the prevalence of underweight, only BMI.

Single parent family status was a parental factor that was not significantly associated with prevalence of underweight, stunting and wasting (Savva et al, 2005).

There was evidence in this literature review that a number of parental factors were associated with being underweight in childhood, including: level of maternal education; maternal underweight pre-pregnancy; older maternal age; drinking in pregnancy and maternal stress. However, there was evidence that in the UK, levels of maternal education were not associated with being underweight in childhood.

4.1.9 Rural/ Urban area of residence

Three studies explored the relationship between living in a rural or urban area and the prevalence of underweight in childhood (Wang, Monterio and Popkin, 2002, Janevic et al, 2010 and Savva et al, 2005). However, the studies did not reach a consensus of opinion.

Savva et al (2005), found no significant differences in prevalence of underweight, stunting and wasting by area of residence (either rural or urban) for pre-school children in Cyprus. In contrast, one international study (involving China, Brazil, Russia and the US) reported that the prevalence of underweight was greater in rural areas in Brazil and China than compared to urban areas (Wang, Monterio and Popkin, 2002). The third study of Romani children in Serbia, reported that living in an urban area was significantly associated with wasting. However, the only significant predictor for underweight was region of residence, but the authors did not clarify if the region in question was urban or rural (Janevic et al, 2010).

There was inconclusive evidence in this literature review, to say whether there is any association between area of residence and being underweight.

4.1.10 Height

Six studies in the review also examined factors associated with children's height (Taylor et al, 2005, Yngve et al, 2007, Janevic et al, 2010, Murrin et al, 2012, Bhandari et al, 2002 and Kherkheulidze et al, 2010). The findings have been included as the different growth parameters are closely linked.

There was evidence of differences in children's height by gender (Yngve et al, 2007), differences in height of children between different European countries (Yngve et al, 2007), and differences in children's height between ethnic groups in the UK (Taylor et al, 2005). Yngve et al (2007) reported that across nine European countries, Portugal had the highest prevalence of stunting (boys and girls). In addition, across all nine countries, boys had a significantly lower prevalence of stunting than compared to the girls. Taylor et al (2005) reported a difference in height of adolescents, between different ethnic groups, in the UK. The authors reported that adolescents from Black African and Black Caribbean ethnic groups were the tallest, while adolescents from Bangladeshi and Pakistani ethnic groups were the shortest. The authors also reported a positive correlation between BMI and height and concluded that the study may have overestimated the prevalence of underweight in ethnic groups who are shorter than the general population (i.e. adolescents in the Bangladeshi and Pakistani ethnic groups and girls in the Indian ethnic group) and underestimate the prevalence in children from ethnic groups who are on average taller e.g. the Black Caribbean ethnic group.

Two studies identified a number of significant factors associated with stunting in children, including (Kherkheulidze et al, 2010 and Janevic et al, 2010): a low wealth score; low levels of maternal education; a history of a child being left in the care of another child; age; gender; bottle feeding and type of solid foods eaten. In contrast, Bhandari et al (2002) identified that having ≥17 years of parental education and a non-vegetarian diet were significantly associated with a higher length-for-age (less likely to be stunted).

Murrin et al (2012) reported the findings from the Lifeways cross-generational cohort study in Ireland. The authors reported that a child's BMI was correlated with that of their mother and that of their maternal grandmother. In addition, both maternal and paternal lines contributed to offspring height. It should be noted that this study did not look at the association between underweight children and paternal height and weight.

There is evidence in this literature review, that there are differences in children's height by gender; differences in children height between European countries and differences in children's height between ethnic groups in the UK. In addition factors which are associated with a low height included: a low wealth score; low levels of maternal education; a history of a child being left in the care of another child; age; gender; bottle feeding; type of solid foods eaten in infancy and diet in childhood.

4.1.11 Summary of Findings: Literature Review

In summary, this literature review identified that the prevalence of underweight children, was associated with gender; and that boys were at increased risk of being underweight than compared to girls. This review also identified that the prevalence of underweight children varied between ethnic groups; with a higher proportion of children from non-White ethnic groups being underweight, than compared to children from White ethnic groups. In addition, a number of parental factors, infant and/or child factors were also found to be associated with being underweight in childhood.

However, there was inconclusive evidence in this literature review to determine whether there was an association between the prevalence of underweight children and socioeconomic deprivation, and between area of residence and being underweight.

4.2 Univariate analysis

Univariate analysis of aggregated Child Measurement Programme data was undertaken to look for any associations between key variables, as identified from the literature, and being underweight in childhood. Not all variables, identified in the literature review could be used to analyse the Child Measurement Programme data, as certain information such as maternal education and birth weight of a child are not collected as part of the Child Measurement Programme. Therefore, univariate analysis was undertaken using the following variables:

- Gender;
- Ethnic group;
- Socioeconomic deprivation;
- Rural / urban area of residence.

4.2.1 Prevalence of underweight children

Key findings:

- In Cardiff LA, a significantly higher proportion of children aged 4-5 years were underweight, than compared to their peers across Wales (Cardiff 1.47%, *95%CI 1.25 to 1.71* and Wales 0.67%, *95%CI 0.62 to 0.73*).

In 2013/14, a total of 30,669 Reception aged children (4-5 years), in Wales participated in the Child Measurement Programme; this equates to 90.8% of those eligible to participate (33,794 eligible children). Of those who participated, across Wales, a total of 248 children were classed as underweight. This equates to 0.80% of children in Wales, who participated in the Child Measurement Programme, in 2013/14, being underweight (Public Health Wales, 2015).

In Cardiff LA, 3,172 children participated in the Child Measurement Programme during 2013/14 (75.0% of the 4,229 eligible children). Of those who participated, 66 children were classed as underweight. This equates to 2.10% of children in Cardiff LA, who participated in the Child Measurement Programme, in 2013/14, being underweight. This was significantly higher than the proportion of underweight children, across Wales (Cardiff 2.10%, *95%CI 1.6 to 2.6* and Wales 0.80%, *95%CI 0.7 to 0.9*) (Public Health Wales, 2015).

Therefore, the initial univariate analysis suggested that a significantly higher proportion of children in Cardiff LA are underweight than compared to their peers across Wales. The reason for this difference was not clear; and further analysis of aggregated Child Measurement Programme data was undertaken.

Across Wales, between 2011/12 and 2013/14, a total of 89,316 Reception aged children, had their height and weight measured as part of the Child Measurement Programme. During this three year period, a total of 598 children were classed as underweight. This equates to 0.67% of all children in Wales, who participated in the Child Measurement Programme, between 2011/12 and 2013/14, being underweight.

In Cardiff LA, a total of 10,576 children participated in the Child Measurement Programme between 2011/12 and 2013/14. Of those, 155 children were classed as underweight. This equates to 1.47% of all children in Cardiff LA, who participated in the Child Measurement Programme, between 2011/12 and 2013/14, being underweight. This is significantly higher, than compared to the proportion of underweight children, across Wales (Cardiff 1.47%, *95%CI 1.25 to 1.71* vs. Wales 0.67%, *95%CI 0.62 to 0.73*).

Children from Cardiff LA made up 11.84% of all children (all weights) in Wales, who participated in the Child Measurement Programme between 2011/12 and 2013/14. However, children from Cardiff LA, made up a disproportionately higher proportion (25.92%) of all underweight children (across Wales), in the Child Measurement Programme, during this period.

Table 4: Proportion of all children aged 4-5 years participating in Child Measurement Programme, who were underweight, Wales and Cardiff local authority, count and percentage, single year of data 2013/14 and aggregated data 2011/12 - 2013/14

	Wales			Cardiff		
	count	%	95% CI's[1]	count	%	95% CI's[1]
Single year of data 2013/14*	248	0.80	(0.7 to 0.9)	66	2.10	(1.6 to 2.6)
Aggregated data 2011/12, 2012/13 & 2013/14**	598	0.67	(0.62 to 0.73)	155	1.47	(1.25 to 1.71)

Data supplied by Public Health Wales Observatory

[1]95% Confidence Intervals

Source:
*Public Health Wales: Child Measurement Programme for Wales 2013/2014.
**Public Health Wales Observatory: Child Measurement Programme three years of aggregated data 2011/12, 2012/13 and 2013/14

Numerator: Underweight children aged 4 to 5 years.
Denominator: All children of all weight categories aged 4 to 5 years.

4.2.2 Gender

Key findings:

- Across Wales, a significantly higher proportion of boys aged 4 to 5 years were underweight, than compared to girls (Boys 0.82%, *95%CI 0.75 to 0.91* and Girls 0.51%, *95%CI 0.45 to 0.58*);
- In Cardiff LA, a higher proportion of boys aged 4 to 5 years were underweight, than compared to girls (Boys 1.75%, *95%CI 1.43 to 2.13* and Girls 1.17%, *95%CI 0.91 to 1.50*); however, this difference was not statistically significant.

In 2013/14, the Child Measurement Programme reported that across Wales a significantly higher proportion of Reception aged boys (aged 4-5 years) were underweight, than compared to girls (1.0% vs. 0.6%) (Public Health Wales, 2015). Analysis of Child Measurement Programme data by gender had previously been limited due to the small number of underweight children in any one year. Aggregation of three years of data (2011/12, 2012/13 and 2013/14) therefore allowed further analysis by gender. This showed that across Wales, a significantly higher proportion of boys were underweight, than compared to girls (Boys 0.82%, *95%CI 0.75 to 0.91*+ and Girls 0.51%, *95%CI 0.45 to 0.58*). Similarly in Cardiff LA, a higher proportion of boys were underweight than compared to girls (Boys 1.75%, *95%CI 1.43 to 2.13* and Girls 1.17%, *95%CI 0.91 to 1.50*); however, this difference was not statistically significant.

Table 5: Proportion of all children aged 4-5 years, participating in Child Measurement Programme, who were underweight, by gender, count and percentage, Wales and Cardiff local authority, 2011/12 - 2013/14

	Wales			Cardiff		
	count	%	95% CI's[1]	count	%	95% CI's[1]
Boys	376	0.82	(0.75 to 0.91)	94	1.75	(1.43 to 2.13)
Girls	222	0.51	(0.45 to 0.58)	61	1.17	(0.91 to 1.50)

Data supplied by Public Health Wales Observatory

[1]Confidence Interval

Source:
Public Health Wales Observatory: Child Measurement Programme three years of aggregated data 2011/12, 2012/13 & 2013/14

Numerator: Underweight boys or girls aged 4 to 5 years.
Denominator: All boys or girls of all weight categories aged 4 to 5 years.

4.2.3 Ethnicity

Key findings:

- Across Wales and Cardiff LA, the ethnic group with the highest proportion of underweight children was the Asian ethnic group;
- The proportion of children aged 4 to 5 years from the Asian ethnic group who were underweight, did not differ significantly between Wales and Cardiff LA (Wales 3.41%, *95%CI 2.54 to 4.58* and Cardiff 4.24%, *95%CI 2.91 to 6.14*);
- Across Wales, a significantly higher proportion of children aged 4 to 5 years from the Asian ethnic group were underweight, than compared to children from the White ethnic group (3.41%, *95%CI 2.54 to 4.58* vs. 0.58%, *95%CI 0.52 to 0.65*);
- In Cardiff LA, a significantly higher proportion of children aged 4 to 5 years from the Asian ethnic group were underweight, than compared to children from the White ethnic group (4.24%, *95%CI 2.91 to 6.14* vs. 1.24%, *95%CI 0.96 to 1.61*);
- In Cardiff LA, a significantly higher proportion of children aged 4 to 5 years from the White ethnic group were classed as underweight, than compared to children from the White ethnic group across Wales (Cardiff 1.24%, *95%CI 0.96 to 1.61* and Wales 0.58%, *95%CI 0.52 to 0.65*).

When analysing Child Measurement Programme data by ethnic group, there are a number of caveats which need to be considered, including (Public Health Wales, 2015):

- The recording of ethnicity on the Community Child Health Database is not complete.
- In the 2013/14 Child Measurement Programme cohort, 11% of children in Wales had their ethnicity recorded as unknown.
- A proportion of child records were coded for ethnicity using a coding system that was replaced in 2002, suggesting that the child’s ethnicity may have been taken from their birth mothers records.
- Pre 2002 codes do not have a code for mixed race and it is not known what code was used to record such children.

However, in Cardiff and Vale Local Health Board, 86% of Child Measurement Programme data was coded, using post 2002 codes.

In 2013/14, 83.1% of all children who participated in the Child Measurement Programme were recorded as being from the White ethnic group. 5.9% of children were recorded as having an ethnic group other than white and 11% of children had their ethnicity recorded as unknown / not recorded (Public Health Wales, 2015).

To date, analysis of Child Measurement Programme data, by ethnic group, has been undertaken at an all Wales level, due to the small numbers of children in each ethnic group at local authority level (Public Health Wales, 2015). Therefore, in order to analyse and compare the proportion of underweight children, in Wales and Cardiff LA, by ethnic group, two years of Child Measurement Programme data have been aggregated (2012/13 and 2013/14).

Two years of aggregated Child Measurement Programme data (2012/13 and 2013/14), identified that 427 children across Wales and 114 children in Cardiff LA, were underweight. Analysis of this data by ethnic group showed that for both Wales and Cardiff LA, the ethnic group with the highest proportion of children, who were underweight, was the Asian ethnic group (Wales 3.41%, *95%CI 2.54 to 4.58* and Cardiff 4.24%, *95%CI 2.91 to 6.14*). There was no statistical difference between these two proportions.

Across Wales and in Cardiff LA, a significantly higher proportion of children, from the Asian ethnic group, were underweight (Wales 3.41%, *95%CI 2.54 to 4.58* and Cardiff 4.24% *95%CI 2.91 to 6.14*), than compared to children from the White ethnic group (Wales 0.58% *95%CI 0.52 to 0.65* and Cardiff 1.24%, *95%CI 0.96 to 1.61).*

In Cardiff LA, a significantly higher proportion of children from the White ethnic group were classed as underweight, than compared to children from the White ethnic group across Wales (Cardiff 1.24%, *95%CI 0.96 to 1.61* and Wales 0.58%, *95%CI 0.52 to 0.65*).

Table 6: Proportion of all children aged 4-5 years, participating in Child Measurement Programme, who were underweight, by ethnic group, count and percentage, Wales and Cardiff local authority, 2012/13 - 2013/14

	Wales			Cardiff		
Ethnic group	**count**	**%**	**95% CI's[1]**	**count**	**%**	**95% CI's[1]**
White	291	0.58	(0.52 to 0.65)	57	1.24	(0.96 to 1.61)
Asian	42	3.41	(2.54 to 4.58)	26	4.24	(2.91 to 6.14)
Black	-	-	-	-	-	-
Mixed	16	1.80	(1.11 to 2.90)	8	1.76	(0.90 to 3.44)
Chinese or other	-	-	-	-	-	-
Unknown / not recorded	58	0.90	(0.70 to 1.17)	15	1.68	(1.02 to 2.75)

Data supplied by Public Health Wales Observatory
- To avoid disclosure small numbers and some larger complementary numbers have been suppressed.
[1]95% confidence intervals

Source:
Public Health Wales Observatory Child Measurement programme two years of aggregated data 2012/13 and 2013/14.

Numerator: Underweight children aged 4 to 5 years, in each ethnic group.
Denominator: All children of all weight categories aged 4 to 5 years, in each ethnic group.

4.2.4 Socioeconomic deprivation

Key findings:

- Across Wales, a significantly higher proportion of all children (all weight categories) aged 4 to 5 years resided in the two most deprived quintiles (25.22% in the most deprived quintile and 21.03% in the next most deprived quintile), than compared to other quintiles;
- In Cardiff LA, a significantly higher proportion of all children (all weight categories) aged 4 to 5 years resided in the most deprived quintile (41.11%), than compared to other quintiles;
- A significantly higher proportion of all children (all weight categories), aged 4 to 5 years, from Cardiff LA, resided in the most deprived quintile, than compared to all children (all weight categories), who resided in the most deprived quintile in Wales (Cardiff 41.11%, *95%CI 40.2 to 42.1* and Wales 25.22%, *95%CI 24.9 to 25.5*);
- For both Wales and Cardiff LA, there was no significant difference in the proportion of children, who resided in the least deprived quintile who were underweight, than compared to the proportion who resided in the most deprived quintile of deprivation;
- In Wales, the proportion of all children who resided in the least deprived quintile who were underweight was 0.65% (*95%CI 0.5 to 0.8*), while in the most deprived quintile the proportion was 0.73% (*95%CI 0.6 to 0.9*);
- In Cardiff LA, the proportion of all children who resided in the least deprived quintile and were underweight was 1.24% (*95%CI 0.9 to 1.8*), while in the most deprived quintile the proportion was 1.43% (*95%CI 1.1 to 1.8*).

The Welsh Index of Multiple Deprivation (WIMD) is as an official measure of relative deprivation for small areas in Wales. It is designed to identify those areas with the highest concentrations of several different types of deprivation. WIMD is currently made up of eight separate types of deprivation, including (Welsh Government, 2014): Income; Employment;

Health; Education; Access to Services; Community Safety; Physical Environment and Housing.

The WIMD is therefore an area based measure of deprivation and not a measure of individual / household poverty.

Due to the small number of underweight children across Wales in any one year, analysis of Child Measurement Programme data by socioeconomic Deprivation (using WIMD), has been undertaken by combining the data of healthy and underweight children. Aggregation of three years of Child Measurement Programme data (2011/12, 2012/13 and 2013/14) has therefore enabled a more in-depth analysis. National fifths of deprivation have been used, to allow comparison between Cardiff LA and Wales.

Across Wales, a significantly higher proportion of all children (all weight categories), who participated in the Child Measurement Programme, resided in the two most deprived quintiles (25.22% in the most deprived quintile and 21.03% in the next most deprived quintile), than compared to the least, next least and middle deprived quintiles (see table 7).

Table 7: Proportion of all children (all weights), aged 4-5 years, participating in Child Measurement Programme, by Welsh Index of Multiple Deprivation, count and percentage, Wales and Cardiff local authority, 2011/12 - 2013/14

	Wales			Cardiff		
	Count	%	95% CI's[1]	Count	%	95% CI's[1]
Least deprived	15,739	17.62	(17.4 to 17.9)	2,573	24.32	(23.5 to 25.1)
Next least deprived	15,215	17.03	(16.8 to 17.3)	1,153	10.90	(10.3 to 11.5)
Middle	17,058	19.10	(18.8 to 19.4)	1,009	9.54	(9.0 to 10.1)
Next most deprived	18,786	21.03	(20.8 to 21.3)	1,495	14.13	(13.5 to 14.8)
Most deprived	22,526	25.22	(24.9 to 25.5)	4,349	41.11	(40.2 to 42.1)

Produced by Public Health Wales Observatory using CMP data (NWIS) and WIMD 2014 (WG)
[1]95% Confidence Interval

Source:
Public Health Wales Observatory: Child Measurement Programme three years of aggregated data 2011/12, 2012/13 and 2013/14

Numerator: All children of all weight categories aged 4 to 5 years, in each quintile of deprivation.
Denominator: All children of all weight categories aged 4 to 5 years.

In Cardiff LA, a significantly higher proportion of all children (all weight categories), who participated in the Child Measurement Programme, resided in the most deprived quintile (41.11%), than compared to the other quintiles in Cardiff LA (see table 7). In addition, the proportion of all children (all weight categories), from Cardiff LA, who, resided in the most deprived quintile, was significantly higher than the proportion of all children (all weight categories) from across Wales who resided in the most deprived quintile (Cardiff 41.11%, *95%CI 40.2 to 42.1* and Wales 25.22%, *95%CI 24.9 to 25.5*).

Table 8 shows there is a similar distribution of all persons aged 16 and under (all weights) across the quintiles of deprivation as identified in table 7, for children (aged 4 to 5 years), who participated in the Child Measurement Programme.

Table 8: Proportion estimates by deprivation fifth, all persons aged 16 and under, counts and percentage, Cardiff local authority, 2014

Population estimates by deprivation fifth, all persons aged 16 and under, counts and percentage, Cardiff local authority, 2014

Deprivation fifth	Count	%
Least deprived	20,089	29.06
Next least deprived	8,509	12.31
Middle	6,461	9.35
Next most deprived	9,503	13.75
Most deprived	24,565	35.54
Total population	**69,127**	-

Produced by Public Health Wales Observatory, using MYE (ONS) and WIMD 2014 (WG)

The distribution across the quintiles of deprivation described in table 7 and table 8 may in part be explained by the number and distribution of Lower Super Output Areas (LSOA) in each of the quintiles of deprivation. Table 9 shows that Cardiff LA has a higher proportion of LSOA in the least and most deprived quintiles and fewer LSOAs in the next least, middle and next most deprived quintiles.

Table 9: Lower Super Output Areas by deprivation fifth, counts and percentage, Cardiff local authority, 2014

LSOAs by deprivation fifth, counts and percentage, Cardiff local authority, 2016

Deprivation fifth	Count	%
Least deprived	66	30.84
Next least deprived	36	16.82
Middle	27	12.62
Next most deprived	26	12.15
Most deprived	59	27.57
Cardiff LSOAs	**214**	-

Produced by Public Health Wales Observatory, using WIMD 2014 (WG)

Table 10 shows the proportion of all children who are underweight by deprivation quintile. In Wales, the proportion of all children who resided in the least deprived quintile who were underweight was 0.65% (*95%CI 0.5* *to 0.8*), while in the most deprived quintile the proportion was 0.73% (*95%CI 0.6 to 0.9*). In Cardiff LA, the proportion of all children who resided in the least deprived quintile and were underweight was 1.24% (*95%CI 0.9 to 1.8*), while in the most deprived quintile the proportion was 1.43% (*95%CI 1.1 to 1.8*). For both Wales and Cardiff LA, there was no significant difference between proportions.

However, Cardiff LA, had a significantly higher proportion of all children in every quintile of deprivation that were underweight, than compared to Wales (see table 10); this reflects the higher number of underweight children in Cardiff LA.

Table 10: Proportion of all children aged 4-5 years, participating in Child Measurement Programme, who were underweight, by Welsh Index of Multiple Deprivation, count and percentage, Wales and Cardiff local authority, 2011/12 - 2013/14

	Wales			Cardiff		
	Count	**%**	**95% CI's**	**Count**	**%**	**95% CI's**
Least deprived	102	0.65	(0.5 to 0.8)	32	1.24	(0.9 to 1.8)
Next least deprived	94	0.62	(0.5 to 0.8)	18	1.56	(1.0 to 2.5)
Middle	103	0.60	(0.5 to 0.7)	19	1.88	(1.2 to 2.9)
Next most deprived	134	0.71	(0.6 to 0.8)	24	1.61	(1.1 to 2.4)
Most deprived	165	0.73	(0.6 to 0.9)	62	1.43	(1.1 to 1.8)

Produced by Public Health Wales Observatory using CMP data (NWIS) and WIMD 2014 (WG)

Source: Public Health Wales Observatory: Child Measurement Programme three years of aggregated data 2011/12, 2012/13 and 2013/14

Numerator: Underweight children aged 4 to 5 years, in each quintile of deprivation.
Denominator: All children of all weight categories aged 4 to 5 years, in each quintile of deprivation.

4.2.5 Urban / rural area of residence

Key findings:

- Across Wales, a significantly higher proportion of all children, aged 4 to 5 years, who resided in an urban area, were underweight (0.54%, *95%CI 0.5 to 0.6*), than compared to all children, aged 4 to 5 years, who resided in either a 'less sparse' rural area (0.08%, *95%CI 0.1 to 0.1*) or a 'sparse' rural area of residence (0.04%, *95%CI 0.0 to 0.1*).

It is possible to assign a child's postcode to an urban, 'less sparse' rural or 'sparse' rural classification (Public Health Wales, 2015). Therefore, it has been possible to analyse three years of aggregated Child Measurement Programme data (2011/12, 2012/13 and 2013/14) by area of residence. For the purpose of this report, aggregated Child Measurement Programme data has been analysed by area of residence at an all Wales level, as Cardiff LA is an urban area. Across Wales, a significantly higher proportion of children, who resided in an urban area, were underweight (0.54%, *95%CI 0.5 to 0.6*), than compared to children who resided in either a 'less sparse' rural area (0.08%, *95%CI 0.1 to 0.1*) or a 'sparse' rural area of residence (0.04%, *95%CI 0.0 to 0.1*).

Table 11: Proportion of all children, aged 4-5 years, participating in Child Measurement Programme, who were underweight, by urban or rural area of residence, Wales, count and percentage, 2011/12 -2013/14

	Count	%	95% CI's[1]
Rural 'Sparse'	40	0.04	(0.0 to 0.1)
Rural 'Less sparse'	75	0.08	(0.1 to 0.1)
Urban	483	0.54	(0.5 to 0.6)

Produced by Public Health Wales Observatory using CMP data (NWIS)

[1]95% Confidence Interval

Source:
* Public Health Wales Observatory: Child Measurement Programme three years of aggregated data 2011/12, 2012/13 and 2013/14

Numerator: Underweight children aged 4 to 5 years, in each area of residence.
Denominator: All children of all weight categories aged 4 to 5 years.

4.3 Census data

In Wales, Cardiff is unique in its size and demographic profile, 2011 census data has therefore been used to describe the demographic profile of the Cardiff population, including the country of birth, the ethnicity and the household language. Census data for Cardiff has been compared against census data for Wales.

Key findings:

- 92.82% of children, aged 15 years and under, in Cardiff were born in the UK;
- Cardiff had a lower proportion of the usual resident population (adults & children), who were born in the UK, than compared to Wales (86.72% vs. 94.52%);
- In Cardiff a higher proportion of usual resident population (adults & children), were born outside of the EU, than compared to Wales (9.41% vs. 3.28%);
- In Cardiff a lower proportion of children, aged 7 years and under, were from the White ethnic group, than compared to Wales (73.05% vs. 92.30%);
- In Cardiff, a lower proportion of the usual resident population (adult & children), described themselves as being from a White ethnic group, than compared to Wales (84.69% vs. 95.59%);
- The second most populated ethnic group in Cardiff and Wales was the Asian/Asian British ethnic group (8.06% and 2.29% respectively);
- Cardiff has a lower proportion of households (90.47% vs. 96.73%) where the household has English (or Welsh) as a main language and a higher proportion of households where they do not have any person (adult or child) who has English (or Welsh) as a main language (5.20% vs. 1.67%), than compared to Wales.

4.3.1 Country of birth

The 2011 census describes country of birth as the country in which a person was born (ONS, 2011). Data from the census reported that

92.82% of children aged 15 years and under, in Cardiff, were born in the UK (ONS, 2011). In comparison 86.72% of the usual resident population (adults and children), in Cardiff, were born in the UK, 0.60% were born in Ireland, 3.28% in other European Union (EU) countries and 9.41% were born in a country outside of the EU. Compared to Wales, Cardiff has a higher proportion of the usual resident population (adults and children) who were born outside of the UK (13.29% vs. 5.49%), and a higher proportion of the usual resident population who were born outside of the EU (9.41% vs. 3.28%) (ONS, 2011).

Table 12: Usual resident population (adult and children), census data, by country of birth, Wales and Cardiff, percentage, 2011

	Wales	Cardiff
	%	%
United Kingdom	94.52	86.72
Ireland	0.40	0.60
Other EU	1.81	3.28
Other countries	3.28	9.41

2011 census data, table KS204EW (ONS), accessed through nomis

Census Statistical Disclosure Control: In order to protect against disclosure of personal information from the 2011 Census, there has been swapping of records in the Census database between different geographic areas, and so some counts will be affected. In the main, the greatest effects will be at the lowest geographies, since the record swapping is targeted towards those households with unusual characteristics in small areas.

4.3.2 Ethnic group

In the 2011 census, ethnic group of the usual resident population is categorised according to the individuals own perceived ethnic group and cultural background (ONS, 2011). Table 13, shows that across Wales, 95.59% of the usual resident population (adults and children) described themselves as being from a White ethnic group; Of these, 1.91% described themselves as other White (not English, Welsh, Scottish, Northern Ireland, British, Irish, Gypsy or Irish traveller) (ONS, 2011).

In Cardiff, 84.69% of the usual resident population described themselves as being from a White ethnic group and of these 4.18% described themselves as other White (ONS, 2011). The second most populated ethnic group in Wales and Cardiff was the Asian/Asian British ethnic group (2.29% and 8.06% respectively).

Table 13: Usual resident population (adults and children), census data, by ethnic group, Wales and Cardiff, percentage, 2011

	Wales	Cardiff
	%	%
White	95.59	84.69
Mixed/multiple ethnic groups	1.03	2.90
Asian/Asian British	2.29	8.06
Black/African/ Caribbean/ Black British	0.60	2.37
Other ethnic group	0.50	1.98

2011 Census data, table KS201EW (ONS), accessed through nomis

Census Statistical Disclosure Control: In order to protect against disclosure of personal information from the 2011 Census, there has been swapping of records in the Census database between different geographic areas, and so some counts will be affected. In the main, the greatest effects will be at the lowest geographies, since the record swapping is targeted towards those households with unusual characteristics in small areas.

Data from the 2011 census (table 14), reported that in Cardiff, a lower proportion of children, aged 7 years and under, were from the White ethnic group, than compared to Wales (73.05% vs. 92.30%).

Table 14: Proportion of all children aged 7 years and under, census data, by ethnic group, Wales and Cardiff, 2011

	Wales	Cardiff
Ethnic Group	%	%
White	92.30	73.05
Mixed/ multiple groups	2.44	6.39
Asian/ Asian British	3.53	12.62
Black/ African/ Caribbean/ Black British	0.83	4.12
Other Ethnic group	0.91	3.82

2011 Census data, table DC2101EW (ONS), accessed through nomis

Census Statistical Disclosure Control: In order to protect against disclosure of personal information, records have been swapped between different geographic areas. Some counts will be affected, particularly small counts at the lowest geographies. Census definition of age:
Age is derived from the date of birth question and is a person's age at their last birthday, at 27 March 2011. Infants less than one year old are classified as 0 years of age.

4.3.3 Household main language

2011 census data can also be used to look at classification of households by the combination of adults and children within a household that have

English (English or Welsh in Wales) as a main language (ONS, 2011). Table 15, shows that, across Wales, 96.73% of all households reported having English (or Welsh) as a main language and 1.67% of all households do not have any person (adult or child) who has English (or Welsh) as a main language.

In comparison, Cardiff has a lower proportion of households (90.47%) where the household has English (or Welsh) as a main language and a higher proportion of households where they do not have any person (adult or child) who has English (or Welsh) as a main language (5.20%).

The census data highlights that the population of Cardiff is more ethnically diverse than compared to the population of Wales.

Table 15: Usual resident population (adult and children), census data, by household language, Wales and Cardiff, percentage, 2011

	Wales %	Cardiff %
All people aged 16 and over in household have English as a main language (English or Welsh in Wales)	96.73	90.47
At least one but not all people aged 16 and over in household have English as a main language (English or Welsh in Wales)	1.38	3.57
No people aged 16 and over in household but at least one person aged 3 to 15 has English as a main language (English or Welsh in Wales)	0.22	0.76
No people in household have English as a main language (English or Welsh in Wales)	1.67	5.20

2011 census data, table KS206EW (ONS), accessed through nomis

Census Statistical Disclosure Control: In order to protect against disclosure of personal information from the 2011 Census, there has been swapping of records in the Census database between different geographic areas, and so some counts will be affected. In the main, the greatest effects will be at the lowest geographies, since the record swapping is targeted towards those households with unusual characteristics in small areas.

4.4 Multivariate analysis

The logistic regression model, included all children, aged 4 to 5 years, in Wales, who participated in the Child Measurement Programme in 2012/13 and 2013/14 (n=59,904); of these 0.71% were underweight (n=427). Univariate analysis of aggregated Child Measurement Programme data was undertaken to identify which variables were associated with being underweight. Significant variables were included in the multivariate analysis.

Key findings:

- The logistic regression model included all children aged 4 to 5 years in Wales, who participated in the Child Measurement Programme in 2012/13 and 2013/14 (n=59,904);
- The logistic regression model identified that children from non-White ethnic groups, were at increased risk of being underweight, than compared to children from the White ethnic group;
- Children from the Asian ethnic group were over five times more likely to be underweight, than compared to children from the White ethnic group (OR 5.45, *p-value 0.000, 95%CI 3.91 to 7.60);*
- Female gender and living in a rural area of residence were protective factors against being underweight in childhood;
- The socioeconomic deprivation variable, showed a small association with being underweight in the univariate analysis. However, when the variable was included in the multivariate analysis there was no discernible difference to the output of the final model (may have been due to the small sample size of underweight children). Therefore socioeconomic deprivation was not included in the final model;
- The logistic regression model had a good 'goodness of fit' indicating that from the (limited) variables available in the data set, the three explanatory variables used in the final model (gender, ethnicity and area of residence) were the best at explaining why children were underweight. However, the final model had poor discrimination, and suggests that the final model has a low predictive power to say that those three explanatory variables alone, can predict underweight in children.
- Explanations for the goodness of fit and the poor predictive power of the final model are the small sample size of underweight children in the sample and that there were insufficient explanatory variables in the Child Measurement Programme data set to predict underweight in children.

Table 16, shows the output from the logistic regression model. The logistic regression model identified that children from all non-White ethnic groups were at increased risk of being underweight, than compared to children from the White ethnic group; with children from the Asian ethnic group being over five times more likely to be underweight (OR 5.45, *p-value 0.000, 95%CI 3.91 to 7.60*) than compared to children from the White ethnic group.

Female gender and living in a rural area of residence were identified in the logistic regression model as being protective factors. The logistic regression model estimated that the odds ratio of being underweight if female was 0.60 (*p-value 0.000, 95%CI 0.49 to 0.73)*, which equates to a 40% reduced risk of being underweight if female than compared to being male. The logistic regression model estimated that the odds ratio of being underweight if a child resided in a 'less-sparse rural' area was 0.65 (*p-value 0.006, 95% CI 0.48 to 0.89)* and for children in a 'sparse rural' area the odds ratio was 0.69 (*p-value 0.045, 95%CI 0.48 to 0.99)*.

Socioeconomic deprivation, showed a small association with being underweight in the univariate analysis. However, when the variable (socioeconomic deprivation) was included in the multivariate analysis, the variable made no discernible difference to the output of the final model. Therefore the variable was not included in the final model. The reasons why socioeconomic deprivation did not influence the final logistic regression model may have been due to the small sample size of underweight children in the sample (0.71%).

Table 16: Odds Ratio of being underweight, all children (all weights) aged 4-5 years participating in the Child Measurement Programme, by gender, ethnic group and urban / rural area of residence , Wales, 2012/13 and 2013/14

Odds Ratio of being underweight, Child Measurement Programme, by gender, ethnic group and urban/ rural area of residence, Wales, 2012/13 and 2013/14

Explanatory variables	Odds Ratio	P value	95% CI[1]
Gender	0.60	0.000	(0.49 to 0.73)
Ethnic group			
Mixed	2.91	0.000	(1.75 to 4.84)
Black	3.02	0.008	(1.33 to 6.85)
Chinese or other	2.06	0.009	(1.20 to 3.54)
Asian	5.45	0.000	(3.91 to 7.60)
Unknown / not recorded	1.54	0.003	(1.16 to 2.04)
Urban / Rural			
Less sparse rural	0.65	0.006	(0.48 to 0.89)
Sparse rural	0.69	0.045	(0.48 to 0.99)

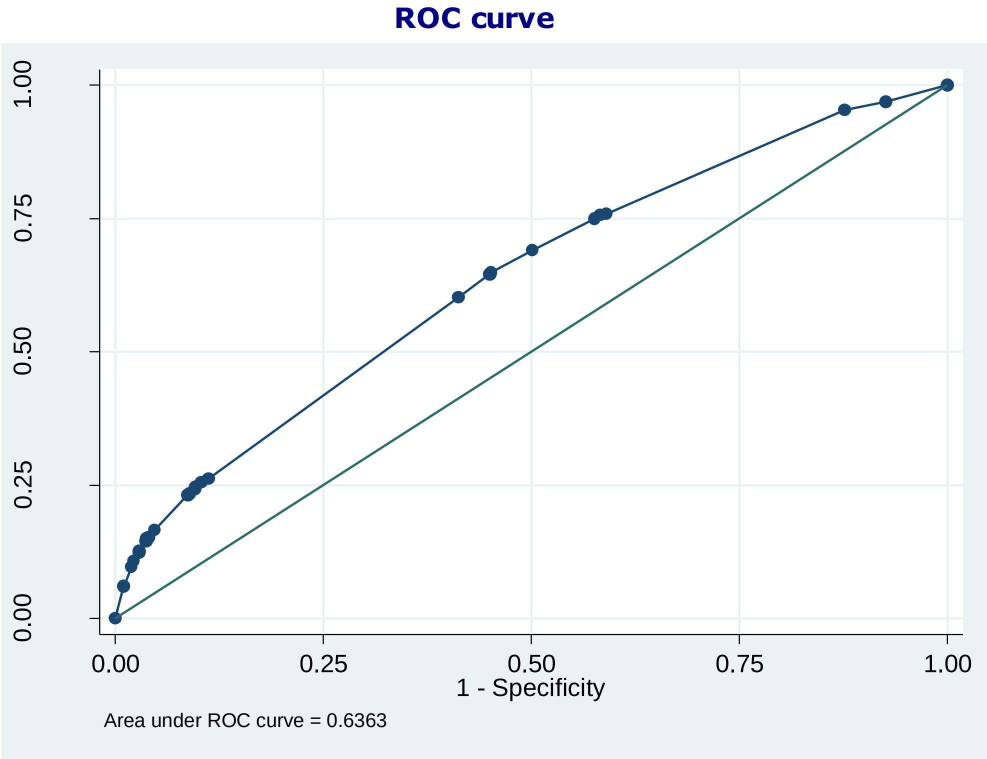
Multivariate logistic regression, where male gender, White ethnic group and uban area of residence are the comparator groups

Data supplied by Public Health Wales Observatory

[1]95% Confidence Interval

The logistic regression model had a goodness of fit test of *p=0.4693*. This indicates that from the (limited) variables available in the data set, the three explanatory variables used in the final model (gender, ethnicity and area of residence) were the best at explaining why children were underweight. However, the ROC curve, for the final model, gives an area under the curve statistic of *0.6363*. This corresponds to poor discrimination, and suggests that the final model has a low predictive power to say that those three explanatory variables alone, can predict underweight in children. Explanations for the goodness of fit and the poor predictive power of the final model are the small sample size of underweight children and that there were insufficient explanatory variables in the Child Measurement Programme data set to predict underweight in children.

Figure 2: ROC curve



Source:
Public Health Wales Observatory, using Child Measurement Programme data 2012/13 & 2013/14

5 Discussion

This report has shown that in Cardiff LA, a significantly higher proportion of children, aged 4-5 years, who participated in the Child Measurement Programme, between 2011/12 and 2013/14, were underweight, than compared to their peers across Wales (Cardiff 1.47%, *95%CI 1.25 to 1.71* vs. Wales 0.67%, *95%CI 0.62 to 0.73*). In addition, the proportion of underweight children in Cardiff LA, was also higher than the proportion of underweight Reception aged children (4-5 years) recorded by the NCMP in England in 2014/15 (1.0%, *95% CI 0.9 to 1.0*) (Public Health England, 2015b).

There was some evidence from the literature review that the prevalence of underweight children, has declined in recent years (Public Health England, 2015a, Wang, Monterio and Popkin, 2002 and Schönbeck et al, 2014). Analysis of the trend in proportions of underweight children in Wales and Cardiff LA, was not undertaken in this report as only three years of Child Measurement Programme data have been collected to date. However, it is important to understand if rates are reducing, not changing or increasing; therefore, analysis of trends in the Child Measurement Programme should be considered when a larger data set has been collected.

Age

This report did not include age as an explanatory variable as the Child Measurement Programme only collects data from children aged 4-5 years. Therefore it was not possible to compare the rates of this age group with another.

In England, the NCMP record the height and weight of children in Reception and in year six (10-11 years). The NCMP reported that in 2014/15, a significantly higher proportion of year six children were underweight than compared to Reception aged children (1.4% vs. 1.0%) (Public Health England, 2015b). A second study in the literature review also reported that older children (>10 years) had a higher prevalence of underweight than compared to younger children (Wang, Monterio and Popkin, 2002). However, two studies contradict this and suggest that younger children (<6 years) had a higher prevalence of underweight than compared to older children / adolescents (Whitaker et al's, 2011 and Schönbeck et al, 2014). Further research is therefore required to understand if age is associated with being underweight.

Gender

This report found a significant difference in the proportion of underweight children by gender, across Wales. Across Wales, a significantly higher proportion of boys (0.82%, *95%CI 0.75 to 0.91*) were underweight than compared to girls (0.51%, *95%CI 0.45 to 0.58*). In Cardiff LA, a higher proportion of boys (1.75%, *95%CI 1.43 to 2.13*) were underweight than compared to girls (1.17%, *95%CI 0.91 to 1.50*); however, this difference was not statistically significant. The logistic regression model reported that the odds ratio of being underweight, if female, was 0.60 (*p-value 0.000, 95%CI 0.49 to 0.73)*, which equates to a 40% reduced risk of being underweight if female than compared to being male.

The findings in this report are in keeping with the evidence in the literature review, which highlighted that the prevalence of underweight varied by gender, with boys being at increased risk of being underweight than girls (Pearce, Rougeaux and Law, 2015). Data from the 2014/15 NCMP report also support this theory; with a significantly higher proportion of Reception aged boys being underweight (1.2%, *95%CI 1.2 to 1.3*) than compared to the girls (0.7%, *95%CI 0.7 to 0.7*). However, this gender difference was reversed for children in year six, where a significantly higher proportion of girls in year six were underweight than compared to the boys (1.6% vs. 1.2%) (Public Health England, 2015b). The literature review also found evidence that this association between gender and underweight may reverse as children aged; with older girls /adolescents having a higher prevalence of underweight than their male peers (Yngve et al, 2007 and Antal et al, 2009).

Ethnic group

This report found that the proportion of underweight children, varied between ethnic groups. Across Wales and Cardiff LA, the ethnic group with the highest proportion of underweight children was the Asian ethnic group (Wales 3.41% and Cardiff 4.24%). These proportions were similar to that reported by the NCMP, for Reception aged children in England, of 3.6% (Public Health England, 2015b). This report also found that, a significantly higher proportion of all children (all weight categories) from the Asian ethnic group, were underweight than compared to children from the White ethnic group. This was the case for both Cardiff LA (Asian ethnic group 4.24%, *95%CI 2.91 to 6.14* and White ethnic group 1.24%, *95%CI 0.96 to 1.61*) and for Wales (Asian ethnic group 3.41 *95%CI 2.54 to* 4.58 and White ethnic group 0.58%, *95%CI 0.52 to 0.65*). The findings from the univariate analysis, were supported by the logistic regression, which found that children from non-White ethnic groups were at increased risk of being underweight, than compared to children from the White ethnic group. For example, the logistic regression model reported that the odds ratio of being underweight for children from the Asian ethnic group was 5.45, (*p-value 0.000, 95%CI 3.91 to 7.60*). This equates to a 5-fold increased risk of children from an Asian ethnic group being underweight, than compared to children from the White ethnic group.

Census data on the demographic profile of both children and the usual resident population (adult and children) of Cardiff and Wales was used in this report to try and provide a description of the population from which the children participating in the Child Measurement Programme derived from. Census data highlighted that Cardiff is an ethnically diverse community. Census data from children aged 7 years and under, reported that Cardiff had a lower proportion of children from the White ethnic group, than compared to Wales (73.05% vs. 92.30% respectively). In addition compared to Wales, Cardiff had a higher proportion of the usual resident population (adult and children) who were born outside of the UK (13.29% vs. 5.49%) and a higher proportion of the usual resident population who were born outside of the EU (9.41% vs. 3.28%).

The evidence in this literature review also supports the theory that, the prevalence of underweight children, varies by ethnic group. The evidence suggested that children from non-White ethnic groups had a higher prevalence of underweight, than compared to children from White ethnic groups (Whitaker et al, 2011, Joosten et al, 2010 and Taylor et al, 2005). However, the studies included in this review did not provide evidence on the reasons why there is a difference in prevalence rates. Therefore, this report recommends that further research is undertaken to understand the reasons why there is variation in prevalence of underweight in children, between ethnic groups.

In addition to differences in proportions of underweight children between ethnic groups, this report also identified a significant difference in proportions of underweight children within the white ethnic group, in Cardiff LA and across Wales. In Cardiff LA, a significantly higher proportion of children from the White ethnic group were classed as underweight, than compared to children from the White ethnic group across Wales (1.24% vs. 0.58% respectively). The Wales proportion (0.58%) was similar to the proportion recorded by the NCMP in England (0.6%, Reception children) (Public Health England, 2015b). The reason for this variation within the white ethnic group was not clear from the univariate analysis, therefore additional information, from the 2011 census was sought. Census data reported that Cardiff had a higher proportion of the usual resident population (adult and children) who described themselves as 'other' White (not English, Welsh, Scottish, Northern Ireland, British, Irish, Gypsy or Irish traveller), than compared to the usual resident population of Wales (4.18% vs. 1.91%). This diversity within the White ethnic group in Cardiff may partly explain the difference in proportions of underweight children within the White ethnic group; however, further research is recommended to fully understand the reason for these differences.

Socioeconomic Deprivation

The univariate analysis in this report found that, a significantly higher proportion of all children (all weight categories), in Wales and in Cardiff LA, resided in the most deprived quintiles. However, the proportion of all children (all weight categories), in Cardiff LA, who resided in the most deprived quintile was significantly higher than, compared to Wales (Cardiff 41.11%, *95%CI 40.2 to 42.1* and Wales 25.22%, *95%CI 24.9 to 25.5*). This may partly be explained by the number and distribution of LSOAs in Cardiff LA, as Cardiff LA has a higher proportion of LSOA in the least and most deprived quintiles and fewer LSOAs in the next least, middle and next most deprived quintiles.

This report found that for both Wales and Cardiff LA, there was no significant difference between the proportions of all children (all weight categories) who resided in the least deprived quintile that were underweight, than compared to the most deprived quintile of deprivation. In Wales, the proportion of all children (all weights) who resided in the least deprived quintile who were underweight was 0.65% (*95%CI 0.5 to 0.8*), while in the most deprived quintile the proportion was 0.73% (*95%CI 0.6 to 0.9*). In Cardiff LA, the proportion of all children who resided in the least deprived quintile and were underweight was 1.24% (*95%CI 0.9 to 1.8*), while in the most deprived quintile the proportion was

1.43% (*95%CI 1.1 to 1.8*). For both Wales and Cardiff LA, there was no significant difference between the proportions.

However, Cardiff LA, had a significantly higher proportion of all children in every quintile of deprivation that were underweight, than compared to Wales; this reflects the higher number of underweight children in Cardiff LA.

In the logistic regression analysis, the socioeconomic deprivation variable, showed a small association with being underweight in the univariate analysis. However, when the variable (socioeconomic deprivation) was included in the multivariate analysis, the variable made no discernible difference to the output of the final model. Therefore the variable was not included in the final model. The reasons why socioeconomic deprivation did not influence the final logistic regression model may have been due to the small sample size of underweight children in the model (0.71%). This may of lead to a type II error, where the 'real' effect of socioeconomic deprivation was not identified.

The NCMP in England (2014/15 cohort), reported an association between the proportion of children classified as underweight and deprivation (Public Health England, 2015b). However, there was inconclusive evidence in this literature review to say whether there was an association between the prevalence of underweight children and socioeconomic deprivation. Three studies reported a significantly higher proportion of children from socioeconomically disadvantaged areas, were underweight, than compared to their peers who lived in more affluent areas (Armstrong et al, 2003, Pearce, Rougeaux and Law, 2015 and Wang, Monterio and Popkin, 2002). These studies included large samples of children, which may have given the studies adequate power to identify a real difference. However, two of the studies that reported no significant difference, also had a large sample size (Whitaker et al, 2011, and Schönbeck et al, 2014). Therefore further research is recommended to understand if socioeconomic disadvantage is associated with being underweight.

Infant, Child and Parental factors

A number of infant and child factors were found to be associated with the prevalence of underweight in childhood, including prematurity, low birth weight and rates of growth in infancy (Pearce, Rougeaux and Law, 2015 and Savva et al, 2005, Fairley et al, 2013, Gishti et al, 2014, Imai et al, 2014, Joosten et al, 2010 and Meyer et al, 2013).

Paternal factors associated with being underweight in childhood, included levels of maternal education, being underweight pre-pregnancy, older maternal age, drinking in pregnancy and maternal stress (Lakshman et al, 2013, Pearce, Rougeaux and Law, 2015, Stenhammar et al, 2010 and Janevic et al, 2010).

Infant, child and parental factors were not included in the analysis in this report, as such information is not routinely collected in the Child Measurement Programme. Research using data linkage techniques should therefore be considered, to look for associations between explanatory variables, not included in the Child Measurement Programme data set, such as birth weight, gestational age at birth, maternal smoking, maternal height and parental BMI, with the prevalence of underweight children.

Urban or Rural area of residence

Cardiff LA is a predominantly urban area of residence; therefore univariate analysis of aggregated Child Measurement Programme data was undertaken at an all Wales level. This report found that across Wales, a significantly higher proportion of all children (all weight categories), who resided in an urban area, were underweight (0.54%, *95%CI 0.50 to 0.60),* than compared to children who resided in either a 'less sparse' rural area (0.08%, *95%CI 0.1 to 0.1*) or a 'sparse' rural area of residence (0.04%, *95%CI 0.0 to 0.1*). This finding was supported by the logistic regression model, which suggested that living in a rural area of residence was a protective factor against being underweight in childhood. With children residing in a 'less-sparse rural' area having a 35% reduced risk of being underweight (OR 0.65, *p-value 0.006, 95%CI 0.48 to 0.89)* and children residing in a 'sparse rural' area having a 31% reduced risk of being underweight (OR 0.69, *p-value 0.045, 95%CI 0.48 to 0.99)*, than compared to children who resided in an urban area. The urban nature of Cardiff LA may therefore partly explain the higher proportion of underweight children identified in Cardiff LA.

In England, the NCMP use a different urban/rural classification system therefore a direct comparison with Child Measurement Programme data cannot be made (Public Health Wales, 2015). However, the authors of the NCMP 2014/15 report, found that the prevalence of underweight children in Reception class, in England, was significantly higher in urban areas than compared to rural areas; with 1.0% living in urban areas, 0.6% living in town areas and 0.6% living in village areas. A similar finding was seen for children in year six (Public Health England, 2015b). In addition, across England there was regional variation in the proportion of children who were underweight. The North East and South West had a lower underweight prevalence (both school years) than the national average. While London and the West Midlands had higher underweight prevalence in reception aged children and London and East Midlands had a higher underweight prevalence rate in year six children (Public Health England, 2015b).

However, there was inconclusive evidence in this literature review, to say whether there was an association between area of residence and being underweight. The three studies which explored the relationship between living in a rural or urban area and the prevalence of underweight in childhood (Wang, Monterio and Popkin, 2002, Janevic et al, 2010 and Savva et al, 2005) did not reach a consensus of opinion. Further research is therefore required to determine whether a rural or urban setting is associated with being underweight in childhood.

Strengths and limitations

The strengths of this piece of work include the comprehensive literature review that was undertaken and was used to inform the data analysis. The literature review identified the paucity of published evidence in this area and this work will add to this currently small evidence base. In addition this piece of work used both univariate and multivariate analysis to investigate differences in rates of underweight children and to identify any association between explanatory variables and risk of being underweight in childhood. This knowledge can be shared with stakeholders and used to support work that investigates this variation further.

The limitations of the logistic regression analysis include the relatively small number of underweight children in the Child Measurement Programme data set (0.71%), which potentially can lead to a type II error. Increasing the power of the study, by increasing the sample size of the data set, may identify associations between being underweight and explanatory variables, which have not been identified in this report. Another limitation was the limited number of explanatory variables available within the Child Measurement Programme data set. Increasing the number of explanatory variables through data linkage techniques, would allow analysis of additional explanatory variables (as identified in the literature review) and may improve the predictive power of the logistic regression model.

6 Conclusions

This report identified a significant variation in the proportion of underweight children, between Cardiff LA and Wales. Univariate analysis of aggregated Child Measurement Programme data identified that the proportion of children in Cardiff LA, who were underweight, varied by ethnic group and by gender, although the later was not statistically significant. However, these factors, plus urban area of residence, were also significantly associated with the proportion of underweight children at an all Wales level and not unique to the Cardiff LA population.

The logistic regression model, which included all children in Wales, who participated in the Child Measurement Programme (2012/13 & 2013/14), identified that children from non-White ethnic groups were at increased risk of being underweight, than compared to children from the White ethnic group; with children from the Asian ethnic group being five times more likely to be underweight. Female gender and living in a rural area of residence were identified as protective factors. Socioeconomic deprivation, showed a small association with being underweight during the univariate analysis of the logistic regression. However, when this variable (socioeconomic deprivation) was included in the multivariate analysis, the variable made no discernible difference to the output of the final model. Therefore the variable was not included in the final model. The reasons why socioeconomic deprivation did not influence the final logistic regression model may have been due to the small sample size of underweight children in the sample.

In addition, the logistic regression model had a good 'goodness of fit' indicating that from the (limited) variables available in the data set, the three explanatory variables used in the final model (gender, ethnicity and area of residence) were the best at explaining why children were underweight. However, the final model had poor discrimination, and suggests that the final model has a low predictive power to say that those three explanatory variables alone, can predict underweight in children. Explanations for the goodness of fit and the poor predictive power of the final model are the small sample size of underweight children in the sample and that there were insufficient explanatory variables in the Child Measurement Programme data set to predict underweight in children.

In conclusion Cardiff LA is an urban area and is more ethnically diverse than other areas of Wales. These two factors may have contributed to the higher proportion of underweight children, aged 4 to 5 years, in Cardiff LA. However, the reason why there is variation between urban and rural areas and the reason why a higher proportion of children from non-White ethnic groups are underweight are not evident from the literature review and from the data analysis in this report. Therefore further work and research are recommended.

7 Recommendations

- The findings of this report will be shared with colleagues in the Cardiff and Vale Local Public Health Team and wider stakeholders; Their expertise and local knowledge are essential in interpreting and adding context to the evidence and data presented in this report.
- Further work is recommended, to understand why there is variation in the proportion of underweight children, both within and between different ethnic groups, in Cardiff LA, and across Wales.
- Analysis of aggregated Child Measurement Programme data should be considered in the future, as a larger data set would increase the power of the study and the predictive power of the logistic regression analysis. Associations which have not been identified in this report e.g. socioeconomic deprivation and underweight in childhood may then be detected.
- Analysis of trends in the Child Measurement Programme data should be considered in the future, when a larger, data set is available.

8 Suggested areas for further research

- Further research is required to understand why there is variation in the proportions of underweight children between different ethnic groups and why children from non-White ethnic groups are at increased risk of being underweight, than compared to children from the White ethnic group.
- Research using data linkage techniques should be considered to look for associations between explanatory variables not included within the Child Measurement Programme data set, such as birth weight, gestational age at birth, maternal smoking, maternal height and parental BMI, with the prevalence of underweight children. Increasing the number of explanatory variables used within the logistic regression model, may increase the predictive power of the model.
- Conversion of Child Measurement Programme data from UK90 reference population to IOTF reference population thresholds, as derived by Cole et al (2007), should be considered so that international comparisons with Welsh data can be made.

9 Appendices

9.1 Appendix A: Summary of literature review

Table 17: Summary of literature review

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Antal et al. Prevalence of underweight, overweight and obesity on the basis of Body Mass Index and Body Fat Percentage in Hungarian schoolchildren: Representative survey in Metropolitan Elementary schools. *Ann Nutr Metab* 2009; 54:171-176	Cross sectional study. Children aged 7 to 14 years in Hungary (n=1,928).	Defined underweight as a BMI<5th centile of the age and gender specific WHO reference data and the BMI-based classification system proposed by the International Obesity Taskforce (IOTF) (pre 2007) and a body fat percentage (%BF) of <5 for boys and <10 for girls.	The prevalence of underweight for boys was 5.1% and for girls was 6.8% (total 5.9%); however the authors did not provide details on whether this difference was statistically significant. When the authors used %BF to estimate prevalence of underweight children they found a lower prevalence of underweight in boys (3.7%) and a higher prevalence in girls (10.1%) (total 6.7), again no data on statistical significance was provided
Armstrong et al. Coexistence of social inequalities in undernutrition and obesity in preschool children: population based cross sectional study. *Arch Dis Child* 2003; 88:671–675	Retrospective cross sectional study in Scotland of 74 500 children aged 3-4 years.	The authors defined undernutrition as a BMI<2nd percentile on the UK90 growth reference charts OR of being underweight per category of deprivation (Carstairs) calculated (crude and adjusted for birth weight)	The authors found that the prevalence of children classed with undernutrition was greater in more deprived areas than in the least deprived areas (4.8% vs. 3.2%) (based on Carstairs Deprivation Categories). Children in the most deprived areas had a 51% increased risk of undernutrition than compared to their peers in the least deprived areas (odds ratio (OR) of 1.51; CI 1.22 to 1.87), this difference remained significant after adjusting for birth weight of the children (OR 1.29; CI 1.03 to 1.62). They also found that undernutrition and obesity co-existed in the most deprived areas.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Bhandari et al. Growth performance of affluent Indian children is similar to that in developed countries. *Bulletin of the World Health Organization* 2002; 80:189-195	Cross sectional study of infants aged 12-23 months in affluent areas of South Deli. N=341 Excluded if premature or chronic disease.	Aim to determine if affluent population in India had a growth performance similar to that found in developed countries. Used the NCHS/WHO reference population and defined underweight as weight-for-age z-score ≤-2 SD, stunting as a length-for-age z-score ≤-2 SD and wasting as a weight-for-length z-score ≤-2 SD.	The authors reported that the prevalence of underweight children in South Deli was 5.9%, the prevalence of stunting was 3.2% and the prevalence of wasting was 3.8%. The authors found that two socioeconomic factors were significantly associated with a higher length-for-age (less likely to be stunted) namely ≥17 years of parental education and a non-vegetarian diet. There was no socioeconomic factor that was significantly associated with weight-for-length.
Boddy, Hacket and Stratton. The prevalence of underweight in 9-10-year-old schoolchildren in Liverpool: 1998-2006. *Public Health Nutrition*. 2008, 12(7): 953-956	Cross sectional study in Liverpool. Time series of weight and height measurements of children aged 9-10 (1998 and 2006).	Used the IOTF growth reference and defined underweight as grade I, II & III. No secondary analysis, p-values or CI.	The authors found that the prevalence of total underweight (grade I, II & III), in boys and girls fell between 1998 and 2006. The prevalence for boys declined from 10.3% to 6.9%, while the prevalence for girls fell from 10.8% to 7.5%). However no details were provided as to whether these declines were statistically significant. The most populated grade of underweight was grade I (least underweight). When the grades of underweight were analysed separately the prevalence of grade II underweight for boys remained similar over the time period while the prevalence for girls fell. However no details were provided as to whether this decline was statistically significant.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
De Wilde et al. Trends in body mass index distribution and prevalence of thinness, overweight and obesity in two cohorts of Surinamese South Asian children in The Netherlands. *Arch Dis Child* 2013; 98:280–285	Retrospective cohort study during two time periods (1974-76 & 1991-93) of Surinamese South Asian children in The Hague, Netherlands. N=2015	The aim of the study was to determine the prevalence of thinness based on either WHO growth standard (0-4 years), WHO growth reference (5-19 years) and IOTF growth reference. Thinness was defined as either severe thinness (WHO BMI<-2 SD, IOTF BMI at age 18 of <17kg/m²) or thinness (WHO BMI≥-2 SD and <-1 SD, IOTF BMI at age 18 of ≥17 and <18).	The authors found that the prevalence of thinness (combined) in the 1974-76 cohort based on WHO growth standard and WHO growth reference criteria was 38.3% and the prevalence when using IOTF cut-offs was 36.4%. In the 1991-93 cohort the prevalence of thinness based on WHO growth standard and WHO growth reference criteria was 23.6% and the prevalence when using IOTF cut-offs was 23.9%. The authors reflected that findings showed an unusually high prevalence of severe thinness for a developed country and concluded that the disproportionately high prevalence of (severe) thinness may be due an expression of body characteristics of South Asian children (thin-fat body composition) and the current universal BMI cut-offs may overestimate rates of thinness in this group
Emond et al. Postnatal factors associated with failure to thrive in term infants in the Avon Longitudinal Study of Parents and Children. *Arch Dis Child* 2007; 92:115–119	Analysis of data from the Avon Longitudinal Study of Parents and Children (ALSPAC). n=11,900 infants to determine which postnatal factors were associated with weight faltering in infancy	Weight and height measured at routine clinics. The authors used the British 1990 growth reference and defined growth faltering as infants <5th centile for weight gain.Note: does not provide information on childhood weight, heights and BMI and no associations were made as to whether weight faltering affected the prevalence of underweight in children.	The prevalence of weight faltering from birth to 8 weeks was 4.5%. The maternal factors which influenced this prevalence included a maternal height <160cm, maternal age >32 years and access to a car. Infant factors included a weak suck, feeding difficulties and infant ill health. The prevalence of weight faltering between 8 weeks and 9 months was 4.2%. Factors which influenced the prevalence included, poor infant feeding, breast feeding >6 months duration, a maternal height <160cm, parity >3 and a mother of Asian origin. No associations were found between the prevalence of growth faltering and measures of social class or level of parental education.

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Fairley et al. Describing differences in weight and length growth trajectories between white and Pakistani infants in the UK: analysis of the Born in Bradford birth cohort study using multilevel linear spline models. *Arch Dis Child* 2013; 98:274–279	Birth cohort study in Bradford, UK. 1707 mothers and children followed up from birth to two years. To estimate individual growth trajectories for weight and length.	Birth weight and length from records, follow up measurements at set intervals. Mothers details by questionnaire. Compared Pakistani boys and girls (based on parental ethnicity) with white British boys and girls. Growth reference not defined.	The authors found that children (boys and girls) from the Pakistani ethnic group were lighter and had a shorter predicted mean length at birth than compared to children from the white British ethnic group. However children (boys and girls) from the Pakistani ethnic group gained more length per month in the first four months of life and gained more weight per month after 9 months of age than compared to children from the white British ethnic group. Measurements at two years showed that the two ethnic groups had similar weights but children (boys and girls) from the Pakistani ethnic group were taller. The authors found that differences in maternal height explained some of the differences in weight and height, however adjustment for maternal height, smoking during pregnancy and gestational age, did not explain the differences in postnatal growth rates described.
Gishti et al. Fetal and Infant Growth Patterns Associated With Total and Abdominal Fat Distribution in School-Age Children. *J Clin Endocrinol Metab* 2014; 99(7):2557–2566	Population-based prospective cohort study of 6464 children born between 2002 and 2006. Part of Generation R study in The Netherlands	Growth characteristics measured in the second and third trimesters of pregnancy, at birth, and at 6, 12, and 24 months. The authors used Dutch growth reference charts.	The authors reported that the BMI of school aged children was associated with their growth in foetal life and through infancy. They reported that length gain in late infancy was positively associated with BMI and that estimated foetal weight and abdominal growth in the 2^{nd} and 3^{rd} semester and weight gain in early, mid and late infancy were all positively associated with childhood body mass index. They also reported that at age 6 girls had higher fat mass index and abdominal body fat measures than boys.

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Howe et al. Socioeconomic disparaties in trajectories of adiposity across childhood. *International Journal of Paediatric Obesity* 2011; 6:e144-e153	A longitudinal cohort study in England (ALSPAC) which followed a cohort of children from birth.	The authors used the IOTF growth reference and collected serial measurements of the children's weight and height	The authors reported boys aged 7 to 10 years had a significantly lower BMI if their mother was degree-educated than compared to A-levels only. The BMI of girls whose mother was degree-educated was also lower than for other educational categories however the finding was not statistically significant (Howe et al, 2011). Note: This study did not report on the prevalence of underweight and how that was affected by maternal education level.
Imai et al. Associations between Infant Feeding Practice Prior to Six Months and Body Mass Index at Six Years of Age. *Nutrients* 2014; 6:1608-1617	A cross sectional study of children in Iceland n=154	Information on feeding patterns from birth to 5 months. Aimed to look at the association between infant feeding practice and BMI.	The authors reported that infants who were formula fed and had solids introduced at 5 months of age grew quicker and had a higher BMI at age 6 years than exclusively breast fed children.
Janevic et al. Risk factors for childhood malnutrition in Roma settlements in Serbia. *BMC Public Health* 2010; 10:509	Cross sectional questionnaire based study of Romani households in Serbia. Part of the multiple indicator cluster survey by UNICEF (2005-06).	3 questionnaires (maternal education, wealth score, health and sociodemographic data, children under 5 data) Used the WHO/CDC/NCHS growth reference population and defined wasting as a weight-for-height z-score<-2 Standard deviation (SD), stunting as a height-for-age z-score<-2 SD and underweight as a weight-for-age z-score<-2 SD.	The authors report that the population studied had a high prevalence of stunting (20.1%), wasting (4.3%) and underweight (8%). The study reported that the factors which were statistically significant in predicting stunting were a low wealth score, low levels of maternal education and a history of a child being left in the care of another child. Significant predictors of wasting were living in an urban area and low levels of maternal literacy. The only significant predictor for underweight was region of residence, however the authors did not clarify if the region in question was urban or rural.

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Joosten et al. National malnutrition screening days in hospitalised children in The Netherlands. *Arch Dis Child* 2010; 95:141–145	Cross sectional study of children admitted to hospitals in Netherlands over 3 days. N= 424 to determine the prevalence of overall, acute and chronic malnutrition on admission to hospital.	Measurement of weight and height on admission (and discharge if stayed longer than 4years). Used a Dutch growth reference population and defined acute malnutrition as a weight-for-height <-2 SD, chronic malnutrition as height-for-age <-2 SD and overall malnutrition was defined as the presence on admission of acute and/or chronic malnutrition.	The authors reported that the prevalence of overall malnutrition of children on admission was 19% (11% acute & 9% chronic) of these 44% had an underlying disease. There was a significant difference in the prevalence of chronic malnutrition on admission between academic and general hospitals (14% and 6% respectively) mainly explained by the higher rates of underlying conditions in the academic hospitals . The authors found that the prevalence of chronic malnutrition on admission was significantly higher in non-white children than compared to white children (19% vs. 7%). When analysis was undertaken to adjust for age, underlying disease, ethnicity and surgery the relationship between chronic malnutrition and non-white children remained significant (OR 2.8, 95%CI 1.2-6.6). The relationship between overall malnutrition and chronic malnutrition on admission and underlying disease also remained significant (OR 2.2, 95%CI 1.3-3.9 and OR 3.7, 95%CI 1.7-7.8 respectively). The authors reported that no factors were significantly associated with rates of acute malnutrition
Kherkheulidze et al. The parameters of physical growth in 5-6 years old children in Tbilisi. *Georgian Medical News* 2010;1(178):52-56	Cross sectional study of children aged 5-6 years in Tbilisi, Georgia. n=754	The authors used WHO growth reference and defined a low weight and height as a z-score<-2 and underweight as a BMI<5th centile.	No significant difference in the prevalence of low weight by gender. The prevalence of underweight was 13%. No risk factors were significantly associated with the prevalence of underweight children, but the authors felt the small sample size may have had some relevance. The authors reported that age, gender, bottle feeding and type of solid foods were significant risk factors for stunted growth.

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Knops et al. Catch-up growth up to 10 years of age in children born very preterm or with very low birth weight. *BMC Pediatrics* 2005; 5:26	Second phase of a prospective cohort study of children from age 5 to 10 years (previously followed from birth) called POPS in the Netherlands. N=649 with data at 5 years and n=510 with data at 10 years.	Children had their weight and height measured at intervals from birth to 10 years (3,6,12 and 24 months plus at age 5 and 10 years) to determine if being premature or being small for gestational age (SGA) affected the height and BMI of children at ages 5 and 10 years. Dutch reference values were used to calculate mean length/height and target height standard deviation scores (SDS).	Included children born <32 weeks gestation (appropriate size for gestational age (AGA) and those born <32 weeks small for gestational age <32 SGA) and those born ≥32 weeks who had a weight<1500g (≥32 SGA). The study reported that despite catch-up growth the children with SGA (both <32 & ≥32 weeks) demonstrated a higher prevalence of short stature (stunting) defined as a height<10^{th} centile at age 10 years. The children who had an appropriate weight for gestational age (AGA <32 weeks) showed little or no stunting and no catch-up growth at age 10 years. BMI for all three groups was approximately 1kg/m² below Dutch reference values (Knops et al, 2005). Note: Large number lost to follow up at 10 years so measurements were modelled based on those who were followed up.
Lakshman et al. Higher maternal education is associated with favourable growth of young children in different countries. *J Epidemiol Community Health* 2013; 67:595–602	Analysed data from cohort studies of children (aged 4 to 6) undertaken in three different countries (UK, Sweden and China). UK n=15,042, Sweden n=17,055 and rural areas of China n=10,327.	The aim of the study was to compare the effects of socioeconomic conditions on childhood growth. The authors used the WHO growth reference and defined stunting as a height<-2 SD, underweight as a weight <-2 SD and thinness as a BMI<-2 SD	Across the three settings a higher maternal education was associated with the child's weight, height and BMI being closer to the WHO standard for optimal growth and that maternal education was positively associated with offspring height. UK prevalence of stunting was 2.2% but had a strong inverse association with maternal education (lowest education level 3.6% to highest level 0.9%), the child's BMI was also inversely associated. UK prevalence of underweight (0.6%) and thinness (0.4%) were not associated with level of maternal education. In China stunting and underweight were more common and were strongly inversely associated with maternal education

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Lazzeri et al. Underweight and overweight among children and adolescents in Tuscany (Italy). Prevalence and short-term trends. *J prev med hyg* 2008; 49:13-21	Cross sectional survey. Children (aged 9) and adolescents (aged 11, 13 & 15). 2002, 2004 and 2006. Tuscany.	The authors used cut-off points for thinness based on IOTF growth reference (Cole et al, 2007). Aimed to estimate the prevalence of thinness (grade I, II and III)	A declining trend in the prevalence of underweight for both children (between 2002 and 2006) and for adolescents (between 2004 and 2006). For children aged 9 years the prevalence of thinness fell from 4.6% to 4.2%. For 11 year olds the prevalence fell from 11.0% to 10.1%, for 13 years olds the prevalence fell from 9.8% and 8.0% and for 15 year olds from 9.8% to 8.7%. However not statistically significant level
Loka , Nossar and Bauman. A comparative study of the growth of South-East Asian children in South-west Sydney born in Australia and overseas. *J. Paediatr. Child Health* 1994; 30:436-438	A comparative study of South-East Asian children in Sydney (Vietnam, Cambodia and Laos only), who were either born in Australia or born overseas. Aged 1 to 10, n=663.	The children's height and weight were measured and the percentage of median height and weight for each child's age were calculated. The authors did not describe the growth reference used.	A significant difference in the height and weight of South-East Asian children born overseas, with children born overseas being on average 1-2% shorter and approximately 10% lighter than those born in Australia. Age and country of birth were significantly related to standard height and weight. No significant relationship between the duration of time a child had lived in Australia and their relative height and weight. Ecological factors e.g. health and nutrition (in the early years of life) contributed to the observed differences in height and weight
Malenfant C. A comparative study of South Indian children with Tamil children born in France. *Indian J Med Res* 2009; 130:590-592	Cross sectional study. N=109. Tamil children born in France (1st generation) (n=82) and children from South India (n=109)	Questionnaire data collected plus sequential height and weight of children. They used the IOTF growth reference and defined underweight as a BMI<3rd centile and thinness as a BMI between the 3rd and 10th centile.	Tamil children born in France had a higher prevalence of thinness (boys 22% and girls 24%) than compared to children from South India (17% in boys, data for girls not provided). The prevalence of underweight reported in Tamil children born in France was 16% for boys and 9% for girls. The prevalence in India was higher with a third of boys and girls being classed as underweight. The authors did not report if this was statistically significant.

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Martínez-Vizcaíno et al. Trends in excess weight and thinness among Spanish schoolchildren in the period 1992–2004: the Cuenca study. *Public Health Nutrition* 2008; 12(7):1015–1018	4 cross sectional studies in Spain. 1992 to 2004. Children aged 9 and 10. The aim of the study was to estimate the prevalence and trends of obesity and thinness. In 2004 (n=1166), 1992 (n=271), 1996 (n=233) and 1998 (n=249).	The BMI of children was calculated and compared using three different growth references: (i) National Health and Nutrition Examination Survey (NHANES I) (ii) The IOTF growth reference and cut-offs (iii) The Centres for Disease Control and Prevention 2000 (CDC)	The authors found that the overall prevalence of thinness (in 2004) varied depending on the criterion used (i, ii or iii above). The highest prevalence of thinness was obtained using the IOTF criterion which was approximately double that obtained by NHANED I and CDC criteria. The authors used the IOTF growth reference cut-offs (grade I, II & III) to determine the trend in the prevalence of thinness between 1992 and 2004. They report that for all children (boys and girls aged 9 and 10 years) there was a significant increase in prevalence of thinness from 2.7% to 9.2%. This increasing trend in prevalence of thinness was found for both boys and girls however it was only significant for girls (Martínez-Vizcaíno et al, 2008).
Meyer et al. Malnutrition in children with food allergies in the UK. *J Hum Nutr Diet* 2013; 27:227-235	Cross sectional study of children (n=97) in the UK being treated for food allergies (at either a primary, secondary or tertiary level).	The authors used the WHO growth standard and reference populations and defined moderate undernutrition as a z-score between -2 SD and -3 SD and severe malnutrition as a z-score<-3 SD. The authors collected anthropometric measurements of the children at a single point in time.	No statistical differences in the growth parameters were found between children cared for in primary, secondary or tertiary care and those with either an IgE-mediated, non IgE-mediated or mixed allergic reactions. However WA did vary according to the number of food groups being excluded with children who excluded ≥3 food groups having a significantly higher prevalence of a low WA (z-score<-2 SD) than compared to those with ≤2 food groups (10% vs. 7.8%). The prevalence of underweight children was 8.5% (weight-for-age z-score<-2 SD), but that the same proportion of children were overweight (8.5% had z-score ≥+2 SD). 11.5% of children had a low height-for-age (z-score≤-2 SD) and 3.7% had a low weight-for-height (z-score≤-2 SD)

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Murrin et al. Body mass index and height over three generations: evidence from the Life ways cross generational cohort study. *BMC Public Health* 2012; 12:81	Analysed data from the Life ways cross-generational cohort study in Ireland. n=669 mothers	The authors used the IOTF growth reference.	They reported that a child's BMI was correlated with that of their mother and that of their maternal grandmother. While both maternal and paternal lines contributed to offspring height. Note: This study did not look at the association between underweight and paternal height and weight
Nightingale et al. 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* 2011; 40:33–44	Cross sectional study of 5887 children aged 9-10 years in UK.	Aim of the study was to observe adiposity patterns and differences in body size between children of South Asian, black African-Caribbean and white European origin. No information on growth reference used.	The authors reported that fat mass percentage and sum of all skin-folds were higher in children of South Asian origin than compared to children of white European origin. The authors also reported that children of South-Asian origin had a lower BMI for any given level of fat mass percentage or sum of all skin-folds. In comparison children of black African-Caribbean origin had a lower sum of all skin-folds but a higher fat mass percentage, and their BMI was higher. Children of Black-Caribbean origin were markedly taller and at any given fat mass, BMI was similar to children of white European origin. Therefore the authors concluded that BMI can be a misleading comparison of levels of adiposity between children of different ethnic groups and levels of adiposity in children of South Asian origin may be underestimated while levels of adiposity in children of black African-Caribbean origin may be overestimated.

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Pearce, Rougeaux and Law. Disadvantaged children at greater relative risk of thinness (as well as obesity): a secondary data analysis of the England National Child Measurement Programme and the UK Millennium Cohort Study. *International Journal for Equity in Health* 2015; 14:61	Secondary analysis of NCMP data and UK MCS. To determine how the prevalence of thinness varied by socioeconomic circumstance.	NCMP data on 4 to 5 year olds between 2007/08 to 2011/12 (n= 2,620,422), no ethnicity data for NCMP. MCS (n=16,715) children aged 3,5 and 7, calculated RRR for thinness by SEC including adjustment for early life factors (maternal pre-preg BMI, maternal age, smoking in pregnancy, alcohol in pregnancy, birth weight, gestational age and breastfeeding). Used the IOTF growth reference, defined thinness as Mild, moderate and severe (Eq. grade I, II & III). The authors excluded participants of South Asian and 'Other' ethnic group from the analysis as the authors stated there was no definitive evidence to explain if the higher prevalence of thinness in these two ethnic groups was due to a biological cause or due to their exposure to poverty as many resided in disadvantaged areas.	NCMP prevalence of thinness in boys 5.88%, in girls 5.2%. Children in the more deprived IMD deciles were at increased relative risk of thinness (and overweight and obesity). MCS prevalence of thinness was 5.22%, this reduced when South Asian/ other ethnicities were excluded. Elevated risk of thinness only seen in most disadvantaged groups. Higher risk of thinness associated with low birth weight, maternal pre-preg underweight, pre-term birth, older maternal age and drinking in pregnancy. These factors were adjusted for and the increased RRR of thinness remained for the most disadvantaged groups. i.e these are not the cause of SE inequalities in thinness. These findings remained when the analysis removed South Asian / other ethnicities (Removed as no evidence to explain if higher prevalence of thinness in these groups is due to biological causes or exposure to poverty as live in more disadvantaged areas). Analysis of NCMP data showed that the prevalence of thinness (all grades combined) in reception boys was 5.88% (CI 5.85-5.93) and for girls was 5.2% (CI 5.16–5.24). Boys were more likely to be mildly thin than girls although the prevalence of moderate/severe thinness was similar for boys and girls. Children in the more deprived IMD deciles had a higher relative risk ratio (RRR) for thinness (all grade) than compared to children living in the least deprived areas. This was also the case for children classed as overweight and obese.

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Continued… Pearce, Rougeaux and Law. Disadvantaged children at greater relative risk of thinness (as well as obesity): a secondary data analysis of the England National Child Measurement Programme and the UK Millennium Cohort Study. *International Journal for Equity in Health* 2015; 14:61			They reported that the prevalence of thinness for children in the MCS was 5.22% (all grade combined) with the majority being mildly thin. The authors reported that the prevalence of thinness (all grades) declined when South Asian/ other ethnicities were excluded. This was significant for children aged 3 and 5 years but not for those aged 7 years. Factors significantly associated with an elevated RRR: • Socioeconomically disadvantaged groups. • Low birth weight. • Maternal pre-pregnancy underweight. • Pre-term birth. • Older maternal age. • Drinking in pregnancy. After adjusting for these, the increased RRR of thinness remained significant in the most disadvantaged groups. They concluded the aforementioned factors were therefore not the cause of the difference in prevalence rates seen between the most and least socioeconomic disadvantaged groups. When adjusted for the above factors and excluded the South Asian and 'Other' ethnic groups the increased RRR of thinness remained significant in those with a low level of maternal education, the lowest quintile of household income and the lowest two categories of maternal social class (NS-SEC), the RRR was not significant between the five IMD quintiles of deprivation in England. There were insufficient numbers to examine socio-economic inequalities in thinness for individual ethnic groups.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Renzaho et al. Over and undernutrition in the children of Australian immigrants: Assessing the influence of birthplace of primary carer and English language use at home on the nutritional status of 4-5 year olds. *International Journal of Paediatric Obesity* 2009; 4:73-80	Data analysed from the Longitudinal Study of Australian Children (LSAC). Children aged 4-5years n=4,983.	They collected data on the height and weight of children and calculated their BMI and prevalence of thinness using IOTF growth reference and defined underweight as grade I, II & III	The prevalence of thinness was 1% (95% CI 0.8 to 1.3). There was a significant relationship between the prevalence of thinness and the primary care's birthplace and the language spoken at home. Boys who used English at home were less likely to be thin than those who spoke a different language at home (OR 0.27, 95%CI 0.12-0.62). This difference was not seen in the girls. In comparison to the primary carer's birthplace being Australia, children whose primary care's birthplace was Asia had a significantly higher prevalence of thinness, girls whose primary care's birthplace was New Zealand and the pacific's and boys whose care's birthplace was 'the rest of Europe' and 'other' area also had a significantly higher prevalence of underweight.
Savva et al. Prevalence and socio-demographic associations of undernutrition and obesity among preschool children in Cyprus. *European Journal of Clinical Nutrition* 2005; 59:1259–1265	Cross sectional study of pre-school children in Cyprus, n=1412 to determine the prevalence of underweight, stunting and wasting.	Anthropometric measurements taken and questionnaire data on SE status, birth weight taken from parents. The IOTF reference population was used and underweight was defined as a weight-for-age z-score<-2 SD. Wasting was defined as weight-for-height z-score<-2SD and stunting as a height-for-age<-2SD.	The prevalence of underweight was 2.3%, wasting 2.8% and stunting 1.1%. No significant differences in prevalence were found when analysed by gender and rural /urban residence. However after adjusting for age, gender, gestational age, fathers height and weight and mothers height and weight, all three growth parameters were significantly associated with a history of a low birth weight (<2500g). The OR of being underweight was 4.09 (95%CI 1.37-12.24), of being stunted was 5.15 (95%CI 1.14-23.31) and of being wasted was 4.22 (95%CI 1.25-14.27). There was no significant association found between underweight, stunting and wasting with gestational age at birth, area of residence, single parent family and parental educational level.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Schönbeck et al. Thinness in an era of obesity: trends in children and adolescents in The Netherlands since 1980. *European Journal of Public Health* 2014; 25(2):268-273	Three cross sectional surveys of Dutch children from 1980 to 2009 (1980, 1997 and 2009). Comparing children of Dutch, Turkish and Moroccan origin n=54,814 aged 2 to 18 years. Children with a diagnosed growth disorder and those on medication that may effect growth were excluded from the study.	The aim of the study was to estimate the prevalence and trends of thinness in children of Dutch, Moroccan and Turkish origin (defined by parent's country of birth). The IOTF growth reference was used and thinness was defined as grade I, II and III. Only children of Dutch origin in 1980 study. Origin was determined by birth place of parent/s	In 2009, the prevalence of thinness (all grades) for children of Dutch origin was 9.8%, for children of Turkish origin the prevalence was 5.7% and for children of Moroccan origin was 6.2%. Across all groups, thinness was more prevalent in children aged <6 years. The authors reported for children of Dutch origin there was no significant difference in the prevalence of thinness across different socio-economic groups (defined by parental educational level). The trend in the prevalence of thinness of children of Dutch origin was calculated between 1980 and 2009. The authors reported the prevalence of grade I & II thinness had significantly fallen over this time period (no significant change in grade III). The trend in prevalence of thinness for children of Moroccan and Turkish origin was calculated between 1997 and 2009. The authors reported that for children of Moroccan origin the prevalence fell significantly between 1997 and 2009; however this trend was not seen in children of Turkish origin. The authors did not provide data on the prevalence of thinness by socio-economic group for children on Moroccan and Turkish origin.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Smith et al. Prevalence and year-on-year trends in childhood thinness in a whole population study. *Arch Dis Child* 2014; 99:58-61	Cross sectional study of school children in Scotland. Children included if born between 1970 and 2006. Used routinely collected height and weight measurements at school n=194,391	Used the IOTF growth reference and defined thinness as grade I, II & III. Also used UK90 growth reference and defined underweight as a BMI<2nd and <5th centile	The authors reported that the prevalence of grade I and grade ≥II thinness declined between children born in 1970 and those born in 2006. The prevalence of grade I thinness fluctuated during this time; however there was a significant decline in the prevalence of grade ≥II thinness over the same period. Children born between 1970 and 1976 who lived in more socioeconomically deprived areas showed a higher prevalence of grade ≥II thinness than their peers in less deprived areas. However this difference was not evident in children born between 2000 and 2006. Trend in prevalence of thinness grade I 1970=6.5% and 2000=6.0%. Grade ≥II 1970=5.2% and 2000-06=1.6%. In addition they used UK90 growth reference and have reported their results using the definition for thinness as a BMI<2nd centile (1970=4.5% and 2006=1.2%) and a BMI<5th centile (1970=6.9% and 2006=2.7%)
Stenhammar et al. Family stress and BMI in young children. *Acta Paediatrica* 2010; 99:1205-1212	Cross sectional study of families in Sweden, questionnaire x2 completed by parents and routinely collected height and weight measurements of children aged 3, n=873	Data on parental stress, attachments, education, age and marital status of parents was collected. The authors used the IOTF growth reference and defined underweight as grade I, II & III. Underweight defined as a BMI< 14.74 for boys and <14.47 for girls.	A child was at higher risk of being underweight if the mother had a positive SPSQ (stress) score (OR 3.08, 95%CI 1.64-5.81). Children were also at increased risk of being underweight (OR 4.26, CI 1.67-10.86) if their mother had a preoccupied attachment style. The authors reported that if a child watched >4 hours of TV on a weekend day, there was an increased risk (OR 14.67, CI 1.36-157.61) of being underweight. However the authors conclude that as the OR was attenuated by adjustment for maternal SPSQ then TV viewing may be associated with the SPSQ score rather than a part of a separate causal pathway.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Taylor et al. Ethnicity, Socio-economic Status, Overweight and Underweight in East London Adolescents. *Ethnicity and Health* 2005; 10(2):113-128	Cross sectional study of 2,482 adolescents (11-14 years) in East London.	They looked at the prevalence of underweight adolescents in each ethnic group and compared it to the prevalence for White British children. The British 1990 growth reference was used and underweight was defined as a BMI<5th centile and a BMI<15th centile on the UK90 growth charts (to mirror overweight and obesity definitions). Socioeconomic measures of the household included: % with car, % eligible for free school meals, % overcrowded and % no employed parent.	Adolescents (Ad) of Black African and Black Caribbean ethnic groups were the tallest, Ad of Bangladeshi and Pakistani ethnic groups were the shortest. Overall prevalence of underweight (BMI<5th centile) was 4% for boys and girls and the prevalence of boys and girls with a BMI<15th centile was 11%. When adjusted for height and age, no sig. difference in risk of either category of underweight was found between girls from white British ethnic groups and girls from any other ethnic group. When the boys data was adjusted for height and age, Ad from Bangladeshi ethnic groups (OR 3.13, 95% CI 1.33-7.14), Indian ethnic groups (OR 3.03, 95% CI 1.16-8.33) and Pakistani ethnic groups (OR 5.88, 95% CI 2.94-12.50) were sig. more likely to have a BMI<5th centile than compared to Ad from the white British ethnic group. Ad boys from the Bangladeshi ethnic group (OR 1.85 95% CI 1.18-2.94) and Pakistani ethnic group (OR 2.94, 95% CI 1.79-4.76) were sig. more likely to have a BMI<15th centile than compared to Ad boys from the white British ethnic group. BMI was not associated with socio-economic (SE) status and although these SE measures did vary by ethnic group, they did not explain the difference in BMI seen in different ethnic groups. The only exception was an association between car ownership and BMI in girls. The authors concluded that as BMI and height were positively associated, there was a risk of overestimating the prevalence of underweight in groups who were shorter and underestimate the prevalence in groups who were taller than average.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Townsend, Rutter and Foster. Age differences in the association of childhood obesity with area-level and school-level deprivation: cross-classified multilevel analysis of cross-sectional data. *International Journal of Obesity* 2012; 36:45-52	Secondary analysis of NCMP data (2007/08). n=788,535 (reception and year six). To determine if there was an association socioeconomic deprivation and mean BMI z-scores.	Analysed the distribution of mean BMI z-scores of individuals by four factors: Individual-level measure, area of residence measure (Child wellbeing index), school-level measure (free school meals) and PCT-level measure.	They reported that over 95% of the variance in BMI z-score was found at the individual-level (student). However there was also a significant positive association between BMI z-score and area of residence (CWI) and school-level deprivation (FSM) measures for both reception and year six pupils. With children from more deprived areas having a higher mean BMI z-score. Further analysis showed that a larger proportion of the variation in BMI z-scores was explained by CWI than by FSM therefore the authors concluded that the link between deprivation and BMI is not only due to financial deprivation but may also be linked to other inequalities related to deprivation such as education and housing.
Wang, Monteiro and Popkin. Trends of obesity and underweight in older children and adolescents in the United States, Brazil, China, and Russia. *Am J Clin Nutr* 2002; 75:971–7	Analysis of cross sectional surveys from four countries using two surveys for each country. China (1991 & 1997), Brazil (1974 & 1997), US (1971/74 & 1988/94) and Russia 1992 & 1998)	They defined underweight as a BMI<5^{th} centile based on the US NHANES I data.	Two of the countries, had a significant decline in the prevalence of underweight children/adolescents (Brazil 14.8% to 8.6% and the US 5.1% to 3.3%). A decline was also seen in China (14.5% to 13.1%) however this did not reach a significant level. The prevalence rose in Russia (6.9% to 8.1%) – not a significant level. In all countries except the US, the prevalence of underweight was lower in children (6-9 years) than adolescents (10-18 years). The prevalence of underweight was greater in rural areas in Brazil and China and was lower in higher Socioeconomic groups (except in the US 1988/94)

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
West et al. UK-born Pakistani-origin infants are relatively more adipose than white British infants: findings from 8704 mother-offspring pairs in the Born-in-Bradford prospective birth cohort. *J Epidemiol Community Health* 2013; 67:544–551	Analysis of data from the Born in Bradford study n=8704 infants	To explore the difference in birth weight and adiposity (fat mass measured cord leptin levels) of children of South Asian origin as compared to children of white British origin	Analysis of data suggests that infants of South-Asian origin have a lower birth weight than infants of white British origin. However they had higher levels of cord leptin and hence had higher levels of fat mass than infants of white British origin even after adjusting for birth weight.
Whitaker et al. The Intergenerational Transmission of Thinness. *Arch Pediatr Adolesc Med* 2011; 165(10):900-905	Analysis of data from the Health Survey for England between 2001 and 2006. Including families with two parents and either a child or adolescent in the household n=70782	The aim of the study was to estimate the prevalence of thinness of children and adolescents in England. The IOTF growth reference was used and thinness was defined as grade I, II & III. Children and parents who were thin due to an illness were NOT excluded.	The prevalence of thinness (all grades), was 5.7%, of whom 1.8% were grade II & III. The prevalence of thinness was higher in younger children (8.1% aged 2 to 5yers, 4.9% aged 6 to 10 years and 4.7% aged 11 to 15 years) and in children and adolescents from non-white ethnic groups (11.4%) than compared to children from white ethnic groups (4.2%). There was no significant trend in the prevalence of thinness between 2001 and 2006 and no significant difference in prevalence of thinness by gender and by socio-economic status of household. Children with thinner parents (BMI< 50% centile) were more likely to be thin but there was no evidence that maternal factors played a greater role than paternal factors.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Wright, Parkinson and Drewett. The influence of maternal socioeconomic and emotional factors on infant weight gain and weight faltering (failure to thrive): data from a prospective birth cohort. *Arch Dis Child* 2006; 91:312–317	Analysis of the Gateshead Millennium birth cohort study. n=923 children followed from birth to 13 months.	To determine factors affecting growth faltering between birth and 9 months. The authors used the British 1990 growth reference and defined weight faltering as a weight gain <5th centile.	The prevalence of weight faltering at any point in time between birth and 12 months was 10%. Sustained faltering was defined as weight faltering in ≥2 age bands; the prevalence of sustained weight faltering was 4%. The authors reported that there was no association between deprivation, maternal or parental education level or maternal markers of eating disorders on either weight gain or weight faltering in infants. Infants of mothers with postnatal depression (EPDS score >12) showed higher rates of slower weight gain and weight faltering at 4 months of age but this difference did not persist by 12 months.
Wright, Stone and Parkinson. Undernutrition in British Haredi infants within the Gateshead Millennium Cohort Study. *Arch Dis Child* 2010; 95:630–633	Analysis of the Gateshead Millennium cohort study. To estimate the prevalence of weight faltering of infants from birth to 13 months.	961 children followed from birth to 13 months of whom 33 were Haredi. Data on weight, height, BMI and breast feeding status was collected.	They found that Haredi infants had similar birth weight to other children however they had significantly higher rates of weight faltering and lower weight gain between birth and 12 months. Factors which had a significant role to play included the number of older siblings, duration of breast feeding, age of weaning and mid parental height z-score. Gender and maternal BMI did not effect the findings (Wright, Stone and Parkinson, 2010). Note: The number of children in the study was small and caution should be used when reviewing these findings.

Paper	Sampling methods and characteristics of study	Growth reference & definition used / Data collection and analysis	Findings
Yngve et al. Differences in prevalence of overweight and stunting in 11-year olds across Europe: The Pro Children Study. *European Journal of Public Health* 2007; 18(2):126–130	Cross sectional pro children study across nine European countries (Austria, Belgium, Denmark, Iceland, The Netherlands, Norway, Portugal, Spain and Sweden). n=8089. Children aged 11 years	The aim of the study was to estimate the prevalence of overweight and stunting across Europe. Questionnaire, parent reported height and weight. BMI and z-scores calculated. Underweight defined as BMI< 5^{th} centile of the CDC-2000 reference population. Stunting was defined as a height-for-age z-score<5^{th} centile on the CDC-2000 reference population.	The authors found that across all nine countries the prevalence of underweight for girls was 7.2% (95% CI 6.5-8.1) and for boys was 5.4% (95% CI 4.7-6.2). The prevalence of underweight in boys was highest in Belgium (11.0%, 95% CI 8.4-14.1) which was significantly higher than in Austria, Iceland, Norway, Portugal and Spain. The prevalence of underweight in girls was also highest in Belgium (12.3%, 95% CI 9.5-15.6), which was significantly higher than Iceland, Norway, Portugal and Spain. The lowest prevalence of underweight in girls was seen in Spain (3.0%, 95% CI 1.5-5.2) and Portugal (3.6%, 95% CI 2.3-5.3). The lowest prevalence of underweight for boys was seen in Sweden (2.3%, 95% CI 1.1-4.1) (Yngve et al, 2007). Across all 9 countries the prevalence of stunting for girls was 2.8% (95% CI 2.3-3.3) with Portugal having the highest prevalence (5.6%, 95% CI 3.9-7.6) which was significantly higher than Sweden, Austria and Denmark. Across all countries the prevalence of stunting for boys was 1.4% (95% CI 1.1-1.8) with Portugal having the highest prevalence (6.2%, 95% CI 4.3-8.5) which was significantly higher than Austria, Denmark, Iceland, The Netherlands, Norway and Sweden. It should be noted that the heights and weights of children were self reported by parents and recorded by questionnaire.

9.2 Appendix B: Definitions of growth references, anthropometric indices and growth parameters

The term underweight has a different meaning for adults as compared to children. In 1995 the WHO suggested that for adults underweight or thinness means an adult with a low BMI. In children they have separate meanings with underweight indicating a low weight-for-age and wasting indicating a low weight-for-height. Cole et al have developed this further by suggesting that the term thinness in children means a low BMI-for-age (WHO, 1995 and Cole et al, 2007).

British 1990 growth reference

The British 1990 growth reference (UK90) provide centile curves for BMI for British children from birth to 23 years of age, they also provide growth reference for height, weight and head and waist circumference. The UK90 define underweight as a BMI cut-off of the 2nd centile for population monitoring and clinical assessment, but are rarely used outside of the UK (Dinsdale, Ridler and Ells, 2011).

In 2012, an expert committee from the Scientific Advisory Committee on Nutrition (Sacn) and the Royal College of Paediatric and Child Health (RCPCH) considered the different thresholds used to define underweight, overweight and obesity. They looked at the advantages and disadvantages of the IOTF thresholds, the WHO 2007 growth references for 5 to 18 year olds and the UK1990 clinical and population thresholds. They concluded that the BMI thresholds for underweight in children over 2 years of age in the UK should be based on the UK90 BMI reference charts, with 0.4th centile describing very thin and the 2nd centile describing low BMI. The committee advised that the latter (a BMI<2nd centile) be used for population monitoring of underweight prevalence in the UK (Sacn and RCPCH, 2012). This was further supported by NICE guidance (CG189) *'Obesity: identification, assessment and management of overweight and obesity in children, young people and adults'* which recommended that BMI measurements in children and young people are applied against the UK90 BMI reference charts to give age- and gender-specific information (NICE, 2014).

International Obesity Task Force cut-off thresholds

International Obesity Task Force (IOTF) cut-off thresholds are derived from BMI data from six cross sectional surveys (Brazil, Great Britain, Hong Kong, The Netherlands, Singapore and the United States of America (USA)). They define three grades of thinness (I, II & III) based on equivalent adult BMI's of 16, 17 and 18.5. They can be used for children aged 2 to 18 years and are often used to compare prevalence rates internationally (Dinsdale, Ridler and Ells, 2011).

Cole et al (2007) proposed that a Body Mass Index (BMI) of 17 at age 18 years of age was a suitable cut off point to define thinness in children and adolescents. This corresponds to a WHO grade two cut off for thinness in adults and a mean z-score of -2 and an 80% of the median for weight-for-age. Therefore a definition of thinness in children would be A *BMI-for-age* that is <-2 SD from the median BMI-for-age of the reference population (Cole et al, 2007).

World Health Organisation child growth standard

The WHO child growth standard are based on the Multicentre Growth Reference Study (MGRS) undertaken with an international population (Brazil, Ghana, India, Norway, Oman and the USA). They have been developed for children aged 0 to 5 years and are used internationally (less so than IOTF). They are the recommended growth standard for 0-4 year olds in the UK (Dinsdale, Ridler and Ells, 2011).

The WHO child growth standard data showed that infants and children living in optimal conditions (particularly optimal nutrition, including prolonged breast feeding) showed very similar growth patterns. The standards provide an effective tool for detecting both undernutrition and obesity. The WHO standards can therefore be used to assess children's development across the world, regardless of ethnicity, socioeconomic status and type of feeding. In addition the WHO standards also identify breastfeeding as the biological norm and establish the breastfed child as the normative model for growth and development (ECOG, 2009).

World Health Organisation 2007 growth reference

The WHO 2007 growth reference have used data from both the MGRS and the USA NCHS/WHO growth reference. The WHO 2007 aligns with the WHO growth standard at age 5 years. They are used internationally for children aged 5 to 19 years (less so than IOTF) and define underweight based on a BMI<-2 standard deviations from the median BMI of the reference population (Dinsdale, Ridler and Ells, 2011).

United States Centres for Disease Control and Prevention 2000 growth reference

The US Centres for Disease Control and Prevention (CDC) 2000 growth reference was developed using five USA national health surveys. They can be used for children/ young people aged 2 to 20 years. Underweight is defined as a BMI below the 3rd centile (BMI<3rd centile) and a BMI below the 5th centile (BMI<5th centile). The CDC 200 growth reference is primarily used in the USA.

Anthropometric indices and growth parameters

The WHO produced guidance on the use and interpretation of anthropometric indices namely weight-for-age; height-for-age and weight-for-height. Deficits in one or more of these indices have often been described as evidence of malnutrition. However it should not be assumed that such deficits are due to nutrient or energy deficiencies (lack of food) as an increased rate of use of nutrients (as in infectious diseases) and impaired absorption can also play a role. Therefore in order to interpret these indices, it is important to understand what anthropometric indices are being used, what is the cause of the deficit and the socioeconomic status of the population being studied (WHO, 1995).

The definitions of the different growth parameters which are based on WHO Child Growth Standards have been published in the *Joint Child Malnutrition Estimates* report and are as follows (UNICEF, WHO and The World Bank, 2012 and WHO, 1995):

- *A low height-for-age is <-2 standard deviations (SD) from the median height-for-age of the reference population*

It can be a normal variation. Stunting implies that the low height–for-age has a pathological cause and often indicates a long term cumulative lack of nutrition or poor health.

- *A low weight-for-age is <-2 SD from the median weight-for-age of the reference population*

Weight-for-age reflects the BMI relative to the persons age. It is affected by both the height (height-for-age) and weight (weight-for-height) of an individuals and can reflect the long term health and nutritional status of that individual.

- *A low weight-for-height is <-2 SD from median weight-for-height of the reference population*

A low weight-for-height is termed thinness. If a pathological process is at play including a recent and severe process leading to weight loss such as starvation and/or severe disease or a chronic deficiency in nutrients or disease then the word wasting should be used to describe a low weight-for-height.

The description of anthropometric indices and growth parameters are often inter-used and can be defined as follows (UNICEF, WHO and The World Bank, 2015 and WHO, 1995):

- *Stunting is a height-for-age that is <-2 SD from the median height-for-age of the reference population*

Stunting refers to a child who is too short for his/her age. Stunting is the failure to grow both physically and cognitively and is the result of chronic or recurrent malnutrition or poor health. Its effects often last a lifetime.

- *Underweight is a weight-for-age that is <-2 SD from the median weight-for-age of the reference population*

Lightness is a descriptive term for low weight-for-age while underweight referes to the the underlying pathological process.

- *Wasting is a weight-for-height that is <-2 SD from median weight-for-height of the reference population*

Wasting refers to a child who is too thin for his/her height. Wasting is the result of sudden or acute malnutrition, where the child is not getting enough calories from food and faces an immediate risk of death. Thinness is a descriptive word for a low weight-for-height.

Note it is possible for a child to show combinations of malnutrition, such as be stunted and overweight or stunted and wasted (UNICEF, WHO and The World Bank, 2015).

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