Dissertation
zum Erwerb des Doctor of Philosophy (Ph.D.)
an der Medizinischen Fakultät der
Ludwig-Maximilians-Universität zu München

Doctoral Thesis for the awarding of a Doctor of Philosophy (Ph.D.)
at the Medical Faculty of
Ludwig-Maximilians-Universität, Munich

vorgelegt von

submitted by

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born in (place of birth)

Bamenda, Cameroon

am (Tag an dem die Dissertation abgeschlossen wurde)

submitted on (day of finalization of the thesis)

30.04.2014

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Date of Oral Defence: 19.09.2014

Contribution of stature and socioeconomic status to overweight and obesity in Cameroon school age children

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KEY WORDS

Height, socioeconomic status, obesity, children.

ABSTRACT

Background: In developed nations, taller children exhibit a greater propensity to overweight/obesity and the socioeconomic pattern of excess body fat is of public health concern. This study investigates whether this height-obesity relationship holds true for Cameroon children using different parameters of obesity including body mass index (BMI), waist circumference (WC) and percentage body fat (%BF) and whether the height-obesity relationship is affected by the socioeconomic status (SES). Additionally, it determines the relationship between high birth weight and physical activity to adiposity.

Methods: In 557 children (287 boys and 270 girls) from the North West Region of Cameroon, height, weight, WC and %BF were measured and BMI calculated. Variables were converted to standard deviation scores (SDS). Participants were divided into quartiles of height SDS, then mean of age and sex-standardized body fat parameters compared across quartiles. The frequency of excess body fat was calculated within each quartile. SES, birth weight and physical activity were obtained using a self administered questionnaire. Regression analyses were used to assess relationships between the determinants and parameters of obesity.

Results: Multiple comparisons indicated a significant increase in mean BMI (-0.08 to 0.65), WC (-0.11 to 0.87) and %BF (-0.52 to 0.36) SDSs with increasing quartiles of height SDS. Among girls, there was a linear relationship between height SDS and BMI SDS ($p < 0.001$). The highest frequencies of excess body fat were observed among high birth weight and tallest children from a high socioeconomic background. High SES (OR 8.3, 95% CI 3.9 – 15.4), fourth quartile of height SDS (OR 9.1, 95%CI 3.4 – 16.7) and high birth weight (OR 0.1, 95% CI 0.06 – 0.2) were independent predictors of overweight/obesity.

Conclusion: This study confirms that children coming from a high socioeconomic background, being tall and having a high birth weight are at particular risk of becoming obese. This is independent of the parameter used in evaluating excess body fat.

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III) ABBREVIATIONS

%BF	Percentage body fat
ALSPAC	Avon Longitudinal Study of Pregnancy and Childhood
ANOVA	Analysis of variance
BIA	Bioelectric Impedance Analysis
BMI	Body mass index
CDC	Center for Disease Control and Prevention
CI	Confidence interval
CPAQ	Children's Physical Activity Questionnaire
DBP	Diastolic blood pressure
DXA	Dual energy x-ray absorptiometry
ECOG	European Childhood Obesity Group
FAO	Food and Agricultural Organization
GH	Growth hormone
HDL-C	High-density lipoprotein cholesterol
IGF 1	Insulin-like growth factor 1
IOTF	International Obesity Task Force
KiGGS	German Health Interview and Examination Survey for Children and Adolescents
LDL-C	Low density lipoproteins – cholesterol
LMS	Lambda Mu Sigma
MUAC	Mid upper arm circumference
NCHS	National Center for Health Statistics
NCMP	National Child Measurement Programme
OR	Odds ratio
PTA	Parents Teachers Association
SBP	Systolic blood pressure
SD	Standard deviation
SDS	Standard deviation score
SES	Socioeconomic status

TG	Triglycerides
UK	United Kingdom
US	United States
WC	Waist circumference
WHO	World Health Organization

1. INTRODUCTION

1.1. Global picture overweight and obesity.

Despite different scientific measures taken in some countries in the world to understand and address the different factors that contribute to the of weight status of individuals, overweight and obesity still remains a growing public health problem and has an overwhelming attention among researchers. This situation has been described as a global threat to health[1], with 750 million and 300 million adults in the world affected by overweight and obesity respectively[2]. This is also seen in children. It is estimated that overweight and obesity now affects approximately 10% of school-age children worldwide[3]. While the highest numbers of those affected are in developed economies such as in the United States and Western European countries, this increase is now occurring at a faster rate in developing countries undergoing nutrition transition[4,5]. However, there are 2 main challenges in the global estimation of overweight and obesity in children. Firstly, there is lack of a universal definition of obesity in children as different parameters of body fat are often used (which could be ethnic specific). Secondly, most data available are not representative of the different countries, thus making international comparisons difficult[5]. Therefore, there is the possibility of an underestimation of the global prevalence of overweight and obesity in children as a result of the inconsistency in methods used to classify excess body fat in this group.

This problem has been more severe in the United States. There has been a steady rise in overweight and obesity between 1999 and 2010 in men, women and children. An updated fact sheet from the American Heart Association indicate that among adults in the United States of ages 20 years and over, the age adjusted prevalence of obesity is 34.4% and 36.1 % in men and women respectively. This corresponds to 79.9 million men and 74.8 million women. As concerns children of ages 2 to 19 years, 23.9 million are overweight or obese. This study reported that the highest prevalence was among the American Indian/Alaskan native youth (17.7%). It was also noted that the excess cost associated to the current obesity trends is $254 billion and it is projected that if the current trend is not halted, healthcare cost attributable to obesity could account for 16 to 18% of US health expenditures by 2030[6].

Europe is also another region where the prevalence is increasing in virtually all countries[7]. For instance, in the UK, available data indicates that approximately 25% of the adult population is affected by overweight and obesity[8]. The direct cost of obesity to the economy of England is 4.2 billion pounds. It is also projected that if current trends continue, more than 50% of the adult population will be obese by 2050[9]. In order to objectively monitor childhood overweight and obesity in England the UK government created the National Child Measurement Programme (NCMP) in 2005 that collects data on height and weight in primary schools on all children[10]. According to the NCMP, findings for the 2012/2013 academic year indicated that at reception (4 – 5 years) 22.2% of children were overweight or obese and in year 6 (6 – 11 years) the prevalence was 33.3%. This was a slight drop when compared to figures of the 2007/2008 academic year[11].

Also, data from the German Health Interview and Examination Survey for Children and Adolescents (KiGGS) showed that 15% of children between 7 – 17 years were overweight and 6% were obese[12].

Developing economies have also been experiencing a dramatic increase in the prevalence of childhood overweight and obesity in the past decades. For instance, in 1995, 17.5 million preschool children in developing countries were overweight[13]. Evidence in 2010 has shown that this number has doubled (35 million). Also, in Africa, the prevalence of childhood overweight and obesity now stands at 8.5% and it is predicted that by 2020, it will reach 12.7%. The authors also indicated a higher relative increase (+65%) in developing countries than developed countries (+48%)[14]. However, these data included only children less than five years of age. In Africa, information relating to the weight status of school-age children is limited. This neglect is concerning as this group is also important. Some countries are beginning to monitor school age children. A recent study among school children in Tanzania showed a low prevalence of child obesity of 5.2%[15]. However, this data was not representative of the Tanzanian school age children. Another study in Egypt had a higher prevalence of 17.7% and 13.5% for overweight and obesity respectively. In this study, obesity was common among the younger children (7 to 8 years), while overweight increased with age[16]. In addition, prevalence estimates for combined overweight and obesity among primary school children in Kenya[17] and Ghana[18] have been indicated to be 19.0% and 17.4% respectively. Because of limited studies in the African continent, evidence that indicates the region's contribution to global estimates of childhood overweight and obesity quite low. More studies are needed in the African region, especially in Sub-Saharan African countries to generate enough evidence in order to increase the utility and validity of any public health initiatives. In other countries undergoing a rapid economic development like Brazil and China, overweight and obesity has also risen sharply among children and adolescents[5].

1.2. The situation in Cameroon.

In Cameroon, the numbers of families affected is on the rise and remains a challenge. A survey of adults of 15 years and over in four Cameroonian towns (Yaoundé, Douala, Garoua and Bamenda) showed that more than 25% of urban men and almost half of urban women were either overweight or obese[19]. Between 1994 and 2003, the age adjusted prevalence of overweight including obesity (BMI $\geq$ 25kg/m^2) increased significantly in the rural area (+54% and +82% for women and men respectively), while the prevalence of central obesity (WC $\geq$ 80cm for women, $\geq$ 94cm for men) increased significantly by +32% for women and +190% for men only in the urban setting[20]. Another study also indicated that in the North West Region of Cameroon the prevalence of overweight and obesity are 23.6% and 6.1% respectively among adults in both rural and urban settings[21]. In addition, figures from the Health of Populations in Transition Research Group-Cameroon show that among adults in Bamenda (an urban area and the capital of the North West Region) 33.6% and 23.3% is overweight and obese respectively[22].

Available data on preschool children indicate that the prevalence of overweight in 1991 was 2.9% for Cameroon[13]. Newer data especially for school age-children is limited for Cameroon. However, one study on urban children and adolescents in Douala (capital of the Littoral Region of Cameroon) recorded a prevalence of 17.8% for overweight and obesity using the WHO 2007 reference[23].

1.3. Statement of the problem.

Obesity during childhood is now a matter of growing concern in developed and developing countries affecting children as indicated above. Until recently, many studies had relied on the

National Center for Health Statistics/World Health Organization (NCHS/WHO) international growth reference, which had its own practical problems. Also, the assessment of childhood obesity has been difficult because of different parameters used, which has made international comparisons difficult.

The WHO has now established new BMI reference curves for children, which includes data from six countries (Brazil, Ghana, India, Norway, Oman and US)[24]. Even though it is now recommended for this reference to be used worldwide, Africa's representation in this data is questionable. Also, this reference is based on body mass index which has its limitations[25-27].

Obesity in children has detrimental effects that can result to physical inactivity, poor diet and excess weight[28]. It is also known that obesity increases the risk of morbidity in childhood and is related to more serious health outcomes which include the risk of type 2 diabetes[29,30] , hypertension[31], cardiovascular disease[32], certain cancers[1], asthma[33], and psychosocial problems such as self-esteem[34]. Several studies have suggested that the propensity to an irregular growth pattern could explain to some degree overweight and obesity in children[35-37]. A study among urban adults in Cameroon showed a positive association between socioeconomic status (SES) and obesity[38]. However, information indicating the interaction between height, SES and weight status in Cameroon school-age children is lacking and obesity in this group would be of much importance. This is because a systematic review indicated that overweight and obese children are at risk of becoming overweight or obese in adulthood, with an estimated proportion of overweight and obese children likely to become overweight and obese adults ranging from 34% to 83%[39].

Epidemiological factors that contribute to overweight and obesity in children have been examined extensively in developed countries and there is a consensus in the rising numbers of children affected globally. However, some of these factors have not been examined in Sub-Saharan countries (including Cameroon), which are undergoing a nutrition transition. These transitional economies are experiencing increasing numbers of overweight and obese children and if nothing is done, these children will be exposed to the above health threats. This will pose a major human and financial cost to the community, with serious implications for the sustainability of the healthcare system, which is already overburdened with infectious diseases. It is therefore interesting to explore the interactions between height and the socioeconomic pattern of body fat in Cameroonian children. This study looks comprehensively at obesity by not only using BMI, but waist circumference (WC) and percentage body fat (%BF) as parameters of obesity. The study also indentifies the prevalence of overweight and obesity using international references and adds to the current knowledge on obesity in Sub-Saharan Africa.

1.4. Definition of overweight and obesity.

Generally, obesity is defined as excess adipose tissue present in the body and overweight is a lesser degree of excess body fat than obesity. This increased accumulation of body fat increases the risk of morbidity and premature death of an individual[40]. Overweight and obesity develop when there is an imbalance between energy intake and energy expenditure. The WHO has established a criterion reference standard to be used in classifying obesity in adults based on BMI (Table 1.1).

Table 1.1: The WHO classification of obesity.

Weight classifications	**Cut-off points for BMI (kg/m^2)**
Underweight	< 18.5
Normal	18.5 – 24.9
Overweight	≥ 25.0
Preobese	25.0 – 29.9
Obese	≥ 30.0
Obese class I	30.0 – 34.9
Obese class II	35.0 – 39.9
Obese class III	≥ 40.0

Source: WHO[41].

Unlike the universally accepted definition of adult overweight and obesity, there are variations on how childhood obesity is defined. This is because during the growth phase among children and adolescents, BMI changes substantially with maturation[42]. In children, normative reference standards are used which compare the child's performance relative to a defined group[43]. The WHO has established age- and sex-standardized growth reference charts based on BMI that are used to determine the weight status of children. There are other country specific definitions based on different measures of body fat like waist circumference[44] and percentage body fat[45]. The following section summarizes some of the parameters used to identify overweight and obesity.

1.5. Assessment of overweight and obesity in children.

Best estimates of body fat require extensive methods such as dual energy x-ray absorptiometry (DXA) and densitometry[46]. However, these methods are expensive, time consuming and require sophisticated apparatus and techniques, which are practically unsuitable for epidemiological studies. It is for this reason that current definitions make use of simple anthropometric measures like height, weight, waist circumference, skinfold thickness, and hip circumference in population based studies.

1.5.1. Body mass index (BMI).

BMI is a simple weight-for-height index commonly used as a measure of weight status. It is calculated by dividing the weight in kilograms (kg) by the height squared in meters and expressed as kg/m^2. Generally, BMI is used to define obesity clinically[47] because it is quick to measure, easy to calculate, inexpensive, non-invasive[1] and it correlates with body fat[48]. However, it does not differentiate between fat mass and fat-free mass[25]. Also, the relationship between BMI and body fat is affected by age, tanner stage, muscle mass and ethnicity[49,50]. In addition, BMI can misclassify high numbers of children with high body fat as a result of its low sensitivity[27]. Further, a study suggested that over time, there have been changes in the contribution of lean body mass and body fat to BMI, which has led to underestimations of the BMI prevalence of overweight and obesity[51]. There is evidence that not all subjects with the same BMI have the same body fat percentage. For instance, a study in Mexico showed that short stature subjects had a higher percentage body fat than tall subjects of the same BMI[52]. This indicates that the validity of BMI to estimate an individual's body fat level is limited. The question whether BMI reflects adiposity or excess weight is still a subject of debate.

1.5.2. Waist circumference.

Waist circumference is measured midway between the rib cage and the iliac crest using a flexible measuring tape. It is an index that is easy to measure with high reproducibility[53]. Waist circumference has an advantage over BMI in that it provides information about fat distribution in the body. Studies have shown that WC could be the most useful measure of fat distribution for children when compared to BMI, skinfold thickness and waist-to-hip ratio[54-56]. It also correlates highly with both intra-abdominal fat and subcutaneous abdominal fat[57]. Excess abdominal fat has been associated to adverse obesity related outcomes[58]. Also, in children and adolescents, waist circumference is associated with cardiovascular risk factors like increased blood pressure[59] and adverse lipid profiles[60]. Given the above advantages of waist circumference, it is still a surrogate measure that is unable to quantify body fat percentage directly. Also, there is no international agreement on appropriate cut-offs to define central obesity and no internationally accepted definition of the waist.

1.5.3. Skinfold thickness.

This involves the measurement of subcutaneous fat layer at different sites of the body such as the biceps, triceps, subscapular and suprailiac skinfolds. There is evidence that in adolescents, the sum of skinfold measures at four different sites predicted body fat in adulthood more than BMI[61] and that in screening children for obesity, the sum of skinfolds at 4 different sites was also shown to be a better than BMI[62,63]. However, the use of skinfold measurement in population based studies is limited because skinfold thickness measurements vary by ethnicity and gender[64]. Also, the intra and inter-observer reliability of skinfold measurement is poor[65].

1.5.4. Bioelectric impedance analysis (BIA).

The principle behind BIA is that when an applied current is passed through the body, the voltage drop reflects the resistance provided by body fat mass. It is a non-invasive measurement of body fat used in many epidemiological studies and unlike BMI and WC, it is able to distinguish between fat mass and muscle mass. Compared to other extensive methods, BIA is inexpensive, portable, not time consuming and equipment requires minimum training to operate[66,67]. Also, studies have shown the validity of body fat percentage measurements using BIA in adults[68,69], adolescents[70] and children[71]. However, a review has shown that impedance vary among different ethnic groups, environmental changes and stage of menstrual cycle. The authors concluded that BIA can only be effective in large population based studies if specific calibration equations are established for the different groups included in the study[72].

1.6. Application of reference systems and cut-offs.

The WHO BMI criteria for identifying overweight and obese adults are now widely accepted. However, in children, the rising numbers with overweight and obesity has urged researchers to come up with different reference systems (some with limitations) to use in identifying those at risk of becoming obese and those in need of intervention. This has made an international agreement on which reference system to adopt difficult to reach.

1.6.1. WHO 2007 growth reference data.

This reference was established after considering the practical problems with the National Center for Health Statistics/World health Organization (NCHS/WHO) international growth reference. The NCHS/WHO reference was old and the data was not internationally representative because it was based on a sample of children from the US[73]. Also, this data described how children grew at a particular place and time and did not represent how children should grow in all countries[74,75]. The WHO 2007 growth reference now includes cross-sectional and longitudinal data from USA, Oman, India, Ghana, Brazil and Norway[24]. Using this reference the WHO established the age- and sex-specific BMI cut-off of +1standard deviation (SD) for overweight and +2SD for obesity in children[76]. Even though the children included in this data were from different cultural backgrounds and ethnicity, evidence from a Chinese study has shown that the use of WHO 2007 reference could classify approximately 5% of normal weight children as underweight when compared to the Chinese reference HK1993[77]. Also, despite the fact that many countries have signed up for this WHO 2007 data, a study has indicated that there exist differences in growth curve construction factors such as age categories, methods, sample size, socioeconomic status of subjects and data quality[76], which may have not been included in the WHO 2007 reference.

1.6.2. UK 1990 reference data.

In the UK, the BMI cut-off points are the 91st and 98th centiles (standard deviation scores of +1.33 and +2) to define overweight and obesity respectively[42] based on the UK 1990 reference data. The Avon Longitudinal Study of Pregnancy and Childhood (ALSPAC) in the UK showed that the use of BMI greater than the 98th centile had a high specificity of 98% in detecting obese children. However, the sensitivity was low (71%)[78]. The UK has also made use of other parameters of obesity to construct reference curves. In using percentage body fat, the 85th and 95th centiles were established as cut-off points for overfat and obesity respectively[45]. Also, for waist circumference, the 91st centile is used as the cut-off point for central obesity[44]. The limitation of these references is that the data were collected exclusively on a white population[79]. Therefore, this reference is not nationally representative of the UK childhood population, thus, its external validity is questionable.

1.6.3. International Obesity Task Force (IOTF).

The use of cut-off points was described as arbitrary by the IOTF[47]. The expert committee of the IOTF made use of pooled data from six international BMI references (Brazil, Great Britain, Hong Kong, Netherlands, Singapore and United States) to establish BMI cut-off points. The Lambda, Mu Sigma (LMS) method[80] was used to construct centile curves for each dataset. Each centile curve identified a cut-off point through childhood, which fitted to the cut-off points of 25kg/m^2 and 30kg/m^2 for adults at the age of 18[47]. This approach ensures continuity in obesity between childhood and adulthood[73]. However, this study did not include data from African countries and it remains unclear if this reference can be applied in this region of the world.

1.6.4. Other reference systems.

Using data from five health surveys, the Center for Disease Control and Prevention (CDC) in the US recommends the 85th and the 95th age- and sex-adjusted centiles for overweight and obesity respectively[81]. On the other hand, the European Childhood Obesity Group (ECOG) recommends 90th and 97th age- and sex-specific centile for overweight and obesity respectively[82].

The data used in establishing these references are collected at different moments in different populations making international comparisons difficult to achieve. Other countries make use of different weight-for-height indices to define overweight and obesity in children. However, the sensitivity and specificity of these definitions remain a challenge. A high sensitivity avoids failure in identifying obese children. This leads to early intervention and thus preventing long term adverse outcomes[83]. Also, a high specificity ensures that non obese children are not misclassified as obese, hence avoiding unnecessary stigmatization or treatment. However, a definition with high sensitivity may be more appropriate for early detection of those in need of intervention. A study suggested that in order to improve detection of pediatric overweight and obesity, ethnic-specific cut-offs should be established[84].

1.7. Epidemiological factors contributing to overweight and obesity.

The etiology of obesity includes multiple interactions between different extra and intra-individual factors that affect the energy balance. This is usually a joint action of biological, environmental and behavioral factors[85].

1.7.1. Family history and genetic factors.

Parental obesity has been shown to be an important risk factor of pediatric obesity and observations have been consistent[86,87]. Findings from a retrospective cohort indicated that parental BMI was a contributing factor to obesity in children. On comparison with children without obese parents, those whose parents were obese had 91% higher odds for being overweight[88]. Even a study on adopted children also confirmed that there was a strong relation between the weight status of the adopted children and the BMI of their biological parents. In this study, there was no relation between these children and the weight status of their adoptive parents[89]. Also, having at least one or just one obese parent increases the risk of overweight and obesity in children[87,90,91]. Further, a study demonstrated that the association between maternal obesity and overweight in children was almost two times that of paternal obesity[92]. The possibility of obesity trends within families could be explained by the fact that the family members have a common practice towards exercise, food and eating patterns[93]. However, this relation between parental obesity and their children's weight status has been suggested by some authors to represent a genetic influence[94].

It has been shown in twin and family studies that genes contribute between 40% to 70% of variations in obesity[95,96]. Also, some studies have demonstrated the heritability of BMI. In a study on twin pairs age 8 – 11 years, a combined heritability of BMI and waist circumference was shown to be 77%. This study also showed that 60% of the heritability of waist circumference was common to BMI and 40% due to genetic factors[97]. A systematic review also indicated that high BMI heritability in pre-adolescents, young adulthood and old adulthood ranged from 61% to 80% in the study population[98]. Also, a twin and family study indicated that the heritability of BMI was higher (0.47 – 0.90) for twin studies than that of family studies (0.28 – 0.81) and that the effect of genetic factors on BMI is higher in children than adults[99]. The first gene to be found contributing to obesity in humans was the fat mass and obesity associated gene (*FTO*). This gene showed significant associations with obesity traits in several European studies in both children and adults[100]. Another gene is the *MC4R* which has shown a strong association with weight in children during the first 20 years of life[101]. The above points indicate that obesity cannot be explained only by genetic variation. It could also be explained by gene – nutrient intake interactions. For instance, some studies have found associations between FTO and weight of food intake[102], total energy intake[103,104,105] and intake of energy from fat[104].

1.7.2. Lifestyle factors.

Dietary habits:

A positive energy balance in individuals resulting from the consumption of more energy from food and beverages than that spent through physical activity also accounts for the development of overweight and obesity in children and adults. Cameroon is currently experiencing an increase in obesity numbers as mentioned earlier. This could be explained by evidence from the Food and Agricultural Organization (FAO) indicating that the average dietary energy intake in Cameroon increased from 2,000 to 2,457 kilocalories/capita/day between 1962 and 2009. Dietary fat consumption also increased from 31.2 to 41.1g/capita/day while protein intake increased from 52.9 to 62.3g/capita/day over this period[106]. Evidence on the relation between dietary fat intake and weight status has been inconsistent[107,108] and the contribution of fat intake to overweight and obesity in Western countries is still a subject of debate[109,110,111]. There is consistent evidence demonstrating the relation between the high consumption of aerated soft drinks with added sugar and changes in weight[112], but it is still a debate if reducing the intake of sweetened soft drinks can lead to weight loss[113]. A study has shown that the risk of overweight was associated to higher energy intake in urban Cameroon men[114]. The WHO has also reported that the evidence showing a positive association between obesity and the consumption of energy dense foods poor in micronutrients is convincing. The report further indicated an inverse relationship between high intake of dietary fiber and obesity[115]. Another study has indicated the association of high intake of fast foods, low intakes of fruits and vegetables and large portion sizes to overweight and obesity[116].

The assessment of the nutrient intake at the population level faces challenges. It is known that under-reporting of dietary intake is more common among obese than non obese individuals[117,118,119]. Also, different methods of nutritional assessment have been used in the above studies, which have their advantages and limitations[120]. The cross-sectional nature of some of the studies has failed to explain elements of causality. In addition, limited memory spans, snacking out of home, changes in food habits during growth, dietary restraint, unorganized eating patterns, and limited ability to obtain reliable dietary information from untrained parents/guardians are among the factors that make nutritional assessment in children difficult[121]. The situation is even worse in Cameroon and other Sub-Saharan countries where food composition data is not available, making it difficult to study the impact of foods and nutrients to obesity.

Physical activity/leisure time activity:

Physical activity has been shown to influence energy expenditure and available data is limited for adults and not available for children in Cameroon. One study among Cameroonian adults in both rural and urban settings indicated that inactivity was associated with higher BMI and physical activity was lower among urban subjects when compared with rural subjects[122]. In a cross-sectional study of 11-year old UK children, it was found that only 0.4 and 5.1% of girls and boys respectively, were able to achieve the recommended level of physical activity (at least 60 minutes of moderate to vigorous physical activity a day)[123]. However, the accelerometer used measured only movement and not energy expenditure related to other forms of activity. After following up US children between the ages of 10 and 15 years, it was realized that when activity increase, BMI dropped[124], and lower levels of exercise has been shown to be associated to increased child adiposity[125,126]. However, other studies did not find any relations[127,128]. Even though this is an indication of inconsistent findings, it is important to take the different methodological approaches in measuring physical activity into consideration. Some of these methods might not have measured physical activity accurately. Also, the studies did not measure the physical activity level of parents, which could be an important reflection of their children's activity level.

Leisure time activities have changed over the past years as a result of advances in technology. Even though there is no documented evidence, Cameroonian children used to spend their leisure time involved in activities that burnt lots of calories especially playing games like hopscotch, ball dodging and hide and seek. Nowadays, especially in the urban settings, children spend more time on sedentary activities like the internet, watching TV and playing video games. Actually, TV watching and playing of video games is common among the younger children, while internet activities are common among the adolescents. Increased television viewing has been shown to be positively associated with childhood overweight[87,129]. A sedentary lifestyle is also common among European children and contributing to overweight and obesity[121]. Additionally, there was a positive association between the use of computer alone and weight status of boys and girls in the USA[130]. In contrast, no associations were found in studies in Canada[131] and Australia[132]. In addition, a study among children in Hong Kong did not find an association between watching TV and obesity[92]. The above findings are inconsistent and it is important for future studies to also look at the influence of snacking or consumption of high calorie foods while watching TV as this could be a potential confounder[133,134].

Sleep duration:

While some studies have demonstrated that a short sleep is associated to an increased risk of obesity in children[87,135], another one has shown that longer sleep duration could prevent overweight and obesity in adolescents[136]. A clinical review indicated that there were mixed findings on the subject in adults. While some cross-sectional and longitudinal studies among adults included in the review showed that both short and long sleep duration were associated with BMI, other studies showed that neither short nor long sleep duration had any association with BMI in adults[137]. The important question here is how sleep duration can be manipulated to study its influence on obesity prevention in children.

1.7.3. Social factors.

Socioeconomic status (SES) and ethnicity:

Sub-Saharan African countries including Cameroon are at various stages of economic development. Because of the increased attention gained by social inequalities in health, the close monitoring of the socioeconomic pattern of weight status especially among school children[138] in this region is important. A study in urban Cameroon found out that there was a positive association between socioeconomic status indicators (household amenities and occupational level) and adiposity in adults and the prevalence of overweight and obesity was higher among the women[38]. Another study in urban Cameroon adolescents indicated that the prevalence of overweight was high among adolescents from all socioeconomic groups; the low (8%), middle (11%) and high SES (9%), with girls more likely to be overweight than boys[139]. However, in developed countries, the highest rates of overweight and obesity continue to affect those from a low socioeconomic background[116,138,140,141]. Also, a better educational attainment and high socioeconomic status were associated with a lower prevalence of childhood obesity[142,143]. Evidence for the inverse association between socioeconomic status and obesity in children has not been consistent like in adults. A US study on children ages 2 – 18 years indicated that not all disadvantaged groups were at risk of overweight and that the inverse association existed only in white children and not black children[144]. Also, weaker associations between socioeconomic status and obesity have been observed in children[145]. This indicates that ethnicity needs to be considered when exploiting relations between SES and obesity.

Ethnic and migrant studies have indicated that in African American children and adolescents there was no inverse association between SES and obesity [146]. In Germany, obesity is more pronounced among migrants than non migrants[147,148]. Socioeconomic status and ethnicity are factors that lead to differences in lifestyle that could eventually affect health. Cameroon has many ethnic groups with different cultures. Studies need to be carried out to provide evidence on the influence of ethnicity and cultural differences on the dietary patterns of children and adults. This will help in understanding the impact of cultural differences on overweight and obesity in Cameroon.

1.7.4. Risk factors in early life

Birth weight:

Weight at birth is a parameter of intrauterine growth. A positive relation between high birth weight and obesity has been established by some studies[149,150]. However, a study did not find strong association between birth weight and four parameters of adiposity[151]. Also studies have indicated that low birth weight was associated to parameters of central body fatness and a U-shaped relation between birth weight and adult obesity was obtained and high birth weight was associated to increased levels of overall body fat in adults[152]. These findings indicate the importance of the intrauterine environment to obesity later in life.

Weight gain at infancy:

A study showed that children who exhibit catch-up growth in the first two years of life had higher levels of parameters of adiposity at age 5 years than those who did not exhibit catch-up growth[153]. Also, weight gain during infancy has been indicated to predict obesity later in life. For instance, a cohort study on European American subjects indicted that weight gain during the first week of life is associated to overweight later in life. However, height and weight measurements were self-reported which could have led to an underestimation of overweight and obesity[154]. Another study did not only confirm this association in adulthood, but also in childhood[155].

Maternal smoking during pregnancy:

Another early life risk factor is maternal smoking during pregnancy. A study including six countries in less affluent Central/Eastern European region indicated that maternal smoking during pregnancy is associated with childhood overweight. However, the associations with obesity were less consistent[156]. A meta-analysis of 14 studies also confirmed that children whose mothers smoked during pregnancy were at an increased risk for overweight compared to those whose mothers never smoked during pregnancy[157]. However, a case control study did not identify any effect of maternal smoking on overweight. Instead, childhood overweight was significantly associated with having a father who was a current smoker[92]. The magnitude of the effect of paternal smoking and childhood obesity has been shown to be similar to that of maternal smoking during pregnancy[158].

Maternal weight gain during pregnancy:

The chances of a child to become obese are also linked to the mother's weight gain during pregnancy. As compared to mothers with a normal weight, a study has shown that maternal obesity and excessive weight gain during pregnancy was associated to childhood obesity[159]. Also, it has been indicated that BMI in childhood increases by 0.022 for every 1kg increase in maternal weight during pregnancy· However, this study could not control for pre-pregnancy BMI[160]. In addition, this association between weight gain during pregnancy and childhood obesity had been shown to be very strong among pre-pregnancy underweight women[161]. The above suggests that studies demonstrating the relation between maternal weight gain and offspring weight status should consider other important maternal factors like physical activity level, nutrition status and genetic background, which could be interacting. This will help in getting the independent effect of such variables.

Breastfeeding:

Breastfeeding has also been shown to be protective of childhood obesity. Even the WHO has endorsed exclusive breastfeeding for the first six months of life to help reduce risk of pediatric obesity[162]. Studies have concluded that breastfeeding in infancy may be important in protecting obesity development[163] and the duration of breast feeding has also been shown to be more protective[164]. Also, a review came to the conclusion that three months of exclusive breastfeeding is the minimal duration needed to significantly reduce the risk of overweight and obesity in children[165]. In addition, a meta-analysis that compared non breastfed infants to breastfed infants indicated that among the breastfed infants, the risk of overweight was lowered by 25%[166]. However, other studies did not find any inverse relationship between breastfeeding and obesity in childhood[142,167,168]. This contradiction in findings could possibly be explained by differences in study design, sampling methods and small sample sizes.

1.7.5. Growth and development factors

Adiposity rebound:

Adiposity rebound is a second increase in BMI between the ages of 5 – 7 year. Some studies have found a positive relation between early adiposity rebound and risk of obesity later in life[169,170,171]. It was not clear earlier whether it is the increased BMI before adiposity rebound or the BMI at adiposity rebound that is related to obesity. However, this relation has also been confirmed after adjusting for BMI before adiposity rebound and current BMI at adiposity rebound[172,173].

Early maturation:

A longitudinal study has reported that early maturation (measured by the age at menarche) is a predictor of overweight and obesity in adulthood. Nevertheless, this study relied on self-reported height and weight[174]. In a study, the risk of being overweight in young adulthood was increased by both pre-pubertal weight status and early pubertal maturation among boys and girls[175].

Stature:

Evidence indicates that pediatric obesity is also characterized by increased stature. For instance, a recent study in Chile, a transition economy, indicated that there is a positive association between obesity and higher height-for-age in children[176]. Also, studies in 3 year old English children showed that the increase in obesity was greatest among the tallest children[177]. In addition, similar analyses have shown tallness to be associated to thicker skinfolds in children[178] and that height (during childhood) in obese children is independently associated with adult body mass index (BMI)[179]. Thus, the authors concluded that childhood height monitoring could be useful in identifying children at risk of becoming overweight or obese. However, the mechanism for this relation has not been fully explored.

1.8. Health consequences of overweight and obesity.

Childhood overweight and obesity can lead to an increased risk of long term mortality and morbidity that may affect their physiological and psychological well being. The World Health Organization has identified the persistence of childhood obesity into adulthood as the most significant long term consequence of childhood obesity along with increased risk of different adverse health outcomes[180].

1.8.1. Cardiovascular diseases.

Some studies have provided evidence relating childhood obesity and cardiovascular health[181,182]. In fact, childhood overweight and obesity has been associated with cardiovascular conditions like dyslipidemia, hypertension and coronary artery abnormalities. A study showed that cardiovascular risk factors were significantly different between overweight and normal weight prepubescent children[32]. Another study indicated that more than half of obese children of ages 5 to 17 years had at least one cardiovascular risk factor and significant odds ratios were obtained for raised serum lipids, fasting insulin concentrations and hypertension in these obese children[183]. Obesity in children has been found to contribute to the development of atherosclerotic lesions. Some imaging studies have found out that obesity in childhood has adverse consequences like arterial wall stiffness and intima-media thickness of the carotid artery [184,185,186]. During the Bogalusa Heart Study, autopsies were carried out on young people and the findings indicated strong evidence relating atherosclerotic lesions with body mass index[187]. Another autopsy study among teenagers has indicated that waist circumference was associated with intima thickness of the left anterior descending artery. However, no association was found with body mass index[188]. This is an indication that the distribution of body fat is an important factor in studying associations between children's weight status and cardiovascular health.

Hypertension is another cardiovascular disease risk factor that has become increasingly common among obese children. Studies carried out in several countries have indicated that obese children tend to have higher blood pressure levels than normal weight children[189,190,191]. Also, a longitudinal study in the UK has shown that obesity among adolescents have a detrimental effect on systolic blood pressure (SBP) later in life[192]. It has been indicated that increases in childhood

BMI were significantly associated to SBP in young adulthood[193]. The only study that measured blood pressure in children in Cameroon indicated that blood pressure was higher among urban boys when compared to rural boys, but BMI was higher among the rural boys[194]. The higher physical activity levels in rural settings could explain this difference. Central obesity has been shown to affect blood pressure levels in children and adolescents[195]. For instance, a study has shown that waist circumference among girls was independently associated to diastolic blood pressure (DBP) among girls[196]. When family history of hypertension was taken into consideration, a study on obese children showed that increased SBP was associated with visceral accumulation of fat and hyperinsulinemia[197]. The impact of being overweight on cardiovascular health could be reversed with weight loss, healthy diet and exercise[198]. Also another study indicated that among obese children, the duration of watching TV was related to hypertension and severity of obesity. The authors concluded that the duration of TV viewing could be a target for addressing hypertension in obese children[199].

Dyslipidemia is another important cardiovascular risk factor among overweight individuals[200]. A study indicated that obese children with the lowest physical activity had increased triglycerides (TG) and the lowest high-density lipoprotein cholesterol (HDL-C)[201]. These changes in lipid profiles raise concerns as there is a risk of having other metabolic problems. It has been indicated that diet can also help in reversing dyslipidemia[202].

1.8.2. Psychosocial conditions.

The psychological damage caused by overweight or obesity is a huge health burden, which may impact a child’s emotional development. The psychological consequences may include lowered self esteem, clinical depression, sense of isolation, binge eating, and stigmatization.

Stigmatization and discrimination are some of those factors that have a negative impact on children’s psychological development[203]. It has been demonstrated in some studies that normal weight children are unlikely to interact well with their obese peers[204,205], and this negative perception has been shown to begin early in life. For instance a study showed that by the time a child reaches the age of six years, they have already picked up negative messages about overweight[206]. It has also been shown that this negative view of overweight and obesity is common among preschool children[207] and teachers[208]. However, this situation is seen differently in some developing countries like Cameroon where being fat is seen as a sign of wealth and good living. Parental criticism has been shown to contribute to other psychological consequences like low self esteem[209].

Poor self esteem can be used as a term to describe an imbalance between an individual's achievements and aspirations. The relationship between obesity and self esteem has been studied in children. It has been indicated that there is an association between obesity and low self esteem in girls[210]. However, another study indicated a weak association and the authors believed there were subgroups that could be susceptible to poor self esteem[211]. Another study indicated that in obese children, a third of boys and two thirds of girls experience low self esteem in sports activities, physical appearance and self worth[212]. This confirms that not all obese children experience low self esteem. The feeling of low esteem has been found to depend on certain factor like age, gender and parental evaluation of the children's body size[213]. Additionally, low self esteem has been shown to predict a poor mental health later in life[214].

Body dissatisfaction is closely associated with poor self esteem. The relationship between body dissatisfaction and weight status in children has been documented by many studies. For instance, it is documented that perceived body image was associated to being overweight and obese[215,216]. However, body dissatisfaction was also shown among girls who are not overweight or obese[217]. There is also documented evidence that body dissatisfaction is associated with binge eating and purging[218,219]. In addition the body dissatisfaction – obesity relationship gets stronger with age in both boys and girls[220].

As concerns depression, longitudinal studies have indicated that an association between depression in childhood and later development of obesity exists[5,211]. Adolescent obesity has been associated to depression in adulthood[221]. A systematic review and meta-analysis indicated that there were higher odds for developing obesity as a result of depression and that depression was more common among Americans than Europeans[222].

These consequences have been shown to have an effect in adulthood. A study indicated that there was a negative correlation between adolescents' weight status and earnings in young adulthood[209]. It was also found out in another study that 18-year old obese men were less likely to move up the social hierarchy than their normal weight peers by the age of 30 years[223].

The above indicate that some obese children may not have a good quality of life, which will continue to affect them in later years. Also the psychosocial consequences of obesity may be influenced by culture and the area where the patients live. For instance, a fat person in a developing country like Cameroon may feel very little or no depression as a result of his weight status because fatness portrays good health and well being.

1.8.3. Respiratory conditions

Obesity also affects respiratory well being. The prevalence of asthma has been increasing among obese children and adolescents in the past decades[224,225]. A study indicated that children with high BMI levels had a higher risk of getting asthma after controlling for age, gender, exposure to tobacco smoke, socioeconomic status and ethnicity[226]. Because of difficulty in breathing physical activity levels among asthmatic children will be low. In a study among 4 to 11 year old English children from different ethnic groups, obesity was positively associated with symptoms of asthma in all ethnic groups and this relation was more consistent with BMI than skinfold thickness[227]. Also, it is indicated that girls who became obese between 6 and 11 years were 7 times more likely to develop new symptoms of asthma at the age of 13 years[228]. In addition another study indicated that regardless of BMI levels early in life, children with a high BMI at age 7 years were at an increased risk of developing asthma at age 8 years[229].

A breathing disorder during sleep like obstructive sleep apnoea has been associated with childhood obesity. A study indicated that disordered sleep occur in about 94% of obese children[5]. This lack of adequate sleep among obese children has been shown to have a negative effect on learning and memory[230].

1.8.4. Type 2 diabetes and related conditions.

The incidence of type 2 diabetes has been on the rise during the past decades. Obesity is an important risk factor for type 2 diabetes in children and adolescents[231]. There is a parallel increase in obesity rates and the number of children affected with type 2 diabetes[232] and obesity accounts for approximately half of new cases diagnosed with type 2 diabetes in some areas[233]. A review has indicated that in the Cincinnati area, there was a 10 fold increase in the prevalence of type 2 diabetes among newly diagnosed overweight and obese children, who also had a family history of type 2 diabetes[29]. Insulin resistance (decreased effect of insulin), which has been shown to be positively associated to obesity[231] is believed to be an important contributing factor to the development of type 2 diabetes[234,235,236]. A longitudinal study has indicated that childhood and adolescent obesity were associated to markers of insulin resistance in young adulthood[237]. Also, diabetes onset in childhood is related to an increased risk of micro- and marcrovascular complications later in life[231]. Studies have shown that pediatric obesity increases the risk of developing metabolic syndrome, which is a combination of obesity, dyslipidemia, impaired glucose control and hypertension[238, 239]. In terms of mortality and morbidity among adults, it has been shown that men and women newly diagnosed with type 2 diabetes at age 40 years will lose 11.6 and 14.3 life years respectively[240]. Available data for Cameroon indicate that there was a 10 fold increase in the prevalence of diabetes between 1994 and 2003[241,242]. Current data indicates the national prevalence to be 4.9% for Cameroon[243].

1.8.5. Hepatic diseases.

Liver diseases are another set of complications that could result from obesity in childhood. Two main complications have been identified, which include; steatosis and non-alcoholic steatohepatitis[244]. In a study among overweight participants, the frequency of non-alcoholic fatty liver disease (steatosis) was detected in 65.3% and 62.7% of children and adults respectively[245]. Obese children with steatosis have the tendency to manifest other complications including hypertension, altered glucose metabolism and dyslipidemia, which are components of insulin resistance syndrome[246]. Non-alcoholic steatohepatitis is also increasingly appearing in obese children[247]. Cirrhosis has been observed in a 10 year and a 14 year old boy, which resulted from non-alcoholic steatohepatitis [248].

1.8.6. Malignancies.

A review by the World Cancer Research Fund and the American Institute for Cancer Research indicated that obesity increases the risk of having certain cancers including cancer of the breast, kidney, esophagus, liver, pancreas, gall bladder and others[249]. Because obesity results from the interaction of different factors including lifestyle and hereditary factors, it may be difficult to assess if obesity can independently lead to cancer development[250].

1.8.7. Skeletal abnormalities.

It has been indicated that obesity leads to some structural consequences in the body. A study indicated that the incidence of genu valgum is higher in overweight/obese children[251,252] and may contribute to a lower physical activity levels. The pattern of growth in critical areas like the epiphyseal plate can be altered by excess weight on the skeletal structure[253]. In line with this, cross-sectional and longitudinal studies have indicated knee osteoarthritis to be common among obese indicividuals[254].

A lower vertebral bone mineral content has been observed among obese children. This low bone mineral content cannot compensate for the excess weight accumulated by the obese children[255].

1.9. Prevention of childhood obesity.

There is currently limited data of identified problems in Cameroon that could provide information on childhood obesity prevention. The dramatic global increase in childhood obesity has led to the development of evidence-based prevention strategies in different parts of the world. However, the evidence on how best to prevent pediatric obesity is still weak[256]. This is because causal pathways include a mix of environmental, genetic and behavioral factors. Because of the difficulty in identifying all children at risk of developing obesity, researchers have suggested a population-based approach to tackle the problem for the simple reason that such an approach will be beneficial to both overweight/obese and normal weight subjects[257,258]. Many intervention studies have been carried out to tackle some of the issues surrounding childhood obesity. Also, there are many reviews that have attempted to synthesize evidence from these trials. These trials most of the time focus on behavioral changes, physical activity and dietary intake and most have been carried out in the school environment[259]. The school setting has been shown to be a conducive environment to reach out to children, and the intervention activities include introduction of school meal standards, physical education, behavior change and nutrition education. Some of these interventions usually involve parents[260,261] and the evidence generated from some of these intervention programs have been inconsistent[262]. Even though the numbers of overweight and obese children is on the rise in developing countries, the evidence generated from Africa is still very small. The prevention strategies mentioned below are those that have been taking place in different countries. Whether some of these strategies can be applied in Cameroon is still a question to be addressed. The European Childhood Obesity Group (ECOG) concluded in a paper that pediatric obesity can be prevented at six different levels, which include; schools, family, health professionals, government, industry and media[263].

1.9.1. School-based interventions.

School settings can provide a good avenue to community efforts to promote healthy behaviors, healthy diets and physical activity[264]. In an integrative review of school-based childhood obesity prevention programs that included 16 studies, 9 studies evaluated the effect of the multi component intervention programs on BMI. Out of these 9 studies only one showed a significant change in BMI between the intervention and control groups[265]. However, there were differences in the duration of intervention in these studies. Another study reviewed six interventions specifically on obese children with interventions ranging from 12 weeks to 18 months. Five out of the six studies indicated that children in the treatment group gained less weight than those in the control group[266]. Also, another review on US and UK studies carried out in school settings targeted physical activity and nutrition related behaviors. This study indicated that TV watching was one of the most modifiable behavior followed by physical activity. However, mixed results were obtained for obesity parameters[267].

A large and comprehensive school-based intervention in the US that included 96 schools with more than 5000 children from different ethnic backgrounds found significant changes on exercise and measures of food intake. However, no significant results were obtained on the three-year health outcomes on parameters of obesity including BMI and skinfold thickness[268]. In addition, another study had targeted a curriculum to reduce TV watching and other electronic multimedia use. This study showed a difference in BMI, tricep skinfold, wasit-to-hip ratio, waist circumference between the treatment school and the control school[269]. Further, another study that centered on TV watching, found differences in prevalence of obesity over a two-year intervention period. The prevalence decreased from 23.6 to 20.3% among girls in the intervention schools and increased from 21.5 to 23.7% in the control schools. This study which included five treatment schools and five control schools indicated that there was a 15% reduction in the likelihood of becoming obese for every one hour reduction in the time to watch TV[270]. Even though there is no documented evidence, the play time (long break) in most primary school settings in Cameroon have reduced over that past decades. Some schools especially in the urban settings do not have adequate space (playgrounds) for children to use. This decrease in physical activity time can promote sedentary activities while at schools, further exacerbating the condition of those who are obese or those at risk. In fact, some schools have physical education just once in a week, which may not last for up to an hour depending on the grade of the pupils.

1.9.2. Family-based interventions.

Family-based interventions can lead to a long-term reduction in risky dietary behavior among children. This is because, children's unhealthy dietary behavior are affected by parent's child feeding practices and also the mother's nutrition knowledge[206]. Interventions for behavioral change in children need to start early enough for better results[271,272]. A study confirmed that behavioral changes in obese children can be effective if the intervention begins at the age of 6 – 7 years[273]. A meta-analysis of 39 family-base interventions that targeted physical activity and/or dietary modification indicated that children would be expected to reduce excess weight by 20% for treatment duration of 15 months[274]. Also, a family-based study indicated that during a 2 year intervention period with obese children there was a significant reduction in BMI, low density lipoproteins – cholesterol (LDL cholesterol) and total cholesterol between baseline and end of follow up. Even though the biochemical markers were all within normal range, there was no significant difference in high density lipoprotein – cholesterol (HDL cholesterol) and triglyceride[275]. However, this study had a small sample size and the findings cannot be generalized.

The family is important in addressing childhood obesity. For instance, the physical activity level of children has been shown to reflect the levels of physical activity of their parents. Therefore, the authors concluded that an indirect way to change physical activity levels in children is to change the physical activity patterns of the parents[276]. Thus a study declared that parents have a central role to play to promote healthy eating and more physical activity in their children[277]. Most of the documented successes in family-based interventions have been explained by the fact that parents have been actively involved in the whole process and the ideas generated at family level could be implemented to a wider population[278]. However, a recent review on home-based interventions described the strength of evidence to determine the effectiveness of home-based intervention as low and the authors suggested more interventions at the home setting. In this review that included 6 studies, none had any effect on the weight status[279].

Methodological issues (sample size or power of the study, selection bias, and poorly described randomization) of most of these interventions account for the differences observed[261,280,281]. Thus the quality of the evidence and effectiveness of these interventions are questionable.

1.9.3. The role of health professionals.

These groups of professionals have the responsibility to help parents make informed choices on nutrition and physical activity and also influence them on the consequences of obesity as well as important aspects of pediatric obesity prevention. The health professionals can do this by teaching parents on ways to promote fruit and vegetable consumption and also how to reduce sedentary time. Also, the professionals can help schools fight obesity by giving ideas on how to modify school playgrounds to encourage physical activity, suggest low prices for low energy dense foods, discourage food awards and promote health education[257]. A study has indicated that parents have trust in health professionals and the professionals must tackle the obesity problem using two approaches; carrying out environmental interventions and also addressing the individuals[282]. Also, health professionals (researchers) are instrumental in policy development. These policies are established from sound evidence that have tested for the best solutions of the problem. This will guide the establishment of policies (by policy makers) that will be feasible and have a great impact at the community level[283].

Physicians on their part have an "ethical and professional responsibility to the community they serve[284]" and they can act as "policy entrepreneurs and use their professional authority to communicate with legislators to support legislation[284]" that concerns nutrition. A study came up with a variety of ways physicians could help in the struggle against obesity including supporting legislation by opting to speak in meetings or posting information on websites[285]. A recent review has also identified nine avenues that can help health care providers in preventing obesity in children[286].

The weight status of health professionals involved in counseling is also important. In a study that compared the weight status of pediatricians and the difficulty in counseling, overweight/obese pediatricians were four times more likely to indicate difficulties in counseling compared to the normal weight colleagues[287]. It is therefore important for health professionals to be role models by adopting healthier lifestyles.

Cameroon still has a limited number of professionals (dieticians and nutritionists) that can help the obese children. There is a need for universities to start offering programs in Nutrition and Dietetics to help prospective professionals to advance practical experience and also acquire skills for a critical approach to research in nutrition issues.

1.9.4. Government initiatives.

This section will focus on efforts of the UK Government and that of the US.

The governments of different countries have to adopt a steering, implementation and monitoring role in pediatric obesity prevention programs. For policies to be adequately maintained and updated, the governments need to invest in surveillance, research and evaluation of programs. For instance, in 2005, the UK government introduced an annual National Child Measurement Program to monitor the prevalence of overweight and obesity, raise awareness of the importance of a healthy weight and the findings could be used to inform local planning and delivery of services for children[10]. Also, the National Institute for Health and Clinical Excellence in the UK has established evidence-based guidelines on prevention, identification, assessment and management of overweight in both children and adults[288]. Despite the elaborate nature of this document, there are statements which make it difficult to know what will be the achievement of the guidelines. For instance a statement as such "...the aim of weight management programmes for children and young people may be either weight maintenance or weight loss depending on their age and stage of growth…[288]". This statement appears to be confusing and it is not clear what the researchers want to achieve.

In 2007, the UK Government announced an ambitious plan (to cover a 12-year period) aimed at reversing the rising numbers of overweight and obesity in the country. The components of the initial stage of the program, which focused on children included; the early identification of families at risk, ensuring that all schools implement the food and nutrient-based standards for school meals (healthy schools) and invested 75 million pounds in a social marketing program to help parents make informed choices on nutrition and physical activity of their children[289].

The government of the United States has also proposed policies to combat childhood overweight and obesity in certain areas including; physical education and activity, advertising to children, and school nutrition and education[285]. However, as far as physical activity is concerned, more time is allocated for studies in some schools at the expense of physical education. Another policy is also the restriction on the marketing of foods with high energy density. Despite the measures taken, food companies (who claim to be part of the obesity prevention struggle) still spend approximately $15 billion a year for the advertisement of these high energy dense foods[290]. In addition, different school districts had been encouraged by the US Government to come up with their own policies defining standards for food sold in schools. However, it remains unclear how well these schools designed and implemented their school wellness policies[285]. The Arkansas Act 1220 of 2003 was one of the first steps to fight obesity through school-based policies. The act had addressed some key elements to fight against obesity. However, there were concerns regarding some of the components of the act. For instance, the reporting of children's BMI to their parents was regarded by some as a violation of confidentiality. Also, the restriction of vending machine access raised concerns among school personnel as this might affect the school budgets[291]. A recent study in the US has suggested among others different policy options such as; introducing taxes on high energy dense foods in order to decrease their consumption, increase exposure to healthy and fresh foods, creation of buffer zones around schools to restrict access to fast foods outlets, counter advertisement to show the health consequences of eating unhealthy foods[292].

The above indicate that the solutions to the obesity problem can be complex as many actors with different interests are involved. To effectively halt the current increase in children affected with overweight and obesity, appropriate intervention programs should be developed and properly evaluated. This can be achieved by using an appropriate tool to monitor obesity, which is accurate, easy to use and acceptable with well defined cut-offs[257]. While the effectiveness of some interventions has been carried out, little is done on economic evaluation[293].

Also more studies need to be carried out to determine the cost-effectiveness of obesity prevention programs rather than indicating the scale of the problem. Even though the prevalence of overweight and obesity in developing countries like Cameroon is lower than those of western countries, the developing counties need to start learning from experiences in the developed world. The rate of obesity is increasing at a faster rate in developing countries and it is just a matter of time for the situation to get worse if prevention measures are not put in place.

The International Obesity Task Force (IOTF) has also indicated the need for a strong political will in preventing obesity. The IOTF developed the causal web (Figure 1.1), which shows the interaction of the different environmental factors from different settings that contribute to obesity. This indicates that for interventions to be effective there is need for a multi-sector approach[293].

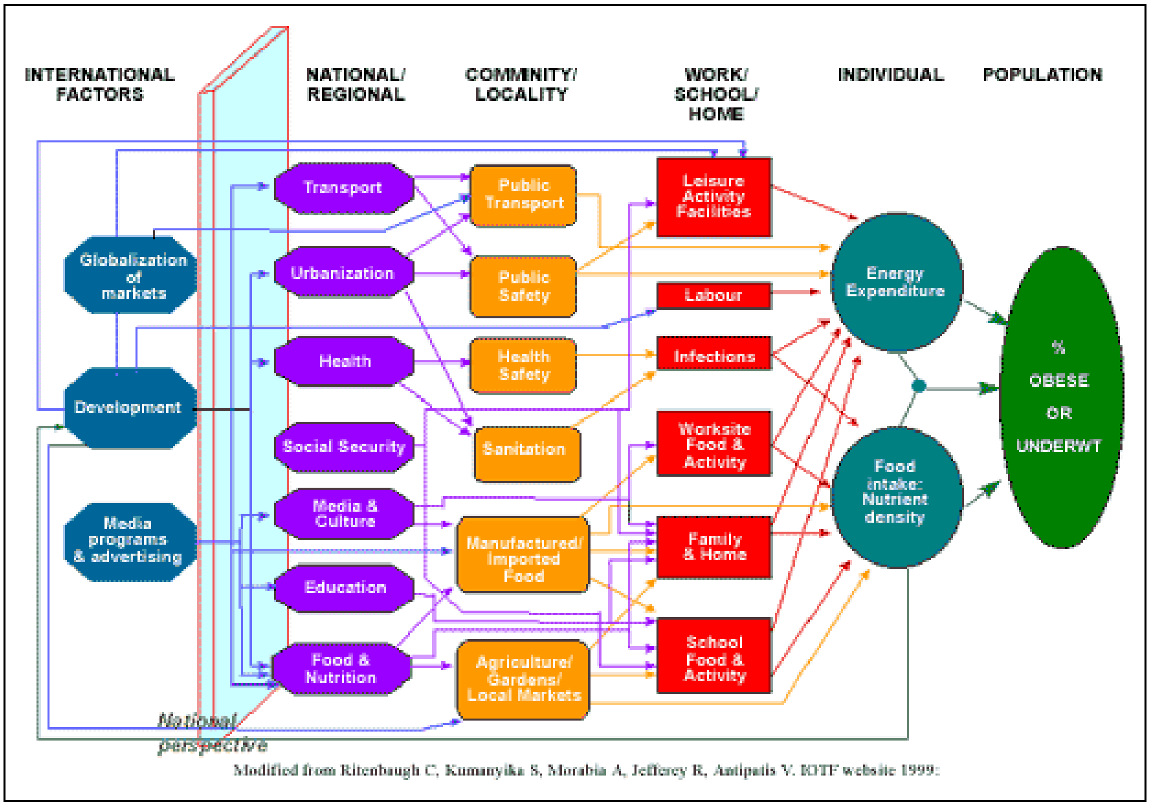

Figure 1.1: Causal Web of obesity developed by the IOTF.

1.10. Objectives of the study.

The increasing rates of overweight/obesity, regardless of measure of body fat used has been shown to be a major public health problem in both developing and developed countries worldwide affecting both children and adults. In developed populations, taller children exhibit a greater propensity to overweight/obesity, whereas childhood height is positively related to socioeconomic status (SES)[141]. Paradoxically, obesity is inversely related to SES in the developed countries. However, studies on developing countries undergoing the nutrition transition demonstrate a direct relation between SES and overweight/obesity[294]. There is a lack of SES-height, SES-overweight/obesity and height-overweight/obesity interactions in Cameroon school age children that may influence adult health outcomes.

The aim of this study therefore is to begin to understand the effects of the current nutrition transition by exploring the interactions between SES, linear growth in childhood and excess body fat accumulation, and test the hypothesis that SES-overweight/obesity association is greater in taller school-age children (aged 5 to 12 years).

Specifically, this study examined:

- The prevalence of overweight/obesity in relation to height-for-age and gender.
- Relationship between height and parameters of obesity.
- The frequency of excess body fat according to height quartiles differentiated by SES and also the frequency in relation to the degree of urbanization.
- Relations between SES, birth weight and physical activity and overweight/obesity.
- Relationship between head circumference and body weight and the difference in head circumference by socioeconomic status.

This study was designed to collect and statistically analyze information to relate childhood height and SES to different parameters of obesity. The parameters of obesity to be assessed include: body mass index (BMI), waist circumference (WC) and percentage body fat (%BF).

2. METHODS

2.1. Study design/subjects.

This study was a cross sectional analysis of data collected from children of ages 5 to 12 years from randomly selected schools (public and private) in both rural and urban settings of the North West Region of Cameroon. The data was collected between February and June 2012. A total of 557 school-age children (270 girls and 287 boys) formed the study population. Also, 173 participants were from the rural settings while 384 were from the urban settings and consisted of a mix of socioeconomic groups. A list of both public and private primary schools was obtained from the North West Regional Delegation for Basic Education and 6 schools were chosen at random and contacted by the principal investigator (L.K.N). In cases when the school administration refused to participate, another school was chosen at random within the area. Consent information, which explained the purpose of the study, was distributed in the schools to parents or guardians and the head teachers accompanied by the study questionnaire. Also, the principal investigator (L.K.N) had the opportunity to explain the aims of the study to parents or guardians during the Parents Teachers Association (PTA) meetings, which usually take place within the academic year. In return a signed informed consent certificate was obtained from each parent or guardian and school head teacher before measurements were carried out. Assent was also obtained from the children. Dates of birth and gender were collected from school records at the same time as the anthropometric measurements.

2.2. Study area.

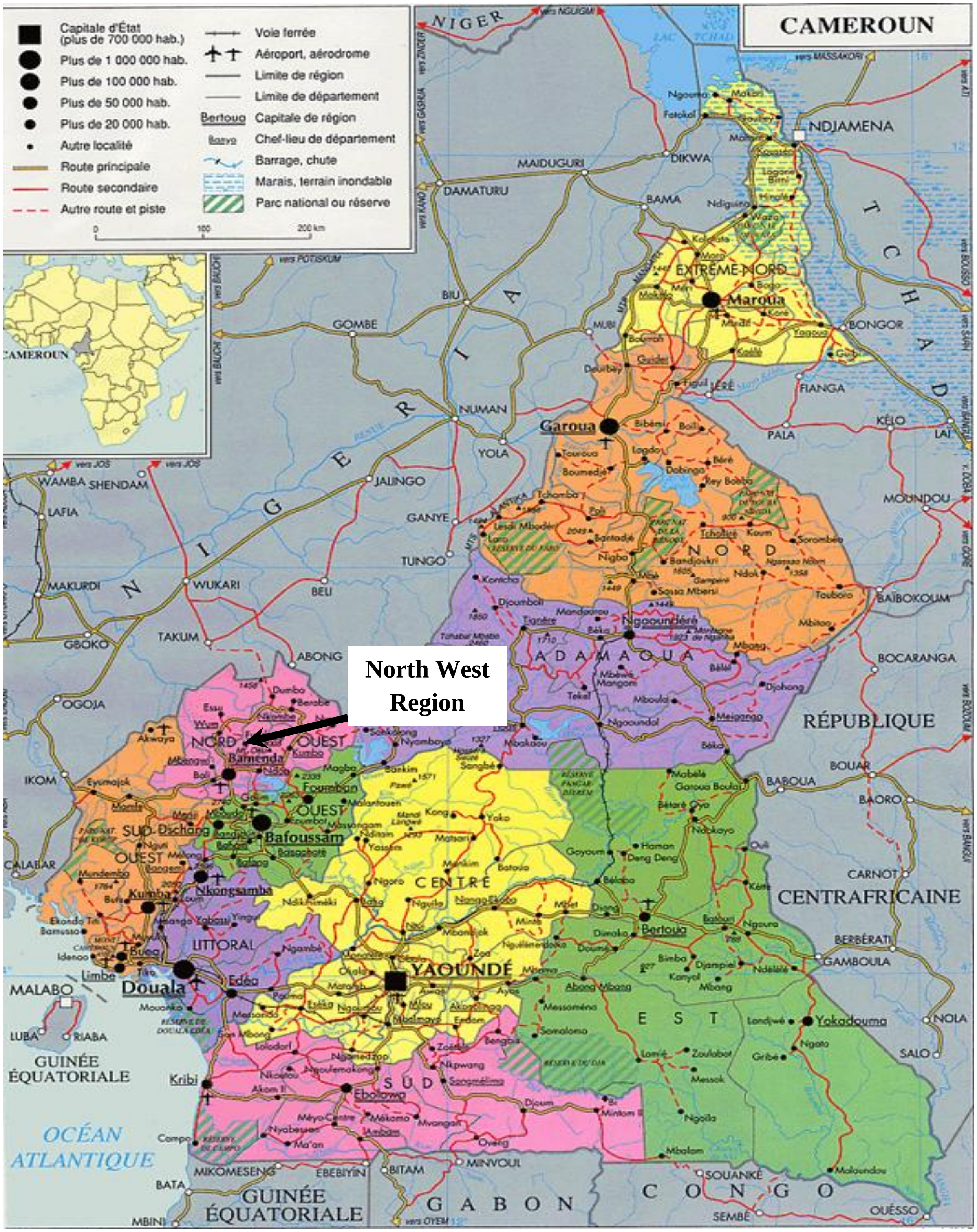

Fig 2.1: Map of Cameroon indicating the study area (North West Region).

Two urban areas (Bamenda and Kumbo) and two rural areas (Bafut and Jakiri) in Mezam and Bui Divisions of the North West Region of Cameroon were included in the study. Bamenda is the capital of the North West Region and forms one of the two English speaking regions of Cameroon. This region is also part of the humid highlands of the country and has a population density of 104.3 persons/km^2 including 862,269 males and 942,426 females[295].

From a nutrition perspective, there is a variation in diet according to the different regions of Cameroon. The North West Region has two main seasons which influence agricultural output. The rainy season begins around mid March and runs until mid November, with the heaviest rains between August and September. The dry season begins from late November and extends to mid March. Based on these seasons, the inhabitants are able to cultivate a variety of crops in this area. The availability of certain crops depends on the season, but generally, green vegetables and major staple foods including plantains, roots and tubers are available all year round. At the beginning of the rainy season, crops that are planted include; maize, groundnuts, beans (red and black), yams and Irish potatoes. These crops are usually harvested between July and September. Other food crops including rice are either cultivated or bought and are available throughout the year. Fruits are also available all year round and mangoes usually reach peak levels in the rainy season between June and July, while oranges peak during the dry season. The North West Region is known for its cattle and pig rearing and the existence of tea, coffee and rice plantations[296].

Food consumption pattern follow three meals a day including breakfast, lunch and supper. Depending on the SES of the family especially in rural settings, the same food can be consumed during the three meals of the day. Most meals generally comprise a major starch staple with either vegetables or soup with meat or fish depending on the economic situation of the family. Some schools especially in urban settings provide meals for children but the content of these meals are not documented anywhere.

The North West Region is also known for its academic activities and currently hosts four universities, one state university and 3 private universities including a mix of English and French- speaking Cameroonians. The North West Region has not been left out with the rapid urbanization in the country. Business activities have also grown rapidly in this region over the past years. In fact, Cameroon had one of the highest urbanization rates in Sub-Saharan Africa when measured in 2002 and it has been predicted that the rate of urbanization will reach 67% by 2025[297]. In both rural and urban settings of the region, occupations range from farming activities to students, white-collar jobs and business activities. Depending on the socioeconomic situation of the family, house construction range from houses made of mud bricks with thatched roofs to houses made from cement blocks with roof made of zinc, some of which have tiled walls and/or floors.

2.3. Sample and sample size estimation.

The sample size for this study was calculated using Cochran's formula[298] as indicated below:

$$N = \frac{(t)^2 \times (p)(q)}{(d)^2}$$

Where t = value for selected alpha of 0.025 in each tail = 1.96

(p)(q) = estimate of variance = 0.25[299]

d = absolute error between the estimated and true value = 5% or 0.05

N = sample size required (calculated to be 384).

A response rate of 80% was expected. Therefore, by dividing 384 by 0.8, the number of subjects to be recruited will increase to 480. This was the minimum number of children needed in the study and also to compensate for non response.

2.4. Data collection.

All measurements were carried out on school premises (on appointment dates fixed by the school authorities) conducted by the principal investigator and well trained nurses ensuring that standard protocols were respected. Assent was obtained from each participant before measurements. Consent was obtained from the respective school head teachers and parents/guardians. All measurements were taken between 7 and 9am. Pupils who were no longer willing to participate were allowed to opt out of the study.

2.4.1. Height.

Standing height was measured to the nearest 0.1cm using a portable stadiometer (Seca 213, Germany). The subjects stood on a horizontal surface without shoes with heels, buttocks, shoulders and back of head against the back of the stadiometer with legs straight. The head of the subject was in the Frankfurt plane (corner of the eye horizontal with middle of ear)[300].

2.4.2. Weight.

A digital scale (Omron BF 511, Japan) was used to measure body weight to the nearest 0.1 kg with children dressed in light school uniforms and shoes taken off.

2.4.3. Body mass index.

Body Mass Index (BMI) was then calculated as weight (kg) divided by height squared (m^2)[42].

2.4.4. Waist circumference.

Waist circumference (WC) was measured in the middle of the 10th rib and the iliac crest to the nearest millimetre with subjects wearing only underwear by a single trained measurer. Readings were recorded with the subjects at a standing position and at the end of a normal expiration[44] using a non-elastic flexible body circumference measuring tape (Seca 201, Germany).

2.4.5. Percentage body fat.

Body fat percentage was estimated using Deurenberg *et al* age- and sex-specific prediction formula for children. %BF = 1.51 x BMI – 0.70 x age – 3.6 x sex + 1.4 (where males = 1, females = 0). The validity of this formula had been determined[301].

2.4.6. Head circumference.

Head circumference was measured using a head circumference measuring tape (Seca 212, Germany) to the nearest centimeter. This was done by placing the tape around the child's head at the same level on each side. It crossed the forehead superior to the supraorbital ridges and passed the prominence of the occiput posteriorly. During measurement, the hairs were firmly pressed against the skull because of the tension of the tape. Measurements were done in duplicates and the largest circumference was recorded[302].

2.4.7. Mid upper arm circumference (MUAC).

MUAC was measured using a measuring tape. The midpoint of the child's upper left arm was calculated to the nearest centimeter with the child's elbow bent to make a right angle. The midpoint was marked with a marker. Then the tape was wrapped at this point ensuring it has the proper tension to be firm on the skin without compressing the tissues[300].

2.4.8. Socioeconomic status.

The Cameroon classification system of occupation and income; civil servants categories C, B and A was used to categorize participants into low, middle and high socioeconomic status (SES) respectively[38]. This information was obtained from parents or guardians whose children participated in the study using a structured questionnaire designed in English and French. The highest level of SES of either parent was used to assign each child to the appropriate category of SES. Parental level of education was also assessed using the questionnaire and four categories were established: illiterate (attended no school), primary (1 – 6 years of education), secondary (7 – 13 years of education) and higher education (> 13 years of education). SES was obtained from 522 out of the 557 parents giving a response rate of 93.7%. Also, a response rate of 89.05% was obtained for parental level of education.

2.4.9. Birth weight.

Birth weight was self reported by parents on the questionnaire and in the analysis high birth weight was indicated as birth weight > 4kg. These readings were obtained from 454 parents giving a response rate of 81.5%.

2.4.10. Undernutrition.

The parameters of undernutrition examined were; wasting (weight-for-height), underweight (weight-for-age) and stunting (height-for-age). These were assessed using the WHO classification system[300].

2.4.11. Physical activity and sedentary time.

Physical activity and sedentary time were determined by using the UK Children's Physical Activity Questionnaire (CPAQ)[303], which had been validated elsewhere[304]. This questionnaire was adapted to suit the realities in children in a Cameroon setting. The questionnaire was administered to the parents of the children and it recorded the activities of the children for the previous seven days.

2.5. Statistical analysis.

Statistical procedures were performed using SPSS for Windows version 16.0 and data was checked for normality using the Kolmogorov-Smirnov (K-S) test. Metric variables were reported as mean (95% CI). Standard deviation scores (SDS) for height, weight and BMI were calculated using the WHO AnthroPlus software, which makes use of the WHO 2007 reference data for children[24]. Also, the SDSs for WC and %BF were calculated by making use of the UK reference data for WC[44] and %BF[45] respectively. The unadjusted and age-adjusted means of anthropometric variables were compared between boys and girls using a *t*-test for independent groups. The WHO cut-off points were used to determine the prevalence of overweight (>+1SD) and obesity (>+2SD). In addition, the 91st percentile of WC[44] and 85th percentile of %BF[45] were the cut-off points to determine the prevalence of excess abdominal fat and excess body fat respectively. The cut-off for the different parameters of undernutrition was < 2 SDS[300]. Head circumference and mid upper arm circumference measurements were also adjusted for age and gender using the reference from the Zurich Growth and Development Study[302] and the cut-offs to determine a small and large head were < 2SDS and > 2SDS respectively. The same cut-offs were used to determine those with small and large mid upper arm circumference.

The study participants were sorted according to increasing height SDS and then divided into quartiles of height SDS. A 1-way ANOVA with post-hoc Bonferroni test was used to compare mean BMI, %BF and WC SDSs and other variables between quartile groups and the prevalence estimates within each quartile of height SDS was calculated. Pearson correlation coefficients were used to assess the relation between height and the three measures of adiposity. This relationship was further demonstrated using the most appropriate linear regression models containing height SDS to predict/quantify the difference in body fatness between boys and girls at different levels of height SDS using the three adiposity measures. In these models, age had no significant association. Also, non-linearity was assessed using residual plots, which did not show any discrete pattern. The plots obtained did not show any increment or diminution in the spread of residuals. Different interaction terms were included in these models to assess for effect modification. Linear regression analysis was also used to determine the relation between head circumference and weight. In the model used, weight and age had a significant association.

The distribution of potential determinants of obesity stratified by SES was calculated. Then, the mean height and weight SDSs and birth weight were also compared across the socioeconomic groups using a 1-way ANOVA with post-hoc Bonferroni test. Height SDS and birth weight showed significant interactions with SES in this study. Therefore, the frequencies of overweight/obesity (BMI), abdominal overweight/obesity (WC) and high body fat/obesity (%BF) stratified by SES, quartiles of height SDS, and high birth weight (determinants) were calculated. This was followed by univariate analysis, which was done using binary logistic regression models to estimate the corresponding odds ratios (OR) (adjusted for age and gender) with 95% CI and *p*-values. In addition, multivariate binary logistic regression analysis was performed to determine the independent association between each of the determinants (that showed significant interactions with obesity in the univariate analysis) and the adiposity measures. SES, height SDS and birth weight showed significant associations with the obesity parameters in the univariate analysis and were included in the model as well as age and gender during the multivariate analysis.

A *p*-value of 0.05 was used to indicate statistical significance.

3. RESULTS

3.1. Main characteristics of the study population.

Table 3.1 shows the differences between variables of the study population (N = 557) according to gender, with almost equal representation of boys and girls. There was no statistical significant difference in height and weight between boys and girls when these variables were unadjusted and age-adjusted. On an absolute scale, there was also no significant difference in BMI by gender. However, on an age adjusted basis, boys had a significantly higher BMI SDS while girls had a significantly higher WC SDS. In addition, girls had a significantly higher %BF, whereas %BF SDS did not differ significantly between boys and girls.

Table 3.1: Differences between boys and girls of the study population [mean (95% CI)].

Variables	Girls N = 270		Boys N = 287		*p*-value
Age	8.9	(8.7 - 9.1)	9.0	(8.8 - 9.2)	0.400
Height (cm)	132.4	(131.0 - 134.1)	133.0	(131.6 - 134.4)	0.536
Height SDS[a]	0.01	(-0.16 - 0.18)	-0.07	(-0.22 - 0.08)	0.494
Weight (kg)	30.8	(29.8 - 31.8)	30.8	(29.9 - 31.7)	0.998
Weight SDS[a]	0.13	(-0.01 - 0.27)	0.19	(0.07 - 0.31)	0.518
BMI (kg/m^2)	17.2	(16.9 - 17.5)	17.1	(16.9 - 17.3)	0.478
BMI SDS[a]	0.19	(0.07 - 0.31)	0.38	(0.29 - 0.47)	0.015
WC (cm)	58.4	(57.7 - 59.1)	58.6	(58.0 - 59.2)	0.679
WC SDS[b]	0.51	(0.40 - 0.62)	0.36	(0.27 - 0.45)	0.039
Body fat (%)	21.0	(20.6 - 21.4)	17.1	(16.8 - 17.4)	< 0.001
Body fat SDS[b]	-0.1	(-0.2 - 0.02)	-0.1	(-0.2 - -0.01)	0.494
HC (cm)	52.8	(52.6 - 53.0)	53.5	(53.3 - 53.7)	< 0.001
HC SDS[c]	0.69	(0.55 - 0.83)	0.55	(0.03 - 1.07)	0.625
MUAC (cm)	19.5	(19.2 - 19.8)	19.0	(18.7 - 19.3)	0.009
MUAC SDS[c]	-0.15	(-0.33 - 0.02)	-0.43	(-0.57 - -0.29)	0.013

a, b, c standard deviation scores (SDS) account for sex and age and differences represent values in this study relative to the WHO 2007, UK 1990 and Swiss 1989 growth reference data respectively. Abbreviations: BMI, body mass index; WC, waist circumference; HC, head circumference; MUAC, mid upper arm circumference.

It is indicated in Table 3.2 that 48.5% of participants were female and 51.5% were male. 31.1% of the subjects were from the rural areas whereas 68.9% from urban areas. Less than 30% of the participants were from the middle or high socioeconomic background. More girls than boys were categorized as overweight or obese on the basis of waist circumference or percentage body fat. Also, more girls had larger heads and mid upper arms than boys.

Table 3.2: Descriptive characteristics by gender, n [% (95% CI)], mean age 9.0 ± 1.8 years.

Variables	Girls N = 270			Boys N = 287		
	n	[% (95% CI)]		n	[% (95% CI)]	
Degree of urbanization						
Rural	83	30.7	(25.5 - 36.5)	90	31.4	(26.2 - 36.9)
Urban	187	69.3	(61.3 - 76.7)	197	68.6	(63.0 - 73.8)
Socioeconomic status						
Low	117	43.3	(37.6 - 49.2)	123	42.9	(37.3 - 48.7)
Middle	70	25.9	(21.0 - 31.5)	74	25.8	(21.1 - 31.1)
High	73	27.0	(22.1 - 32.6)	65	22.6	(18.2 - 27.8)
Missing data	10	3.7	-	25	8.7	-
Body mass index[a]						
Thinness	5	1.9	(0.7 - 4.4)	1	0.3	(0.0 - 1.9)
Normal	219	81.1	(75.6 - 85.0)	235	81.9	(77.0 - 85.9)
Overweight/obesity	46	17.0	(12.9 - 22.0)	51	17.8	(12.1 - 24.7)
Obesity	11	4.1	(2.4 - 7.0)	5	1.7	(0.7 - 4.0)
Waist circumference[b]						
Small	2	0.7	(0.2 - 2.7)	3	1.0	(0.3 - 3.1)
Normal	220	81.5	(74.8 - 87.0)	256	89.2	(80.2 - 98.5)
Abdominal overweight/obesity	48	17.8	(11.8 - 25.1)	28	9.8	(7.1 - 14.0)
Abdominal obesity	12	4.4	(2.6 - 7.5)	3	1.0	(0.3 - 3.1)
Percentage body fat[b]						
Low	8	3.0	(1.5 - 5.7)	3	1.0	(0.4 - 3.0)
Normal	220	81.5	(76.4 - 85.7)	268	93.4	(89.9 - 95.7)
High body fat/obesity	42	15.5	(11.7 - 20.4)	16	5.6	(3.5 - 8.9)
Obesity	3	1.1	(0.4 - 3.2)	0	0.0	(0.0 - 1.3)
Head circumference[c]						
Small	1	0.4	(0.0 - 2.1)	4	1.4	(0.6 - 3.5)
Normal	229	84.8	(81.3 - 87.4)	263	91.6	(88.1 - 94.8)
Large	39	14.4	(10.8 - 19.1)	18	6.3	(3.9 - 9.7)
Missing data	1	0.4	-	2	0.7	-
Mid upper arm circumference[c]						
Small	19	7.0	(4.6 - 10.7)	21	7.3	(4.9 - 10.8)
Normal	232	85.9	(81.2 - 89.7)	256	89.2	(85.2 - 92.1)
Large	18	6.7	(4.2 - 10.4)	9	3.1	(1.7 - 5.8)
Missing data	1	0.4	-	1	0.3	-

a, b, c relative to WHO 2007, UK 1990 and Swiss 1989 growth reference data respectively.

The distribution of overweight /obesity within the investigated population was 14.7% and 2.9% respectively when BMI SDS was used to categorize, while the distribution was 13.6% and 10.4% on the basis of WC SDS and %BF SDS respectively (Figure 3.1). This figure demonstrates that the frequency of overnutrition currently outweighs that of undernutrition in the North West Region of Cameroon.

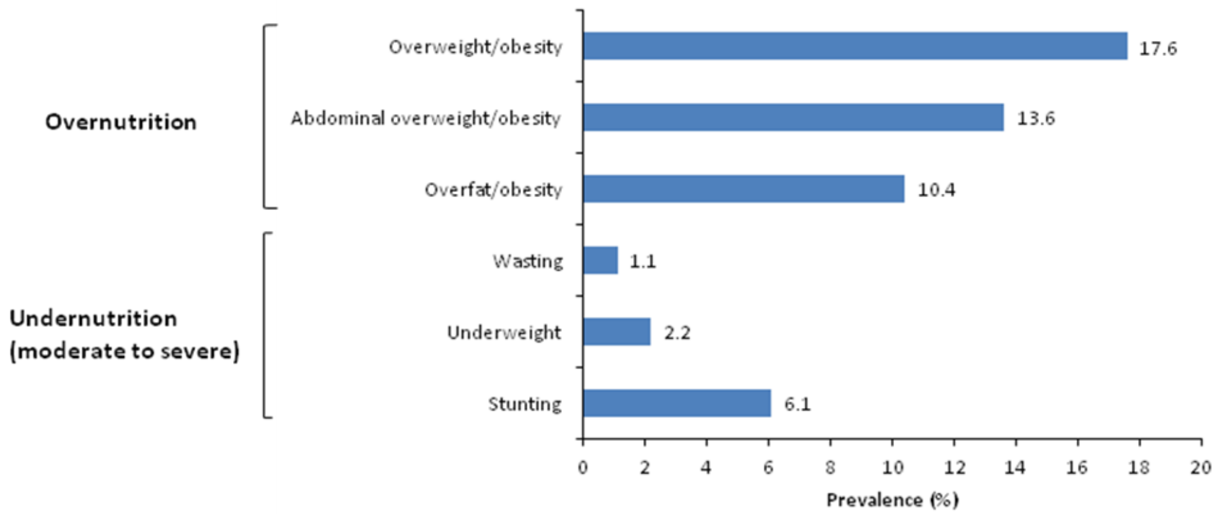

Figure 3.1: Nutrition status of the study population showing the distribution of overnutrition and undernutrition (< -2 SDS of weight-for-height, weight-for-age and height-for-age for wasting, underweight and stunting respectively).

3.2. Prevalence of excess body fat in relation to height SDS and gender.

When the children were divided according to height quartiles of height SDS (mean heights: Q1: 125.6 cm, Q2: 131.1 cm, Q3: 135.1 cm, Q4: 139.1 cm), BMI and BMI-SDS (Table 3.3) as well as WC and WC-SDS (Table 3.4) and %BF and %BF-SDS (Table 3.5) increased with increasing height. Similarly, prevalence of overweight/obesity increased in girls and boys (Tables 3.3 – 3.5). If BMI is used as a parameter the prevalence of overweight/obesity is higher in boys in all height quartiles except for the third quartile. In contrast, the prevalence is higher in girls if WC or %BF is used to classify the children (Tables 3.3 – 3.5).

Table 3.3: Mean BMI SDS and prevalence of overweight/obesity across quartiles of height SDS.

Quartiles of height SDS	N	Mean Height (cm) (95% CI)	Mean Height SDS (95% CI)	Mean BMI SDS (95% CI)	Prevalence of overweight/obesity Overall % (95% CI)	Girls % (95% CI)	Boys % (95% CI)
1	140	125.6 (124.1-127.1)	-1.71 (-1.82- -1.60)	-0.08 (-0.14-0.02)	5.0 (2.4-9.9)	4.3 (1.5-11.3)	5.7 (2.3-13.8)
2	141	131.1 (129.4-132.8)	-0.43 (-0.47- -0.39)	0.29 (0.14-0.44)	19.1 (13.5-26.4)	16.2 (9.2-26.7)	21.9 (13.9-32.7)
3	137	135.1 (133.3-136.9)	0.36 (0.32-0.40)	0.35 (0.22-0.48)	20.4 (14.6-27.9)	25.0 (16.2-36.4)	15.9 (9.1-26.4)
4	139	139.1 (137.1-1.41.1)	1.70 (1.55-1.85)	0.65 (0.48-0.82)	33.1 (25.8-41.3)	31.3 (21.3-43.4)	34.7 (24.9-45.9)

CI, confidence interval; SDS, standard deviation score. Prevalence was estimated using the WHO 2007 BMI cut-off.

Table 3.4: Mean WC SDS and prevalence of abdominal overweight/obesity across quartiles of height SDS.

Quartiles of height SDS	N	Mean WC (cm) (95% CI)	Mean WC SDS (95% CI)	Prevalence of abdominal overweight/obesity		
				Overall % (95% CI)	Girls % (95% CI)	Boys % (95% CI)
1	140	56.5 (55.9 - 57.1)	-0.11 (-0.22 - 0.00)	0.7 (0.1 - 3.9)	0.0 (0.0 - 1.0)	1.4 (0.2 - 7.6)
2	141	58.8 (57.9 - 59.7)	0.45 (0.31 - 0.59)	11.3 (7.8 - 16.3)	16.2 (9.2 - 26.7)	6.8 (2.5 - 15.5)
3	137	58.9 (58.1 - 59.8)	0.52 (0.40 - 0.64)	12.4 (7.6 - 19.3)	17.6 (10.4 - 28.2)	7.2 (3.0 - 16.9)
4	139	60.0 (58.9 - 61.0)	0.87 (0.72 - 1.02)	30.2 (23.0 - 38.5)	39.1 (28.1-51.3)	22.7 (14.4 - 33.6)

CI, confidence interval; WC, waist circumference; SDS, standard deviation score. Prevalence was estimated using the 91st centile WC cut-off.

Table 3.5: Mean %BF SDS and prevalence of high percentage body fat/obesity across quartiles of height SDS.

Quartiles of height SDS	N	Mean %BF (95% CI)	Mean %BF SDS (95% CI)	Prevalence of high body fat/obesity		
				Overall % (95% CI)	Girls % (95% CI)	Boys % (95% CI)
1	140	17.7 (17.3 - 18.1)	-0.52 (-0.6 - -0.4)	2.1 (0.7 - 6.1)	2.9 (0.8 - 9.8)	1.4 (0.3 - 7.7)
2	141	19.0 (18.4 - 19.6)	-0.10 (-0.2 - 0.05)	7.8 (4.4 - 13.4)	13.2 (7.1 - 23.3)	2.7 (0.8 - 9.5)
3	137	19.0 (18.4 - 19.6)	-0.10 (-0.2 - 0.02)	8.0 (4.5 - 13.8)	13.2 (7.1 - 23.3)	2.9 (0.8 - 10.0)
4	139	20.2 (19.5 - 20.9)	0.36 (0.2 - 0.5)	23.7 (17.4 - 31.5)	34.5 (23.9 - 46.6)	14.7 (8.4 - 23.4)

CI, confidence interval; %BF, percentage body fat; SDS, standard deviation score. Prevalence determined using the 85th centile %BF cut-off.

3.3. Relation between height and measures of body fat.

In our study population, the correlation coefficients (*r*) between height and the three parameters of obesity ranged from 0.246 to 0.430. This association was significant at the 0.05 level for boys and girls regardless of the parameter used to quantity adiposity (Table 3.6).

Table 3.6: Association between height and adiposity in girls and boys.

Parameters of body fat	Height SDS	
	Correlation (r)	*p*-value
GIRLS		
Body mass index SDS	0.339	< 0.001
Waist circumference SDS	0.393	< 0.001
Percentage body fat SDS	0.430	< 0.001
BOYS		
Body mass index SDS	0.246	< 0.001
Waist circumference SDS	0.481	< 0.001
Percentage body fat SDS	0.297	< 0.001

Correlation is significant at 0.01 level

Further demonstration of this association was carried out by using linear regression models containing height SDS and age as independent variables to predict levels of the measures of adiposity in both boys and girls. In all three measures of adiposity, the interactions were significant ($p < 0.001$). Figure 3.2a shows the association between height SDS and BMI SDS for both boys ($R^2 = 0.061$) and girls ($R^2 = 0.115$), confirming that the BMI was highest among the tallest children. At all levels of height SDS, BMI was higher for boys than girls.

Equivalent findings (as seen in Figure 3.2b) were observed when height SDS was used to predict levels of WC SDS for boys ($R^2 = 0.231$) and girls ($R^2 = 0.154$), confirming that the tallest children accumulated more abdominal fat that their shortest peers. However, the girls had a higher waist circumference than boys at all levels of height SDS. That notwithstanding, this gender difference was not as pronounced as that for BMI.

Figure 3.2c also shows predicted %BF SDS levels for height SDS in boys ($R^2 = 0.088$) and girls ($R^2 = 0.185$). Even though the %BF among the shortest children was below average (%BF SDS<0), boys had a 0.3 unit higher %BF than girls. However, a different situation was observed among the tallest children with the girls having a 0.2 unit higher %BF SDS than boys. For all the three parameters of body fatness, the mean residual was 0.000 for both boys and girls. Also the standard deviation of the mean residual for boys ranged from 0.80 to 0.81 and that for girls was from 0.83 to 0.94. This indicates a distribution that is almost or near normal.

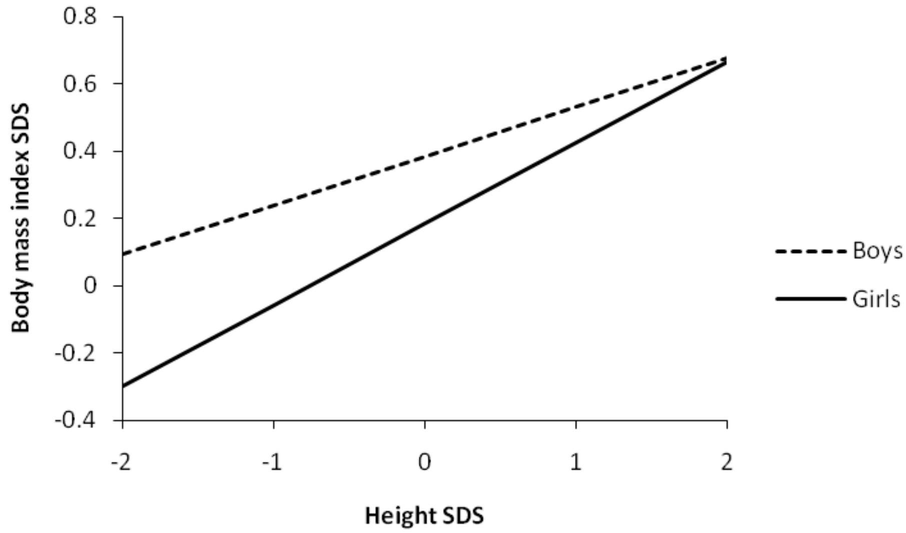

Figure 3.2a: Relation between BMI SDS and height SDS. Boys ($R^2 = 0.061$, $p < 0.001$); Girls ($R^2 = 0.115$, $p < 0.001$).

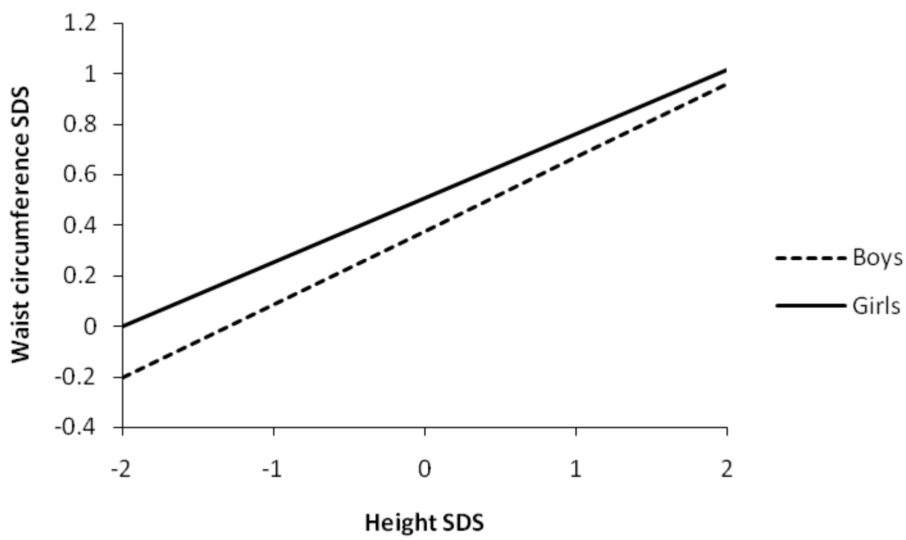

Figure 3.2b: Relation between WC SDS and height SDS. Boys ($R^2 = 0.231$, $p < 0.001$); Girls ($R^2 = 0.154$, $p < 0.001$).

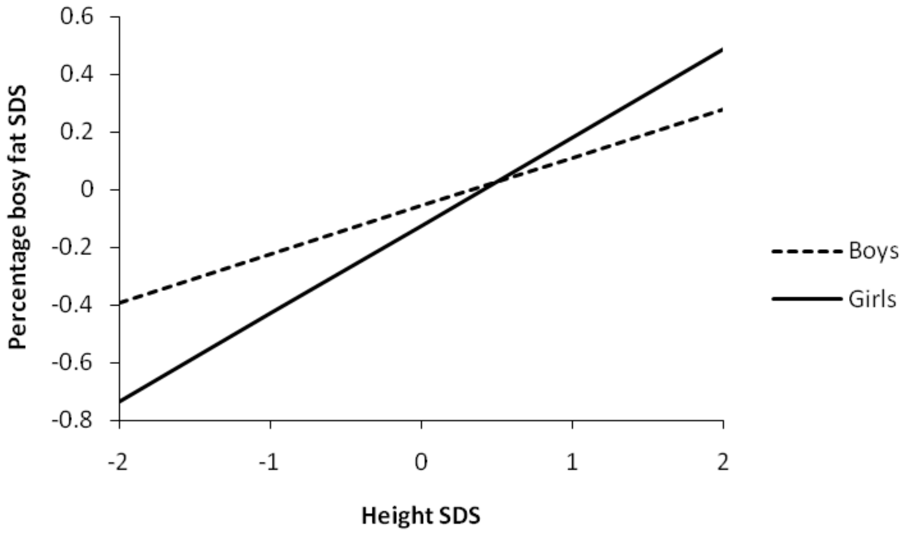

Figure 3.2c: Relation between %BF SDS and height SDS. Boys ($R^2 = 0.088$, $p < 0.001$); Girls ($R^2 = 0.185$, $p < 0.001$).

3.4. Differences by socioeconomic status.

Table 3.7 shows the distribution of the determinants of obesity stratified by socioeconomic status. The variables that showed a similar distribution across all socioeconomic groups included those of the second and third quartiles of height SDS, those with no high birth weight and participants who were able to do physical activity for more than 60 minutes per day and ≤ 2 times in a week.

Table 3.7: Distribution of determinants of obesity stratified by socioeconomic status [% (95% CI)].

Determinants	Socioeconomic status					
	Low (N = 240)		Medium (N = 144)		High (N = 138)	
	%	95% CI	%	95% CI	%	95% CI
Quartiles of height SDS						
First quartile	34.6	(28.9 - 40.8)	22.9	(16.8 - 30.4)	13.0	(8.4 - 19.7)
Second quartile	22.5	(17.7 - 28.2)	25.7	(19.3 - 33.4)	26.1	(19.5 - 34.0)
Third quartile	25.4	(20.3 - 31.3)	23.6	(17.4 - 31.2)	26.1	(19.5 - 34.0)
Fourth quartile	17.5	(13.2 - 22.8)	27.8	(21.1 - 35.6)	34.8	(27.4 - 73.0)
High birth weight (> 4kg)						
Yes	12.1	(8.6 - 16.8)	18.1	(12.6 - 25.1)	26.4	(18.2 - 32.5)
No	62.5	(56.2 - 68.4)	66.0	(57.9 - 73.2)	63.8	(55.5 - 71.3)
Physical activity (> 60 mins/day)						
Yes	15.0	(11.0 - 20.1)	18.8	(13.2 - 25.9)	17.4	(12.0 - 24.6)
No	7.1	(4.5 - 11.1)	7.6	(4.3 - 13.2)	11.6	(7.3 - 18.0)
Physical activity (60 times/week)						
Low (≤ 2 times/week)	12.9	(9.3 - 17.8)	11.1	(7.0 - 17.3)	13.8	(9.0 - 20.5)
Medium (> 2 – 4 times/week)	8.8	(5.8 - 13.0)	10.4	(6.4 - 16.5)	11.6	(7.3 - 18.0)
High (> 4 – 7 times/week)	8.3	(5.5 - 12.5)	10.4	(6.4 - 16.5)	10.1	(6.1 - 16.3)
Sedentary activity (hours/day)						
Low (≤ 1 hour/day)	12.9	(9.3 - 17.8)	9.7	(5.9 - 15.7)	7.3	(4.0 - 12.8)
Medium (> 1 – 3 hours/day)	9.2	(6.1 - 13.5)	11.8	(7.5 - 18.1)	14.5	(9.6 - 21.3)
High (> (3 – 6 hours/day)	5.8	(3.5 - 9.6)	6.3	(3.3 - 11.5)	14.5	(9.6 - 21.3)

N = 522 participants after exclusion of those with missing data in socioeconomic status

Also, Table 3.8 shows that obesity was more pronounced among urban girls than boys when all three parameters of obesity were used.

Table 3.8: Prevalence of obesity in relation to degree of urbanization.

	Gender	Urban		Rural	
		%	(95% CI)	%	(95% CI)
Overweight/obesity	Boys	17.8	(13.1-23.7)	17.7	(11.3-26.9)
	Girls	18.2	(13.3-24.3)	14.5	(8.5-23.6)
Abdominal overweight/obesity	Boys	10.2	(6.5-15.2)	8.9	(4.6-16.6)
	Girls	20.9	(15.7-27.2)	10.8	(5.8-19.3)
High body fat/obesity	Boys	6.6	(3.9-11.0)	3.3	(1.1-9.4)
	Girls	17.6	(12.9-23.8)	10.8	(5.8-19.3)

CI: confidence interval

Figure 3.3 shows that participants from the high socioeconomic background were significantly ($p < 0.001$) taller than those from the low socioeconomic group, which corresponds to a 0.6 unit difference in height SDS. However, there were no significant differences in height SDS between the low and middle SES groups and also between the middle and high SES groups.

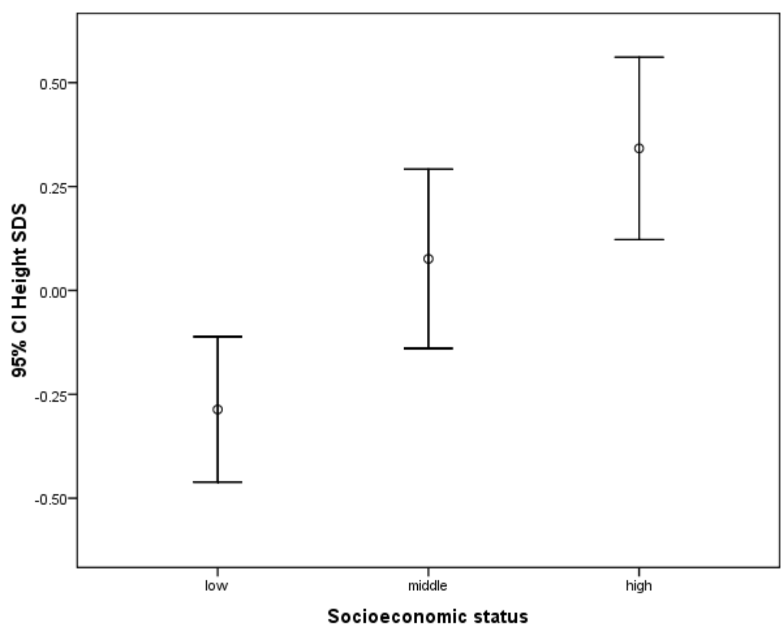

Figure 3.3: Height differences by socioeconomic status. Significant difference observed between low and high SES ($p < 0.001$). N = 522 after exclusion of subjects with no information on SES.

Figure 3.4 also shows a 0.24kg mean difference in birth weight between the low and high income group which was significant (p = 0.008). However, no significant differences in birth weight were observed between the other socioeconomic groups.

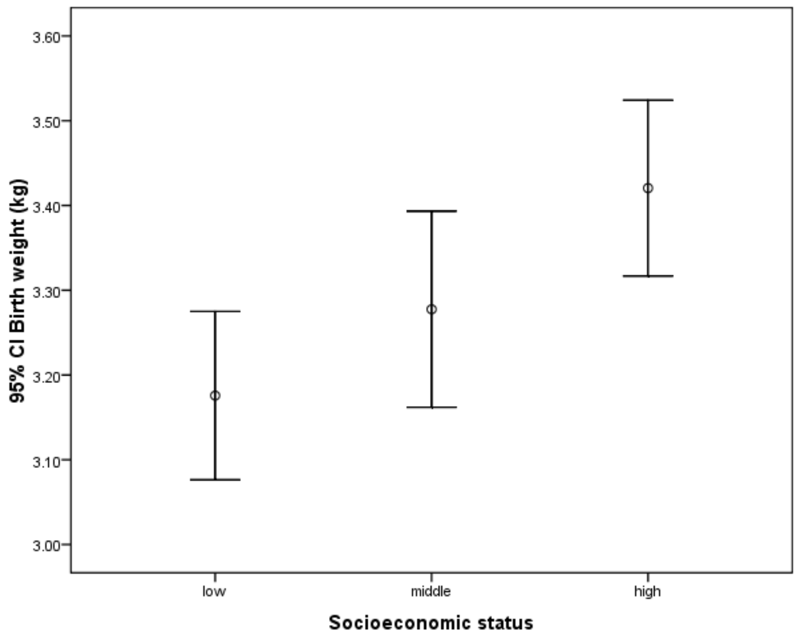

Figure 3.4: Birth weight differences by socioeconomic status. A significant difference in birth weight was observed between low and high SES (p = 0.008). N = 522 after exclusion of subjects with no information on SES.

Based on the significant difference in height SDS and birth weight observed above between the low and high SES group, Table 3.9 shows the frequency of excess body fatness tabulated in the three socioeconomic groups, quartiles of height SDS and high birth weight. With regards to height, it indicates that the frequencies of overweight/obesity, abdominal overweight/obesity and high body fat/obesity were highest among the tallest children from the high socioeconomic group. Also, in the second, third and fourth quartiles of height SDS, there was a progressive increase in the frequency of obesity with increasing SES. Concerning birth weight, highest frequencies of obesity were observed among those who had a high birth weight and who also belong to the high socioeconomic group.

Table 3.9: Frequency of obesity according to quartiles of height SDS and high birth weight differentiated by socioeconomic status.

Height SDS and birth weight	Socioeconomic status					
	Low		Medium		High	
	%	(95% CI)	%	(95% CI)	%	(95% CI)
Overweight/obesity						
Quartiles of height SDS						
First quartile	1.3	(0.4 - 3.6)	2.1	(0.7 - 6.0)	0.7	(0.1 - 4.0)
Second quartile	1.7	(0.7 - 4.2)	4.2	(1.9 - 8.9)	10.1	(6.1 - 16.3)
Third quartile	0.8	(0.2 - 3.0)	1.4	(0.4 - 4.9)	10.1	(6.1 - 16.3)
Fourth quartile	2.5	(1.2 - 5.4)	7.6	(4.3 - 13.2)	18.8	(13.2 - 26.2)
High birth weight (>4kg)						
Yes	4.6	(2.6 - 8.0)	9.0	(5.4 - 14.8)	16.7	(11.4 - 23.8)
No	1.7	(0.7 - 4.2)	6.3	(3.3 - 11.5)	21.7	(15.7 - 29.3)
Abdominal overweight/obesity						
Quartiles of height SDS						
First quartile	0.0	(0.0 - 1.6)	0.7	(0.1 - 3.8)	0.0	(0.0 - 2.7)
Second quartile	1.3	(0.4 - 3.6)	1.4	(0.4 - 4.9)	7.3	(4.0 - 12.8)
Third quartile	1.3	(0.4 - 3.6)	2.1	(0.7 - 6.0)	8.0	(4.5 - 13.7)
Fourth quartile	6.7	(4.1 - 10.6)	6.9	(3.8-12.3)	10.9	(6.7 - 17.2)
High birth weight (>4kg)						
Yes	2.9	(1.4 - 5.9)	5.6	(2.8 - 10.6)	12.3	(7.8 - 18.8)
No	4.6	(2.6 - 8.0)	11.1	(7.5 - 20.9)	12.3	(7.8 - 18.8)
High body fat/obesity						
Quartiles of height SDS						
First quartile	0.8	(0.2 - 3.0)	0.0	(0.0 - 2.6)	0.7	(0.1 - 4.0)
Second quartile	1.3	(0.4 - 3.6)	1.4	(0.4 - 4.9)	4.4	(2.0 - 9.2)
Third quartile	0.0	(0.0 - 1.6)	2.1	(0.7 - 6.0)	5.8	(3.0 - 11.0)
Fourth quartile	2.5	(1.2 - 5.4)	5.6	(2.8 - 10.6)	12.3	(7.8 - 18.8)
High birth weight (>4kg)						
Yes	2.1	(0.9 - 4.8)	2.8	(1.1 - 6.9)	11.6	(7.3 - 18.0)
No	1.7	(0.7 - 4.2)	4.9	(2.4 - 9.7)	10.1	(6.1 - 16.3)

N = 522 after exclusion of subjects with no information on SES; CI, confidence interval.

Figure 3.5a - c show height differences between participants with excess body fat and those of their normal weight peers using the different parameters of obesity. It shows that children with excess body fat were significantly taller than those with normal weight regardless of their socioeconomic background. These significant differences were observed at the 0.05 level.

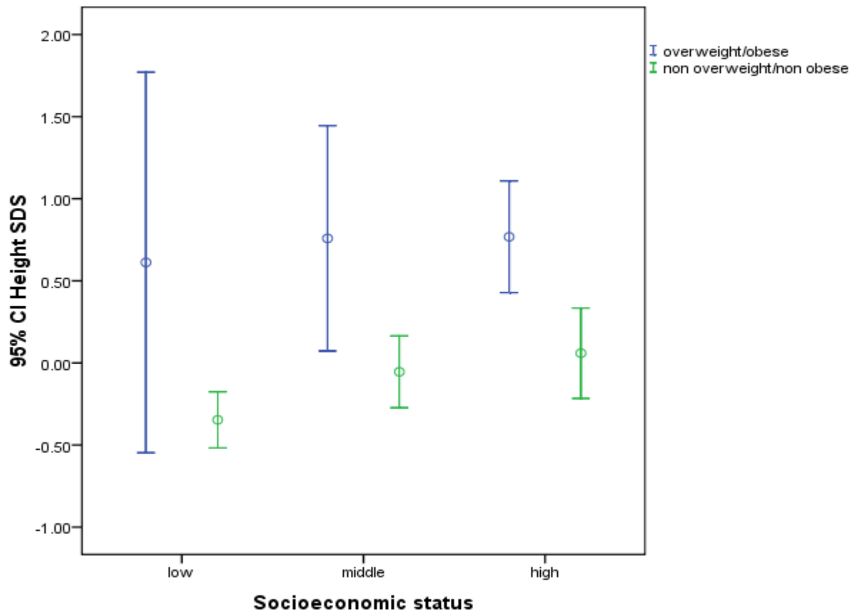

Figure 3.5a: Mean height comparison between those with excess body fat (assessed using BMI) and normal weight subjects in the different socioeconomic groups.

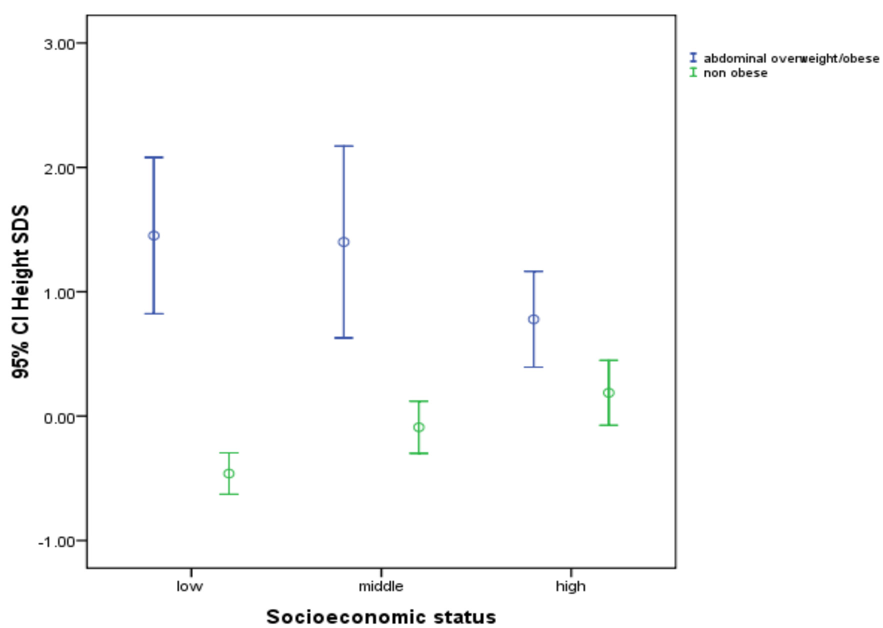

Figure 3.5b: Mean height comparison between those with excess body fat (assessed using waist circumference) and normal weight subjects in the different socioeconomic groups.

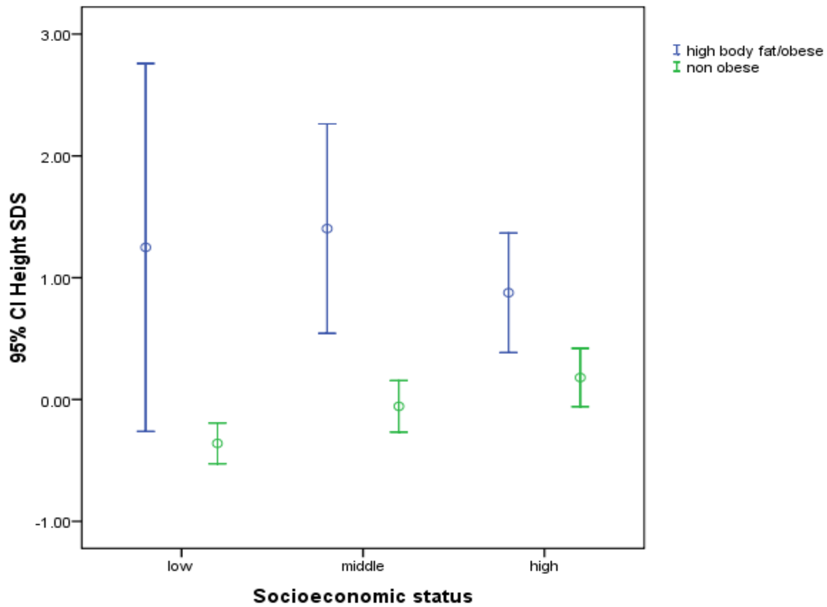

Figure 3.5c: Mean height comparison between those with excess body fat (assessed using percentage body fat) and normal weight subjects in the different socioeconomic groups.

3.5. Univariate and multivariate analysis.

Univariate analysis in Table 3.10a show that regardless of which parameter of obesity used, a high socioeconomic background, tallness and a high birth weight were significantly associated with a higher frequency of overweight/obesity, abdominal overweight/obesity and high body fat/obesity after adjusting for age and gender. This association was more pronounced when BMI is used as a measure of body fat. However, parental level of education (Table 3.10b), physical activity (assessed in minutes per day and times per week) and sedentary time (hours a day) (Table 3.10c) were not significantly associated to any of the three different parameters of obesity. Also, the activity findings were not consistent among the obesity parameters.

The results of the multivariate analysis, which included only determinants with a significant interaction with obesity in the univariate analysis, are shown on Table 3.11. The model showed a statistically significant independent association between overweight/obesity (BMI), abdominal overweight/obesity (WC) and high body fat/obesity (%BF) and SES, height SDS and high birth weight.

Table 3.10a: Frequency and OR (95% CI) for the association of obesity with potential determinants.

Determinants	N 557	Overweight/obesity (BMI)			Abdominal overweight/obesity (WC)			High body/obesity (%BF)		
		Frequency (%)[a]	OR (95% CI)	*p*-value	Frequency (%)[b]	OR (95% CI)	*p*-value	Frequency (%)[c]	OR (95% CI)	*p*-value
Socioeconomic status										
High	138	39.9	10.1 (5.4 - 18.9)	< 0.001	26.1	3.5 (1.9 - 6.2)	< 0.001	23.2	0.2 (0.1 - 0.5)	< 0.001
Medium	144	16.0	3.5 (2.0 - 6.2)	< 0.001	11.1	2.8 (1.5 - 5.3)	0.002	9.0	0.1 (0.05 - 0.3)	< 0.001
Low	240	6.3	ref.		9.2	ref.		4.6	ref.	
Missing data	35									
Quartiles of height SDS										
Fourth quartile	139	33.1	10.9 (4.6 - 25.8)	< 0.001	30.2	4.2 (2.2 - 8.2)	< 0.001	23.7	0.3 (0.1 - 0.7)	0.006
Third quartile	137	20.4	2.3 (1.3 - 4.0)	0.004	12.4	3.8 (2.0 - 7.2)	< 0.001	8.0	0.3 (0.1 - 0.7)	0.007
Second	141	19.1	3.6 (1.9 - 6.6)	< 0.001	11.3	ref.		7.8	0.1 (0.03 - 0.4)	< 0.001
First	140	5.0	ref.		0.7			2.1	ref.	
High birth weight (> 4kg)										
Yes	95	54.8	8.7 (5.2 - 14.5)	< 0.001	34.7	5.2 (2.9 - 9.1)	< 0.001	27.4	7.1 (3.5 - 14.7)	< 0.001
No	359	12.3	ref.		9.7	ref.		7.0	ref.	
Missing data	103									

[a, b, c] Based on WHO 2007 BMI, UK 1990 91st centile and UK 1990 85th centile cut-offs respectively. Abbreviations: OR. Odds ratio; CI, confidence interval. (odds ratios adjusted for age and gender). Overweight/obesity, abdominal overweight/obesity and high body fat/obesity are defined by BMI, waist circumference and % body fat respectively.

Table 3.10b: Frequency and OR (95% CI) for the association of obesity with parental level of education.

Determinant	N 557	Overweight/obesity (BMI)			Abdominal overweight/obesity (WC)			High body fat/obesity (%BF)		
		Frequency (%)[a]	OR (95% CI)	*p*-value	Frequency (%)[b]	OR (95% CI)	*p*-value	Frequency (%)[c]	OR (95% CI)	*p*-value
Parental education level										
Higher education	144	15.3	0.9 (0.4 - 1.8)	0.681	15.3	1.0 (0.5 - 2.2)	0.951	13.9	1.2 (0.6 - 2.7)	0.579
Secondary	154	18.8	0.9 (0.5 - 1.8)	0.784	13.6	1.3 (0.6 - 2.8)	0.477	7.1	1.0 (0.5 - 2.1)	0.947
Primary	113	16.8	0.8 (0.4 - 1.5)	0.449	11.5	1.1 (0.6 - 2.1)	0.805	8.8	1.2 (0.6 - 2.3)	0.629
Illiterate	85	17.6	ref.		14.1	ref.		11.8	ref.	
Missing data	61									

[a, b, c] Based on WHO 2007 BMI, UK 1990 91st centile and UK 1990 85th centile cut-offs respectively. Abbreviations: OR. Odds ratio; CI, confidence interval. (odds ratios adjusted for age and gender). Overweight/obesity, abdominal overweight/obesity and high body fat/obesity are defined by BMI, waist circumference and % body fat respectively.

Table 3.10c: Frequency and OR (95% CI) for the association of obesity with sedentary time and physical activity.

Determinants	N 557	Overweight/obesity (BMI)			Abdominal overweight/obesity (WC)			High body fat/obesity (%BF)		
		Frequency (%)[a]	OR (95% CI)	*p*-value	Frequency (%)[b]	OR (95% CI)	*p*-value	Frequency (%)[c]	OR (95% CI)	*p*-value
Sedentary activity										
Low (≤1 hour/day)	56	16.1	0.8 (0.3 - 2.0)	0.590	14.3	0.5 (0.2 - 1.3)	0.145	7.1	0.8 (0.2 - 4.1)	0.804
Medium (>1-3hours/day)	60	20.0	0.6 (0.2 - 1.7)	0.691	23.3	0.7 (0.2 - 2.2)	0.594	8.3	1.4 (0.3 - 6.9)	0.661
High (>3-6 hours/day)	43	23.3	ref.		18.6	ref.		9.3	ref.	
Missing data	398									
Physical activity										
Low (≤2 times/week)	67	19.4	0.8 (0.3 - 2.0)	0.676	14.9	0.7 (0.3 - 1.8)	0.426	7.4	3.9 (0.3 - 45.8)	0.282
Medium (>2-4times/wk)	52	23.1	1.5 (0.5 - 4.1)	0.444	21.2	0.8 (0.3 - 2.2)	0.638	9.6	4.6 (0.4 - 56.8)	0.239
High (>4-7 times/wk)	50	14.0	ref.		16.0	ref.		2.0	ref.	
Missing data	388									
Physical activity										
Yes (>60mins/day)	88	18.2	0.8 (0.3 - 2.1)	0.693	17.0	1.5 (0.5 - 4.2)	0.462	4.5	0.6 (0.1 - 4.0)	0.585
No (<60mins/day)	45	20.0	ref.		13.3	ref.		6.7	ref.	
Missing data	424									

[a, b, c] Based on WHO 2007 BMI, UK 1990 91st centile and UK 1990 85th centile cut-offs respectively. Abbreviations: OR. Odds ratio; CI, confidence interval. (odds ratios adjusted for age and gender). Overweight/obesity, abdominal overweight/obesity and high body fat/obesity are defined by BMI, waist circumference and % body fat respectively.

Table 3.11: Multivariate binary logistic regression analysis with overweight/obesity (BMI), abdominal overweight/obesity (WC) and high body fat/obesity (%BF) as dependent variable.

	Overweight/obesity (BMI)		Abdominal overweight/ obesity (WC)		High body fat/obesity (%BF)	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Socioeconomic status						
High	8.3 (3.9 - 15.4)	< 0.001	2.5 (1.2 - 5.6)	0.017	0.2 (0.1 - 0.6)	0.003
Medium	3.7 (1.8 - 7.3)	< 0.001	2.1 (1.8 - 7.3)	< 0.001	0.1 (0.05 - 0.4)	< 0.001
Low	ref.		ref.		ref.	
Quartiles of height SDS						
Fourth quartile	9.1 (3.4 - 16.7)	< 0.001	4.1 (1.9 - 8.7)	< 0.001	0.3 (0.1 - 0.7)	0.010
Third quartile	2.1 (1.0 - 4.1)	0.041	3.8 (1.8 - 8.1)	< 0.001	0.4 (0.2 - 0.9)	0.041
Second	3.7 (1.7 - 7.9)	0.001	ref.		0.2 (0.05 - 0.7)	0.014
First	ref.				ref.	
High birth weight (> 4kg)						
Yes	0.1 (0.06 - 0.2)	< 0.001	0.2(0.1 - 0.4)	< 0.001	7.1 (3.2 - 15.9)	< 0.001
No	ref.		ref.		ref.	

OR, odds ratio; CI, confidence interval; (odds ratios adjusted for age and gender). Overweight/obesity, abdominal overweight/obesity and high body fat/obesity are defined by BMI, waist circumference and % body fat respectively.

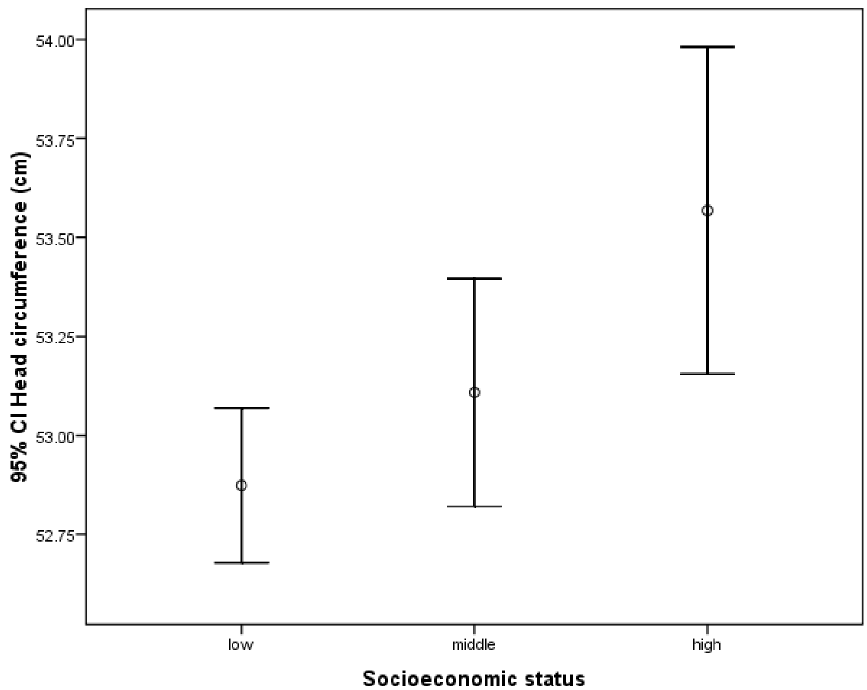

Figure 3.6: Differences in head circumference by socioeconomic group

Figure 3.6 shows a significant difference in head circumference between the low and high socioeconomic group (p = 0.003). On a gender basis, this difference was significant only in boys (p = 0.029).

3.6. Association between head circumference and body weight.

Figure 3.7 shows the association between head circumference (as a continuous variable) and weight SDS for boys (R^2 = 0.251) and girls (R^2 = 0.156). Age and weight had significant interactions (p<0.001) in the model. However, height had no significant interaction in the model, meaning that weight was the strongest predictor of head circumference. The mean residual was 0.0000 for both girls and boys. The standard deviation of the mean residual ranged from 1.1 – 1.3, which is close to a normal distribution.

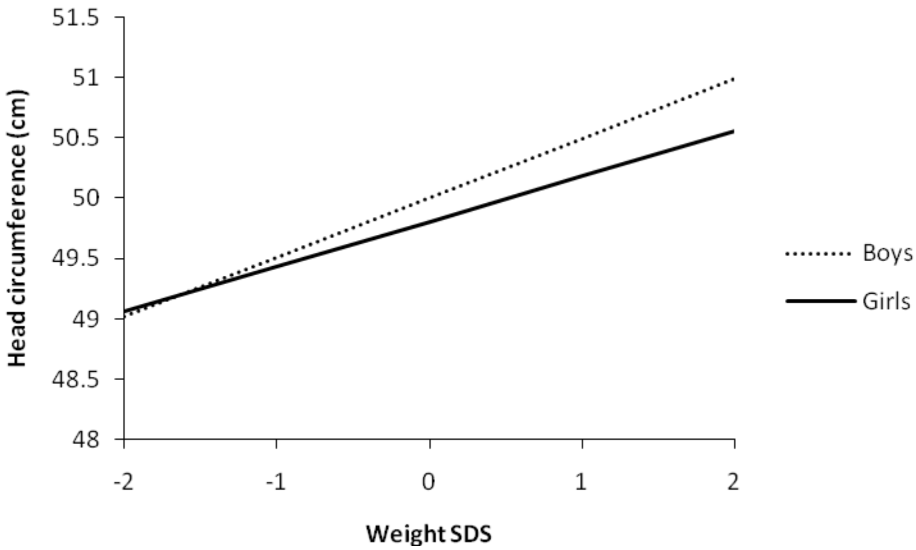

Figure 3.7: Association between head circumference (cm) and weight SDS.

4. DISCUSSION

4.1. Relationship between height and parameters of body fatness.

This current study confirms that with increasing quartiles of height SDS, mean BMI SDS, WC SDS and %BF SDS increased, which corresponded to a significant increase in the prevalence of overweight/obesity (BMI), central overweigh/obesity (WC) and high body fat/obesity (%BF). In other words, this indicates that regardless of the measure of body fat, the highest prevalence is in the top quartile of height SDS, and this was consistent for both boys and girls. The prevalence of overweight/obesity (BMI) in the fourth quartile of height SDS was more than six times that of the first quartile. This indicates that taller children tend to accumulate more body fat. Also, the confidence intervals of the mean SDSs for BMI (Table 3.3) waist circumference (Table 3.4) and percentage body fat (Table 3.5) were close to the mean, suggesting little variability in our sample. Correlation and regression analyses in this study further confirm a positive association between height and body fat assessed by BMI, WC and %BF in both boys and girls.

Height was the strongest determinant in the multivariable analysis. The contribution of height to overweight/obesity is gaining more recognition and there is increasing evidence suggesting that taller children tend to be overweight/obese[176,177,178]. It was formerly thought this association was typical when BMI is used to assess body fat. Like in some developed nations, this study has shown that equivalent relationships are obtained even when other measures of body fat (WC and %BF) were used, suggesting that tallness is likely a predictor of both the level and distribution of body fat. A study had shown a steep rise in overweight prevalence assessed using BMI among the tallest UK children[177]. However, this study included only 3 year old children. A recent experience in the UK Caucasian population has also shown excess body fat to be more pronounced among the tallest children across different age groups[305]. However, the BIA equipment used in the study has been shown to underestimate adiposity in children[306]. Studies have also indicated that this relationship is stronger at a younger age and gets weaker towards adolescence and that a positive relation between height and obesity was observed two years earlier in girls than in boys[178,179,307]. Nevertheless, a study had indicated a weak association between height and obesity in adults and that taller children tend to have higher levels of BMI and skinfolds that could tract into adulthood[179]. In addition to the above field-based findings, the height-obesity relationship has also been examined and confirmed in a laboratory-based study on 7 to 12 year old children using DXA[308]. Also, this laboratory-based study indicated that children with a higher height SDS were more insulin resistant than their shorter peers[308] suggesting that insulin resistance could explain to some extent the higher levels of waist circumference observed among the tallest children in our study.

In contrast to the above evidence (both field and laboratory-based) in support of the relationship between tallness and obesity, studies have demonstrated that obesity is associated to stunting in developing and transitional economies. For instance, a study indicated a relationship between stunting and increased abdominal fat in Guatemalan children[309]. Another study during the nutrition transition in Chile has demonstrated a relationship between stunting and obesity among 6 year-old children, which was at a lesser degree when compared to obesity and tallness relationship[310]. However, in the same country, tallness was associated to obesity in preschool children and this indicated that the nutrition transition was at a post-transitional phase where stunting could no longer be considered a risk factor of obesity[311].

There are different explanations for this height-adiposity relationship. From a dietary point of view, early high protein intake has been hypothesized to account for the fact that children of today tend to be taller and heavier. For instance, a French study on 10-year old children showed that mean energy intake dropped between 1978 and 1995 as a result of a decrease in fat and carbohydrate intake. However, over the same period percentage energy from protein increased, children had a higher stature, accumulated more abdominal fat and there was an 8.1% increase in obesity among children[312]. Similarly, a study among English pre-school children of age 1.5 to 2.5 years showed a 219kcal drop in mean daily energy intake between 1967 and 1993. Over the same period, percentage energy from fat and carbohydrates fell, while percentage energy from protein increased[313]. There is no data available to assess if similar nutritional changes could explain our observations in our sample of school age children from the North West Region of Cameroon. Another study has demonstrated that a high protein intake during the early years of life (< 24 months) is associated with increased obesity (assessed by BMI and %BF) at the age of 7 years[314]. The source of protein and timing also matters as a study has shown that dairy protein in particular at 12 months of age is associated with increased adiposity at age 7 years[315]. Furthermore, a study indicated that a positive relation between height and body fat could be a result of excess energy stored (in the form of fat) which was more than the required amount needed for linear growth[178].

Some other biological factors in infancy and childhood have been shown to promote linear growth. For example, Ong *et al*. have demonstrated that children who displayed catch-up growth in the first two years of life had greater adiposity and were taller for their age compared with those infants who grew at a slower rate and did not display catch-up growth[153]. Also, a recent study has shown that rapid weight gain early in life was associated with higher stature, which itself predicted overweight status at age 3 years[316].

In a review by Scacchi *et al*, it is indicated that insulin-like growth factor 1 (IGF-1) and growth hormone (GH) reflect nutritional status and that obese children have a higher level of IGF-1 and a decreased level of GH[317]. High protein intake has been suggested to account for this increase in the secretion of IGF-1[315], and the high level of IGF-1 has the ability to promote adipose tissue hyperplasia and growth[318]. In addition, decrease in GH levels caused by excess protein intake could lead to a reduction in its lipolytic effect[317] hence leading to an increased accumulation of body fat.

It is worth noting that children with excess body fat were also present to a lesser level in the bottom quartiles of height SDS in this study. For instance, within the first and second quartiles of height SDS, 5 to 19%, 0.7 to 11.3% and 2.1 to 7.8% of the children were overweight/obese (BMI), abdominally overweight/obese (WC) and overfat/obese respectively (%BF). This will have policy implications because the drivers of their excess body fat may not be the same as those exhibiting a higher height SDS or a greater linear growth. These short children cannot be described as exhibiting greater linear growth and studies are needed in the future to differentiate possible drivers of excess body fat in both taller-for-age and shorter-for-age children. Whether this height – obesity relationship holds true for children of different ethnic backgrounds within the same country, also remains an avenue for exploitation in future studies. Even though there is currently no data on height differences among ethnic groups in Cameroon, it can be observed physically that people from the Northern Region of Cameroon tend to be very tall and slim, and this is could reflected in the low prevalence of obesity (0.5%) among preschool children in this part of the country[319]. The Eastern Region on the other hand, has more stunted people. This is an indication that a nationally representative data will be needed to substantiate our current findings.

The limitations of this section of the study are worth mentioning. This study was carried out exclusively with school-age children in one (North West Region) out of the ten administrative regions of Cameroon. Therefore, the prevalence estimates may not be representative for the whole country. Also, the reference data for percentage body fat and waist circumference refer to UK children and it is unclear whether they can be applied to Cameroonian children. Body fat percentage was predicted using an equation that was validated in a predominantly European population. It is also unclear if this can be applied to our study population as studies have shown ethnic differences in adiposity[320] and that ethnic and gender specific equations are needed to estimate fat mass and fat free mass in children[321]. In addition, care should be taken in the interpretation of waist circumference findings because studies have shown that an enlarged spleen (which can be asymptomatic) is common in malaria endemic areas[322]. This study did not carry out any malaria diagnosis; therefore, there is the possibility that some WC readings may have been falsified in children who may have an enlarged spleen as a result of malaria. Furthermore, the assessment of pubertal development was not carried out. This could have potentially confounded the association between height and obesity especially at the upper end of age distribution (10 – 12 years) in girls. Also, the influence of genetics on height cannot be completely ignored.

The cross sectional nature of our study could not enable us determine the time at which obesity developed during growth in childhood. However, a study among prepubescent children had examined this and indicated that obesity development after the age of 3 years was not associated with increased stature. In the same study, children with early onset of obesity (before the age of 3 years) had a significantly higher height SDS when compared to those with late onset of obesity (after 3 years of age). The authors concluded that rapid growth earlier in life may predict later development of obesity[323].

In conclusion, children who are taller for their ages tend to have higher adiposity levels; a relationship which is positive and linear not only by using BMI but also WC and %BF for both boys and girls. However, a more precise method for determining body fatness like bioelectric impedance analysis (BIA) and a more objective monitoring of height through longitudinal studies may be needed to substantiate these findings.

4.2. Height-SES-obesity interactions.

This second stage of the study set out to examine the effect of socioeconomic background on the relationship between height SDS and three measures of obesity.

This study has shown that children with excess body fat were significantly taller than their normal weight peers regardless of their socioeconomic background. The study also show that excess body fat was more pronounced among the urban subjects especially girls. In addition, children from a high socioeconomic background were significantly taller than those from a low socioeconomic background. In addition, it has demonstrated that the frequency of excess body fat and a higher height are associated with high SES group. Furthermore, the study confirmed from the multivariate analyses that high SES, tallness, and high birth weight were strong independent predictors of obesity. This was consistent for the three parameters of obesity.

A recent study among adults in urban Cameroon showed a positive association between obesity and SES[38]. This has been attributed to the current nutrition transition experienced in Sub-Saharan countries. As the economies and peoples' earnings are getting better, they tend to adopt Western lifestyles decreasing their physical activity levels[20,122]. A shift in dietary pattern from fruits, vegetables and grains to an increased intake of animal fats, sugar and salt as a result of better income has also been attributed to the rise in obesity levels in developing countries[324]. These lifestyle changes are reflected in Cameroon children and could explain why some of them accumulate more body fat.

A study in urban Cameroon among adolescents has indicated that the prevalence of overweight was high among adolescents from all socioeconomic groups; the low (8%), middle (11%) and high (9%), with girls more likely to be overweight than boys[325]. Our study has also found a higher frequency of excess adiposity among urban girls. In addition to the latter, our study has demonstrated the existence of a much more pronounced SES gradient in the distribution of the prevalence of excess body fatness in children. More children from the high socioeconomic background are affected than their peers from the low socioeconomic group. Even though there is no documented evidence, in the past, children used to walk to school, an activity that burnt lots of calories in children. However, motorized transportation to schools nowadays, a common phenomenon in urban settings, which is easily affordable by parents of a higher socioeconomic status, could contribute to some extent in lowering physical activity levels in children. Also children now spend more hours in sedentary activities like television watching, which has been associated to overweight and obesity in developed countries[326]. However, in relation to income group, studies in the developed world have shown that overweight and obesity affects mostly people from disadvantaged groups[116,141,327].

Children from the high SES group were significantly taller than those from the low SES group. A recent study came out with similar observations and described this situation to be "largely associated to a relative height-growth restriction"[141]. However, in our study, age and sex-adjusted weight was significantly different in the socioeconomic groups, meaning that overall weight could also have contributed to the high prevalence of excess body fatness among children from the high SES group. This height-obesity-SES interaction was examined in a study in a US study which found that overweight and obesity (assessed using BMI) was more pronounced among taller subjects. However, there was an inverse relationship between family SES and obesity[328], which could be the result of cheap low nutrient foods with high energy density easily bought by families with a low socioeconomic background[116]. An earlier study on preschool children in the Central Region of Cameroon indicated that belonging to a low socioeconomic background was an independent risk factor for a child to be stunted-overweight[329]. The consequence of this is that policies may need to target children at different age ranges as the latter confirms an association between low SES and obesity in stunted preschool children, while our study confirms the association between obesity and tallness in high income school-age children. Future studies need to focus on genetics and nutrition status of children to explain these discrepancies.

The high prevalence of obesity among subjects from a high SES could also be explained by the fact that food preparation patterns have changed over time with homemade foods gradually being replaced by more convenient and high calorie ready to eat foods[324] especially in urban areas. Also, historically, children used to take home made lunch to school. Nowadays, high income earners prefer to give pocket allowances to children who will spend it on high sugar containing snacks sold near school premises. In addition, children are a target to the advertisement of fizzy drinks and confectioneries[324], which are easily afforded by the rich parents in developing economies. No dietary information was obtained from the children in this study to substantiate the above points. In fact, a study indicated the potential of poor nutrition and decreased physical activity to regulate body fat and linear growth in children[141].

Our study has shown a significant relation between height SDS and obesity. Similar findings have been indicated in other studies[178,179]. As explained earlier, possible reasons for this relationship include a hormonal imbalance between insulin-like growth factor 1 and growth hormone[317] and early high protein intake[314]. The source of protein is still a subject of debate.

This study did not find any association between parental level of education and the different parameters of obesity in the children. Similarly, a study in urban Cameroon did not find any significant association between obesity and level of education in adults[38]. The authors indicated that this reflects the Cameroon society of today where a better education is not necessarily associated to a higher salary. Those involved in financially rewarding economic activities are often the less educated[38].

4.3. High birth weight and obesity relationship.

This study also examined the relationship between high birth weight and body fatness in children. Early life has been shown to be important in the development of obesity. In this study, high birth weight was also associated to obesity in both univariate and multivariate analyses. In other words, high birth weight was an independent predictor of excess body fat. However, possible confounders of this relation such as birth order, maternal age, and area of residence at birth were not recorded[330]. A review indicated that high birth weight is associated to higher obesity levels in adulthood[331]. Compared to the univariate analysis, the odd ratios changed in the multivariate analysis when BMI and WC were used as parameters of obesity. The odds ratio did not change when body fat percentage was used. In contrast to our findings a German study showed that low birth weight was also associated to obesity in boys[332]. In addition a study showed that low birth weight was a risk factor only in children who had exhibited a catch-up growth[153]. Further a study had examined this birth weight-obesity relation and found that children who had a low birth weight had a higher chance of remaining shorter and lighter throughout childhood, while those with a high birth weight had a greater chance of remaining taller, heavier and have a greater risk of obesity. In the same study the authors reported that for each half a kilogram increase in birth weight, mean height SDS increased by approximately 0.25[333]. The intrauterine environment could explain to some extent the association between high birth weight and obesity[334]. Intrauterine constraint of fetal growth can lead to a faster postnatal growth and weight gain. The above indicates that the association between birth weight and obesity is complex and both low and high birth weight children should be closely monitored in infancy.

This study had limitations worth mentioning. Birth weight was not available for all participants and recall bias could have been possible as birth weight was self reported by parents. Also, the tanner stages of children were not estimated and early puberty could have affected the height-adiposity relationship especially among girls who had higher WC and %BF readings. This study used parental occupation and income to determine the SES of participants. However, a study in urban Cameroon has shown the World Bank household amenities score as a better indicator for SES in developing economies[38]. Information on SES was not available for all subjects in this study. It is possible that some of the parents considered this as confidential information or were unwilling to confide as to what may happen with this information[38]. This study used the Cameroon public service classification system which does not adequately reflect the SES of those in the private sector as well as housewives at any one moment.

Concluding this study in Sub-Saharan African children shows an association between a high frequency of adiposity and tall stature with high socioeconomic status. The effect of socioeconomic background on height-obesity relationship in school age children needs further exploitation using a more accurate indicator of SES like household amenities in other regions of Cameroon and Africa.

4.4. The relationship between physical activity/sedentary time and obesity.

Physical activity did not show any significant association with obesity in the univariate analysis. This can be explained by the fact that there was missing data on physical activity levels of the children. Even though the physical activity questionnaire was pre-tested, it was realized during the study while talking to parents that they had some reasons for not completing the questionnaire. Firstly, the questionnaire appeared difficult to understand especially in the rural settings. Secondly, some parents said it was pure guess work to estimate their children's physical activity level for a week. Thirdly, some did not have enough time to answer the questions as school authorities gave only one day for the questionnaires to be returned. This was a modified version of the children physical activity questionnaire (CPAQ) of UK children. A further modification of this questionnaire for better understanding could have led to the tool losing its validity.

Currently, there is no data indicating physical activity levels in Cameroonian children. There is need for future studies to examine this aspect in children using tools that have been validated in an African or Cameroonian setting.

Though the findings on physical activity and sedentary time were not significant, similar patterns with current literature were observed. For instance, the frequency of excess body fat was lower among children who were more active (> 60 minutes/day, > 4 – 7 times/week) and those with a low sedentary activity (≤ 1 hour/day). Also, a higher frequency of obesity was observed among those who were less active (< 60 minutes/day) and involved in high sedentary activity (> 3 – 6 hours/day). This was consistent for BMI and percentage body fat. A study had observed similar findings that were significant among primary school children[335]. It is known that energy expenditure in children is increased when they are involved in physical activity and this lowers the risk of overweight and obesity[3,336]. A study in Cameroon among adults had indicated that the daily energy expenditure in rural subjects was more than that of urban subjects[112]. This could explain the lower prevalence of excess body fat observed among rural subjects in the study.

People in the rural settings of Cameroon are involved in more long distance walking and high intensity activities[112] like farming and this extends to children. In fact a study had shown a significant association between parents owns physical activity level and that of their children[337].
In addition to the moderate reduction in obesity rates, physical activity has also been shown by recent systematic reviews to have additional health benefits including; a lower rate of mental health problems, reduced blood pressure levels, lower cholesterol levels as well as a reduction in the incidence of metabolic syndrome[338,339].
Sedentary activity in this study included; watching TV/videos, travel by car/bus to school, use of internet/computer games, sitting talking and playing board games. Because of insufficient data, these aspects could not be examined independently. However, as mentioned earlier, excess body fatness was more pronounced among those with a higher sedentary time. Studies have shown the association between independent sedentary activities and the risk of overweight[269,334,335,340]. Studies have also associated sedentary lifestyle to urbanization and high income background[341], and this could explain why more children especially girls with excess body fat were found in the urban settings of our study. The WHO recommends that behavioral interventions targeting sedentary activities like time spent watching TV, could contribute in reducing obesity rates among children[341].

The school environment has been proven in other countries to provide an impetus in efforts to fight excess body fat accumulation among children. However, this may not be the same in some urban settings in Cameroon. This is because the rapid urbanization and population growth has lead to an increase in enrollment in schools. Some schools are under pressure because new infrastructure is needed, which come at the expense of the limited school play grounds available. A study has shown how utilization and physical activity increased when renovations were carried out on schoolyards[341]. Therefore, policies need to be put in place in Cameroon and evaluated as regards the standards for running schools, which will include opportunities for physical activity in children during and after school and also the nutrient content of the food that children eat while at school. Some schools have large TV sets and promote sedentary behavior by allowing children to sit and watch TV during play time. Thus portraying the image of a ‘very good school’ with nice facilities. This means that in the future, culturally oriented behavioral intervention studies will need to be carried out[342], as fatness is still being regarded as a sign of good health and well being in Cameroon communities.

4.5. Association between head circumference and body weight.

Head circumference measurement gives an indication of growth and development. A head that grows too fast (macrocephaly) or too slow (microcephaly) is an indication of abnormality. In our study, more girls had larger heads than boys. The study also confirms a positive relationship between head circumference and body weight for both boys and girls. However, no association was observed between head circumference and height. Evidence from the Dutch nationwide survey indicated head circumference to be associated with height and weight in children. However, the association was stronger with weight SDS and the authors suggested that the genes involved in head growth and weight may outnumber those involved in head growth and height[343]. Another study in Nigeria also observed that weight and height were significantly correlated with head circumference, with girls having a larger mean head circumference than boys, and boys having a larger head length than girls at all ages[344]. In using anthropometric measurements to assess children in a clinical setting, some studies have suggested the use of height in combination with head circumference to diagnose irregular patterns in growth[343]. In line with this, a study indicated that a child having a small head circumference and also born short and small for gestational age has an increased risk of a defect in insulin-like growth factor 1 (*IGF 1*)[345]. This defect, which can lead to lower levels of *IGF 1*, has been shown to be reflective of malnutrition characteristics including lower linear growth and lower muscle mass[346]. In addition, lower levels of IGF 1 may affect lipolysis[347], resulting in shorter children also accumulating body fat. Policies need to be established that enable children with these characteristics to be monitored early in life as head circumference is one of the indicators of undernutrition associated with limited intellectual ability[348].

This study also confirms that mean head circumference was significantly higher among children of high SES than those of low SES. A previous study among children from 9 months to 9 years had indicated that a high socioeconomic background is associated with greater head circumference[349]. Another study that used maternal level of education as an indicator of SES showed that children of mothers with a low educational level had smaller head circumferences when compared to those whose mothers were of a higher educational level. The variables that explained this were the child's length and weight, birth weight and gestational age[350]. The authors also suggested that these socioeconomic differences could have occurred prenatally.

Other studies have shown head circumference to be associated to other health aspects. For instance, a study had shown an association between head circumference at birth and higher rates of coronary heart disease[351]. Also a recent study has shown an association between a small head circumference at birth and an early age at adiposity rebound[352] and early adiposity rebound has been associated with increased risk of obesity later in life[173].

The limitation of this part of the study is the head circumference measurements were adjusted for sex and age using the Swiss 1989 growth reference data. It remains unclear if this reference can be applied to Cameroonian children.

4.6. Methodological considerations.

The current data is not representative of the Cameroon childhood population and the cross-sectional nature of the study does not permit any elements of causality to be established. A study had proposed certain criteria that can be used to examine causality, which are often used in epidemiologic studies[353]. Whether these criteria are sufficient remains a subject of debate. The nature of this study only permits associations to be examined. A nationally representative data from all the 10 regions of Cameroon is needed because the different regions have different cultures that could help in behavioral interventions.

This study has also used different parameters to assess excess body fatness in children with reference data from different countries and it is not clear if such data can be applied to Cameroon. However, the use of the WHO 2007 BMI reference data to assess overweight and obesity allows for international comparison of the prevalence of overweight and obesity in children.

The development of overweight and obesity involves a complex interaction of variables. Taking SES as an example, this study has shown that high SES and tallness are associated to overweight and obesity in the North West Region of Cameroon. Another study had shown that low SES is associated to stunting and overweight in preschool children in the Central Region of Cameroon[329]. In addition, people in the Northern Region of the country appear to be very tall and slim. This could explain the low prevalence of overweight and obesity among children in the Northern Region[319] as compared to our study. This is an indication of a complex situation and the impact of SES or stature alone can be difficult to establish because these variables could be linked to other behavioral/lifestyle, environmental or biological factors that are associated to overweight/obesity.

Physical activity did not show any significant influence on overweight and obesity. This could have been the result of missing data on physical activity and recent reviews have confirmed that limited data and methodological aspects contribute to unclear or inconsistent relationships[354,355]. Our study did not include dietary information of the children, and it would have been interesting to relate dietary behavior to excess body fat and also determine the effect of SES, nutrients and foods on this relationship. This is because the different tribes in the different regions of Cameroon have their traditional diets, which are consumed habitually. The sample size of the study may not have been adequate especially the overall number of obese subjects and no evaluation was carried out between those who participated in the study and those who did not to see if both groups present similar or different characteristics. This could have led to a possible selection bias[356]. The study included only primary school children leaving out the younger ones (those below 5 years). Thus prevalence estimates may not be an accurate reflection of the situation in Cameroon. It was also not possible to control for the confounding effect of physical development (puberty) as the age range of children included in the study was 5 to 12 years. In addition, the possibility of recall bias cannot be ruled out when birth weight and physical activity levels of the children were reported by parents/guardians. However, this was limited by asking children to hand in the questionnaire only to their parents and guardians (who are presumed to be most familiar with the children) to complete the questionnaire.

Even though this study has limitations as already mentioned, it also had particular strengths. It provides data for the first time in Cameroon on how height, SES and birth weight contribute to

excess body fat in school-age children (a group that had been neglected in health surveys in the country). It has also provided evidence on the relationship between head circumference and body weight. In addition, it has demonstrated that in the North West Region, more children are now affected with overnutrition compared to undernutrition. Even though WC has limitations as mentioned earlier, its use in this study indicated body fat distribution which BMI is unable to do. In addition to BMI, equivalent findings were obtained for WC and %BF, which are parameters that have gained little attention not only in Cameroon but also in Sub-Saharan African countries.
Another positive aspect of this study was the high response rate of 93.7, 81.5 and 89.05% for SES, birth weight and parental level of education respectively in an environment where people could get suspicious of what the information may be used for. The data was collected carefully by well trained nurses and this study sets the basis for future longitudinal studies.

4.7. Conclusions and implications.

Three determinants of excess body fat in school age children were identified in this study. The relationship between these determinants was consistent when all three parameters of obesity were used. The study also demonstrated a positive relationship between head circumference and body weight in both boys and girls.

The main findings of this study are summarized below:

- Children with a higher height SDS tend to have higher levels of body fat.
- Tallness, high SES and high birth weight were associated with higher frequencies of excess body fat.
- A high SES, tallness and high birth weight were independent predictors of excess body fat in children.
- Obesity was more pronounced among urban subjects especially girls than rural subjects.
- Parental level of education, physical activity and sedentary time did not show any association with the parameters of obesity in the children.
- Mean head circumference was significantly higher in those of high SES than low SES. Also, head circumference was positively associated with body weight in both girls and boys.

These findings allow some implications for future studies, prevention and also risk assessment in school children.

This study confirms that excess body fat is associated to a high SES. In epidemiological studies, the most frequently used indicators of SES are educational level, occupation and income and these variables could be related to each other. Since this study included school children (who are unable to earn a living on their own), their SES could only be determined by the socioeconomic background of their parents. In our case this was the Cameroon civil service classification system of occupation and income. There is no best means of estimating SES and each of these indicators are thought to represent different concepts of SES[357]. Education level does not seem to be a good indicator of SES in Cameroon as being educated is not necessarily associated with a better income as indicated in a previous study[38]. The use of both occupation and income in this study indicates the impact of their contribution to health inequality as concerns overweight and obesity. The implications of the above is therefore that any intervention to prevent body fat accumulation in children needs to start early and extend throughout life as this study has also confirmed an association between high birth weight and obesity. In addition, obesity prevention needs to start at the family level beginning with individuals in high income families (especially in urban settings) to the wider society.

Most interventions on overweight and obesity have been carried out in developed countries. There is currently no evidence of any intervention aimed at preventing overweight and obesity in Cameroon children. There is the need to start thinking of this especially in regions presenting with high rates of overweight and obesity. Since obesity involves a complex interaction of many factors it should be kept in mind that behavioral (individual level) and cultural (population level) aspects are of major importance in understanding obesity in a setting where obesity is perceived as a sign of good health while underweight or thinness is problematic. Focusing on biological aspects alone, is unlikely to help reverse the increasing rates of overweight and obesity.

Standing height was also significantly associated to excess body fat in children. This does not mean that all tall children from a high socioeconomic background are at risk of overweight and obesity. Actually a previous study in another region in Cameroon has shown low SES to be associated to overweight and stunting in preschool children[329]. This indicates that a solution in one region may not necessarily be applied in another region. Therefore, there is need for future studies to assess the content of the different diets in the different regions and relate these to obesity. There is the possibility that diets from the different regions may vary greatly in fat, sugar, salt and saturated fat content.

Even though physical activity did not show any significant association with obesity in our sample of children, other studies have indicated the health benefits of physical activity[338,339].

The school environment can significantly influence the development of obesity if adjustments are made to provide nutrition education, opportunities for physical activity and enough time for physical education. The implication of this is that the school environment is important and can be manipulated to encourage a healthy lifestyle among children. However, activities in a school setting may only constitute a small part in the efforts to halt the increasing obesity rates. Therefore, there is need for other settings to be targeted.

Cameroon has different ethnic groups with different cultures. Therefore, etiological and prevention research need to start in the country and should include environmental, biological and behavioral drivers in order to prevent obesity rates from reaching the levels of developed nations.

5. SUMMARY

Overweight and obesity had been declared a global epidemic by the World Health Organization and the numbers of children and adults affected is increasing at a faster rate in developing economies. Many studies have associated some adverse health outcomes with overweight and obesity including type 2 diabetes and cardiovascular diseases. Countries in Sub-Saharan Africa including Cameroon are at various stages of economic development and undergoing an epidemiological transition characterized by an increase in the burden of non communicable diseases. This study indicates how changes in socioeconomic status (SES) and tallness contribute to overweight and obesity in Cameroon children. Risky behavior associated to overweight and obesity in childhood has been shown to persist until adulthood. It is now important for Sub-Saharan African countries to start understanding the health consequences of the current nutrition transition by carrying out studies to identify early life potential risk factors that contribute to excess body fat.

Studies have been carried out on this subject in different parts of the world with different findings. This could be the result of the use of different parameters that define obesity in different ways as well as methodological issues.

Chapter 1 of this thesis exploits the literature on obesity by looking at the global prevalence estimates, the situation in Cameroon and significance of the study. Also, the criteria for defining overweight and obesity, a critical appraisal of tools and reference systems for assessing overweight and obesity in children as well as the potential determinants of overweight and obesity were discussed. In addition, the health consequences of excess adiposity and critical appraisal of prevention strategies were described.

Chapter 2 presents the study participants and the methods. The subjects were randomly selected from primary schools and this study provides data for Cameroon for the first time on this subject. Analyses were performed in a total sample of N = 557. The study looked at obesity in a comprehensive manner by using three different parameters including; body mass index (BMI), waist circumference (WC) and percentage body fat (%BF). This gave an idea of how SES,

height, birth weight and physical activity (determinants) contributed to body fat levels as well as body fat distribution.

The effects of the different determinants are presented in Chapter 3. The frequencies of excess body fat in relation to height SDS were determined. The study showed that the prevalence of excess body fat increased with increasing quartiles of height SDS. The relationship between height and obesity was performed using linear regression models containing height to predict/quantify the difference in body fat between boys and girls at different levels of height. Findings indicated that height was positively associated to the three parameters of obesity. Linear regression analysis also indicated a positive relationship between head circumference and body weight. This was followed by multivariate binary logistic regression analysis to determine the independent association between each of the determinants and the parameters of obesity. The model showed a statistically significant independent association between overweight/obesity (BMI), abdominal overweight/obesity (WC) and high body fat/obesity (%BF) and SES, height SDS and high birth weight. Physical activity, sedentary time and parental level of education did not show any association with the parameters of obesity. Additionally, because height SDS and birth weight showed significant interactions with SES in this study, the frequencies of overweight/obesity, abdominal overweight/obesity and high body fat/obesity according to quartiles of height SDS and categories of birth weight differentiated by the socioeconomic groups (low, medium and high) were calculated. The results indicate that the frequencies of overweight/obesity, abdominal overweight/obesity and high body fat/obesity were highest among the tallest children and those with a high birth weight from the high socioeconomic group. Further, children with excess body fat were significantly taller than their normal weight peers irrespective of the socioeconomic background.

This study has shown that taller children from a high socioeconomic background and those with a high birth weight are at particular risk of overweight and obesity. Therefore, these groups should be targeted for interventions early in life so as to prevent chronic complications in adulthood. The use of waist circumference in combination with body mass index could be useful in identifying those at risk.

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7. CURRICULUM VITAE

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8. LIST OF PUBLICATIONS OF THE THESIS

Research articles

Published:

i) Navti LK, Ferrari U, Tange E, Bechtold-Dalla Pozza Susanne, Parhofer KG. Contribution of socioeconomic status, stature and birth weight to obesity in Sub-Saharan Africa: cross sectional data from primary school-age children in Cameroon. *BMC Public Health* 2014; 14:320.

Under review:

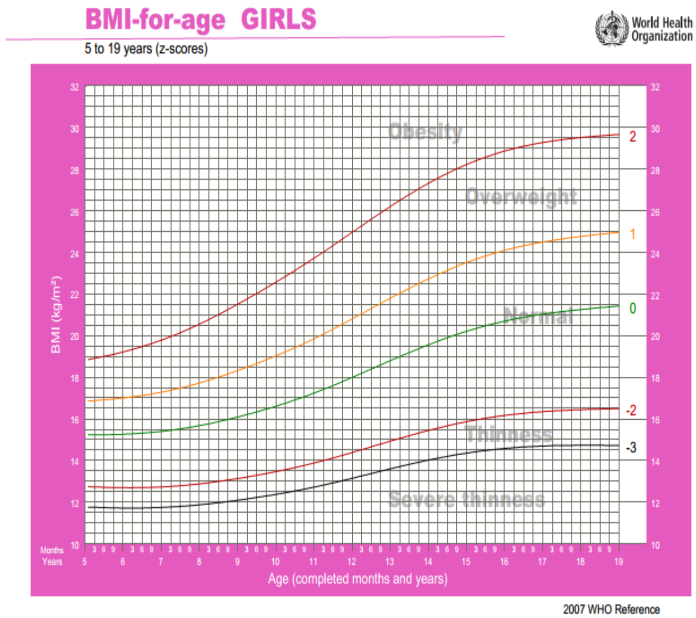
i) Navti LK, Ferrari U, Tange E, Parhofer KG, Bechtold-Dalla Pozza Susanne. Height-obesity relationship in school children in Sub-Saharan Africa: results of a cross sectional study in Cameroon. Submitted to *BMC Pediatrics*.

Abstract

Published:

i) Navti LK, Parhofer KG, Tange E, Ferrari U, Bechtold-Dalla Pozza Susanne. Prevalence of overweight/obesity in relation to height-for-age in Cameroonian children. Abstracts of the 20th International Congress of Nutrition, Granada, Spain. *Annals of Nutrition and Metabolism* 2013; 63(Suppl 1): p1170. ISSN 0250-6807, e-ISSN 1421-9697, e-ISBN 978-3-318-02516-3.

9. APPENDIX



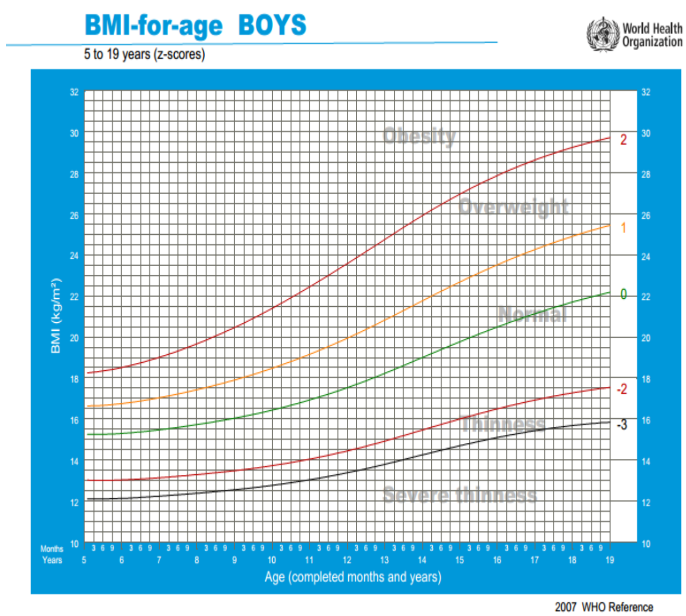


Figure A.1: WHO 2007 BMI reference curves for girls and boys.

Source: http://www.who.int/growthref/who2007_bmi_for_age/en/ [Assessed 16.03.2014].

10. ACKNOWLEDGEMENTS.

I wish to express sincere gratitude to the Center for International Health (CIH) of the Ludwig-Maximilians Universitaet (LMU), Munich, Germany for the receipt of a scholarship to pursue the PhD program in Medical Research – International Health. This scholarship was funded by the German Academic Exchange Service (DAAD) and the German Federal Ministry for Economic Cooperation and Development (BMZ).

My profound gratitude goes to the LMU supervisors: Dr. Uta Ferrari; Priv. Doz. Dr. Susanne Bechtold-Dalla Pozza; and Prof. Dr. med. Dr. h.c. Klaus G. Parhofer for their relentless efforts and substantial contributions to the conception, design, data collection, statistical analysis, interpretation of data and drafting/approval of manuscripts of this study. I appreciate the time and energy you all put into reading my manuscripts. These are attitudes worth emulating.

Also, my sincere appreciation goes to the CIH team: Dr. Guenter Froeschl, Bettina Prueller and Andrea Kinigadner for offering their expertise, time and energy to support me in various aspects of the PhD program.

Additionally, I am grateful to the nurses, the head teachers of the participating schools as well as the children and parents who accepted to participate in this study.

Finally, I reserve special gratitude to my wife, Loveline and my parents for their continuous encouragement and moral support, which came in different ways.