UNIVERSITY FOR DEVELOPMENT STUDIES

BODY FAT COMPOSITION AND ITS DETERMINANTS AMONG ADOLESCENT STUDENTS IN THE BEREKUM MUNICIPALITY

WISDOM PEPRAH

(UDS/MPHN/0017/18)

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THESIS SUBMITTED TO THE DEPARTMENT OF NUTRITIONAL SCIENCES, SCHOOL OF ALLIED HEALTH SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN PUBLIC HEALTH NUTRITION

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DECLARATION

I hereby declare that this work is the result of my own research and the thesis either in full or part has never been presented at any other institution for a degree. All references made from other researches have been duly cited.

.... 18/01/2025

SIGNATURE **DATE**

WISDOM PEPRAH (STUDENT)

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ASSOC. PROF. VICTOR MOGRE (SUPERVISOR)

ABSTRACT

Complementing Body Mass Index (BMI) with Bio impedance Analysis (BIA) provides a comprehensive description of the distribution of body fats, posing clinical and research benefits. Due to increasing levels of overweight and obesity among the adolescent population especially in growing urban settlements, an analytical cross-sectional study design was conducted in the Berekum municipality which is among the fastest growing urbanizations in the Bono region among 424 adolescent students to measure body fat composition and its determinants. The data was captured with a structured questionnaire and analyzed using Statistical Package for Social Science (SPSS) software.

Four hundred and nine questionnaires were completed and included in the data analysis (409) out of 424 questionnaires administered. More than half (54.3%) of the study participants were aged between 13 and 16 years (mean ± SD = 13.88 ± 2.18), females (53.3%) and went to government schools (51.3%). Generally, most adolescents had normal weight (66%), 13% were thin and about 21% were either overweight or obese. Twenty percent of the adolescents had low general body fat whiles 52% were normal and 28% had high/very high BF. Per their muscle fat, 71.4% measured very high, 6.4% were low and 22.2% were normal. Almost half (46.2%) of the respondents practiced 'health-enhancing physical activity' (HEPA) whiles 44.7% were moderately active, but 9.1% were physically inactive. The average dietary diversity score for respondents was found to be 6.40±1.79. Also, it was found that 65.8% had high dietary diversity, 31.3% with moderate dietary diversity and 2.9% reported low dietary diversity. Compared with females, male adolescents had 2.5 odds of having high body fat [OR=2.5; CI (1.3-5.1); p=0.007]. Schooling in urban locations had 4 odds of presenting high body fat than rural schoolers [OR=4.2; CI (2.1-8.5); p<0.001]. Students whose mothers were civil servants significantly had 11.3 odds and those whose mothers were traders had 5.3 of having high body fat compared to their counterparts whose mothers were into farming and other occupations [OR=11.3, p=0.017 & OR= 5.3, 0.011].

Yearly nutrition surveillance is recommended for the school age adolescent group to understand their nutritional situation to guide nutrition policies for the age group.

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LIST OF ABBREVIATIONS

AE	Aerobic Exercise
BAT	Brown Adipose Tissue
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
CHPs	Community-Based Health Planning Services
CVD	Cardiovascular Diseases
EDS	Energy Dense Snack
FANTA	Food And Nutrition Technical Assistant
FAO	Food And Agriculture Organization
FFM	Fat-Free Mass
FM	Fat Mass
FMI	Fat Mass Index
FMO	Fat Mass And Obesity
GBD	Global Burden Of Disease
GDHS	Ghana Demographic And Health Survey
GES	Ghana Education Service
GHS	Ghana Health Service
GPAQ	Global Physical Activity Questionnaire
GSS	Ghana Statistical Services
HEPA	Health-Enhancing Physical Activity
HICs,	High Income Countries
ICU	Intensive Care Unit
JHS	Junior High School
LBM	Lean Body Mass
LMICs	Lower Middle Income Countries
MET	Metabolic Equivalence
MICS	Multiple Indicator Cluster Survey
NCD	Non-Communicable Disease
PA	Physical Activity
PAD	Peripheral Arterial Diseases
RE	Resistance Exercise
REE	Resting Energy Expenditure
SAC	School Age Children
SHS	Senior High School
SPSS	Statistical Package For Social Sciences
SSA	Sub-Sahara Africa
SSB	Sugar-Sweetened Beverages
WAT	White Adipose Tissue
wc	Waist Circumference
WHO	World Health Organization
WtHR	Waist To Hip Ratio

CHAPTER ONE

INTRODUCTION

1.1 Background

The shifts in dietary intakes among the global population has been key causal factor for chronic non-communicable disease (NCD) risks (Ronto et al., 2018). Notably, these shifts in foods consumed are described as the nutrition transition and characterized by a dramatic change in the way the entire globe eats, drinks and moves, influencing our biology and creating major changes in body composition (Popkin et al., 2012). The nutrition transition has led to increase in sugar-sweetened beverages (SSB) consumption causing overweight and obesity same as saturated and trans-fatty acids (WHO, 2015). Albeit unhealthy diet independently could lead to NCD risks, physical inactivity has been found to plausibly exacerbate this life threatening health concern (Swinburn et al., 2011). NCDs are the major causes of mortality globally, contributing to 73.4% of total deaths in 2017 (GBD, 2018). Whiles adult prevalence of overweight and obesity in 2013 was 27.5%, there was also 47.1% prevalence among children and adolescents globally (Ng et al., 2014).

The situation of increased NCD risks and impact are not only limited to the high income countries (HICs), sub-Sahara Africa (SSA) is faced with similar emergency in the backdrop of undernutrition and infectious diseases; the phenomenon of double burden of malnutrition (Owino, 2019). Globally, 41 million of 55 million (71%) deaths in 2019 were NCD-associated, with 77% of these in low- and middle-income countries. And majority of deaths were caused by CVD (17.9 million people), followed by cancers (9.3 million), respiratory diseases (4.1 million) and diabetes (1.5 million) (Banatvala & Bovet, 2023).

The national prevalence of overweight and obesity in Ghana is estimated at 25.4% and is common to both urban and rural populations (Ofori-Asenso, Agyeman, Laar, & Boateng, 2016). Due to inadequate holistic reviews on overweight and obesity prevalence in Ghana, Ofori-Asenso et al., (2016), there is a gap of knowledge on temporal changes and the age group at risk. In spite of this, smaller studies have found equally high prevalence; before Mogre, Gaa, & Abukari's study in 2013 where they found a 17.4% prevalence of overweight/obesity in the Northern region among school-aged children, Biritwum, Gyapong, & Mensah, (2005) had found among 5000 Ghanaians aged 18 years and above the prevalence of 5.5% obesity which varied between males and females. In 2013 Amoah also found 13.6% age-standardized obesity prevalence in Accra. In Kumasi, overweight and obesity has been found to be 13% in Junior High School (JHS) and Senior High School (SHS) students (Kumah et al., 2015). There is subsequent evidence to show the likelihood of children and adolescence with excess weight growing to be obese adults and developing chronic conditions (Sigman-Grant et al., 2015). The 2014 Demographic and Health Survey concluded that obese population in Ghana were more likely to report hypertension (GDHS, 2014). These are indications that the shifts of diet towards unhealthy choices occur in Ghana likewise other countries.

The critical stages for implementing interventions toward fast tracking eating habits are childhood and adolescence mostly to mitigate the occurrence of diet-related chronic diseases in later life associated with poor eating habits in earlier life (Ochola & Masibo, 2014). School children are often confronted with low diet quality, coupling low calorie intakes with high preference to sugar sweetened drinks and saturated fats intake (Taillieet al., 2017). There is the likelihood of school children in Ghana inability to meeting dietary diversity which subsequently diminish their micronutrient intake (Abizari et al.,2017; Ali & Abizari, 2018). Low micronutrient intakes suggest the replacement with savoury snacks, candies and ultra-processed foods making children prone to the risk of metabolic disorders and diminished immunity (Mitsopoulou et al., 2020 & Willett et al., 2019).

Bioelectrical impedance analysis (BIA) is a whole body measurement technique that differentiate between lean body mass and body fat. BIA determines the resistance to the flow of current as it passes through the body, it provides estimates of low conductivity from bone and fat. Tissues with more water content in the human body tend to conduct electricity easily. Fat tissue almost conducts no electricity (Devi et al., 2018).

Complementing Body Mass Index (BMI) with BIA provides a comprehensive description of the distribution of body fats in terms of lean mass and adiposity, posing a lot of clinical and research benefits (Wells & Fewtrell, 2008). BIA reduces the risk of fluctuations between lower and upper body water by using electrodes for both hands and feet to take measurements (Bera, 2014). It also presents a noninvasive, safe, fast, low cost, portable, easy to conduct, hazards free, and safe technique by which fat-free mass, fat mass, total body water, intracellular water, extracellular water and consistency for repeated measures (Bera, 2014).

Given this background, it is evident that, the situation of adolescent adiposity is pervasive and immediate actions should be taking to highlight its levels among adolescents in the society, distribution of fat composition and to determine the contributing factors.

1.2 Problem statement

Diet related chronic diseases are common among people with excess body fat (Burhanset al., 2018), irrespective of their normal BMI ranges (Iyengar et al., 2019).

Without interventions to target the adolescent age group, efforts to reducing obesity seem to be working in vain as a result of the intergenerational cycle of obesity (Heslehurst et al., 2019).

Aside the Ghana Demographic and Health Survey's (GDHS') assertion of a rising concern of overweight and obesity (40 % in women and 16% in men), the situation of malnutrition has been described as presenting greater concern of overweight and obesity than other forms such as thinness (GSS, 2014).

The choices of food at school locations are likely to be limited to 'junk foods' selection (Iyassu et al., 2023). There is also an assumption of a disproportion between consumption of at-home and away-from-home foods by schooling adolescents in urban communities (Landais, et al., 2023). Physical inactivity, observed as a predominant contributing factor to overweight/ obesity is common among these group of students now than before (Pengpid, 2014). Peltzer & Pengpid (2011) have in the past observed alarming levels of physical inactivity among adolescents between thirteen and fifteen years in Ghana and Uganda.

It could be stated that the current obesogenic environment which promotes sedentariness Ekanayake et al. (2023), along with over consumption of energy-dense food subsequently implicates the rife in the situation of adolescent overweight/obesity (Muinga et al., 2024). The influence of unhealthy dietary intakes and physical inactivity for that matter could lead to elevated levels of adiposity among school children, but the distribution of these adipose tissues is not well established. Several studies have linked total fat levels, visceral and subcutaneous fats to different health outcomes.

There is also the problem of premature mortalities often times in our part of the world attributable to NCDs (Bigna & Noubiap, 2019). These deaths could be resulting from buildup of ectopic adipose and could suggest unaware predisposition of groups within the adolescent age brackets to cardiovascular risks which has been found among major causes of mortality (Gruzdeva et al., 2018).

In the evidence that obese adolescence become obese adults (Johnson, 2018), it is important to more fully elucidate the determinants of deposition of excess adipose tissue in adolescents and the associated factors in the Berekum municipality of Ghana. Berekum municipal is among the 12 Municipal and District assemblies in the Bono region and the region is the 7th highest region for adolescent men and 9th for adolescent women in Ghana on the overweight or obesity ranking in the recent Ghana Demographic and Health Survey report (GSS, 2024).

1.3 Main objective

To assess the body fat composition and its determinants among adolescent school children in the Berekum municipality of the Bono region of Ghana.

1.4 Specific objectives

- To assess the distribution of body fat among adolescent school children in the Berekum municipality.
- To assess the prevailing dietary diversity of schooling adolescents in the Berekum municipality.
- To assess the prevailing physical activity levels of adolescent school children in the Berekum municipality.
- To assess the determinants of body fat composition among schooling adolescents in the Berekum municipality.

1.5 Significance of the study

Results from the study could make the basis for health and fitness programs for adolescent school children. By measuring body composition, a person's health status can be more accurately assessed and the effects of both dietary and physical activity programs better directed. Findings from this study could help identify the importance of paying attention to the body fat of school children by correcting the misconception that obese children are being fed well. By extension it would contribute to truncating the risks associated with NCD's.

CHAPTER TWO

LITERATURE REVIEW

2.1 Body fat composition

Body composition is what the human body is made of. Knowledge of the body composition present a useful research, prognostic and clinical significance in both nutritional and physical health (Fosbøl & Zerahn, 2015; Madden & Smith, 2016). Body composition have direct relationship with health Christofolini (2020), implying that normal balance in the body's composition demonstrate good health and longevity (Holmes & Racette, 2021).

There is well documented emphasis of the gender-dependent composition of body fat (10-35%), body water of 60-70%, protein of 10-15% and 3-5% minerals being composite products of the body's estimated 98% oxygen, carbon, hydrogen, nitrogen and calcium (Gibney, Lanham-New, Cassidy, & Vorster, 2009). Excess and imbalance between subdivisions of the body's compartment describes altered body performance and function, and often increase the risk of cardiovascular, diabetes and other chronic diseases (Shah & Bilal, 2009).

In 1992 Wang, Pierson Jr, and Heymsfield (1992) established the five-level body composition model. This model divides the human body into different compartments at the atomic level, molecular level, cellular level, tissue-system level and whole body, given a structural framework for explaining relationships in body compartments.

The body's composition, which is a reflection of total body mass has in recent times been divided into two; as fat mass (FM) and fat-free mass (FFM) (Mann & Truswell (2017)), largely known as the two compartment or classical model. This model is the most used in both clinical and research settings to assess a single cross-sectional determinacy of malnutrition and the efficacy of interventions such as behavioural, pharmacological and surgical, aimed at promoting healthful weight for a healthy life. It is extremely applicable in the population because it is economically practicable to use and of less cost and time in measurement (Andreoli, Garaci, Cafarelli, & Guglielmi, 2016). Also, the recent importance of the two compartment model was suggested by the American Department of Health and Human Services as being simple, safe and accurate across age groups; thus a model with such characteristics is relevant enough to use for research purposes (Lemos & Gallagher, 2017).

2.1.1 Fat free mass (FFM)/lean body mass (LBM)

FFM also known as lean body mass (LBM) whiles being one of the two major components of the body and consisting of total body protein, water and bone mass, it also fundamentally takes into account internal organs such as heart; liver; the central nervous system; skeletal and muscular systems; body fluids and connective tissues. FFM by their function and anatomy differ from FM. With respect to the body's energy metabolism, FFM is the one predominantly responsible (Sokolov et al, 2012). These organ systems, although morphologically distinct, contain matching functional structures such as matrix substance and extra-cellular fluids that support the metabolic exchange and assist in substrate transport with the capacity to execute the synthesis and metabolic processes in the body (Cruz et al, 2019). Earlier reviews on FFM measured in the clinical setting points to the immense significance of its adequacy in the healing process of the sick, whiles diminished levels that yield thinness could lead to overall health impairment, functional incapacity and poor life quality (Capuano et al, 2010). FFM loss has been previously concluded by Amaral et al. (2007) as a predominant cause of decreased survival, increased rate of infections, complications, and increased lengths of hospital stay and recovery**.** Measurement of the FFM has been recommended by Thibault, Genton, and Pichard (2012) that, it could be implemented on a regular basis in clinical practice, with the aim of optimizing the early detection, the management and the follow-up of undernutrition. In the United States, a study on 33 patients in the intensive care unit (ICU) by Robert et al. (1993) found correlated results between some FFM component (cell mass) and macronutrient intakes (protein and energy intakes) in a daily assessment using BIA. It was further established that an average energy intake of 30kcal/kg/day and 1.5g/kg/day of protein intake was able to stabilize the FFM and hence practically able to optimize nutritional status in the ICU patients, probably due to its quantitative assessment of body mass variations and accurate FFM identification.

2.1.2 Body fat mass (FM)

In the human body, fat mass often referred to as adipose tissue is a category of connective tissues composed of adipocytes as their cellular bases Boutens and Stienstra (2016), and non-adipocyte cells, including endothelial cells, preadipocytes, fibroblasts, and various types of immune cells including mast cells, eosinophils, B cells, T cells and macrophages (Zeyda et al., 2010). The functional interplay of roles performed by constituents of adipose tissue is very significant in cell function and life activity. Basically adipose tissue here in referred as storage fat, store mostly triglycerides in the body to use as fuel during times of starvation, protection of vital organs, and insulation (Zeyda et al., 2010).

The fat mass is primarily divided into three main types; white adipose tissue (WAT), brown adipose tissue (BAT) and beige adipose tissue (Cinti, 2000). During the developmental stages of life, BAT emerge as a product of the Myf5- and Pax7- precursor cells in the middle layer of the embryo (mesoderm), and later develop into the body's thermogenic capacity and hub or the mitochondrial bioenergetics (lipolysis) that in all ensure homeostasis (Nedergaard, Bengtsson, & Cannon, 2011; Zwick, Guerrero-Juarez, Horsley, & Plikus, 2018). The significance to human of BAT is throughout life and predominantly underlined during infancy where accumulated deposits during pregnancy has a preliminary thermogenic functions through its simultaneous physiology with uncoupling protein; the mitochondrial protein uniquely expressed in this cell type and therefore considered as the molecular marker of BAT. On like WAT, brown fat is responsible for thermogenic-related weight reduction, making it protective against obesity/diabetes (Kiefer, 2017). Through developing mechanisms, studies are emerging on how arginine-rich foods such as soy, seeds, nuts and beans and antioxidants from fruits and vegetables can trigger brown fats development and how it reduces whole body fat (El Hadi, Di Vincenzo, Vettor, & Rossato, 2019).

Also, among the pathways to weight reduction in heavy people is through energy dissipation. In view of this, Chondronikola et al. (2014) have found and concluded in an experimental study of 12 BAT (7) and non-BAT (5) induced healthy adults, the antidiabetic tissue increase resting energy expenditure (REE) by 15% and significantly increased both whole-body glucose and insulin-stimulated glucose disposal in BAT and not non-BAT participants. Energy metabolism is to some extent regulated by this brown fat levels, and also body mass is affected, reemphasizing the physiological significance of BAT. Surprisingly also, higher BAT levels are correlates of fat reduction Yoneshiro et al. (2013), and its activation also slow down high cholesterol accumulation and development of atherosclerosis, this means without energy expenditure and pharmaceutical weight reduction techniques, BAT activation independently could mitigate against heart disease caused by overweight/obesity (Laurila et al, 2016). Conclusively, there is an inverse relation between BAT activity and body weight or BMI, based on that, stress on dietary in addition to energy dissipation to manage weight needs to be continued for both present and future health gains.

The WAT is the one generally referred to as the bad fat due to its implication in metabolic syndrome; thus the multiple biochemical and physiological anomalies that have been found to complicate the risks of cardiovascular diseases (CVD), strokes, high density lipoprotein cholesterol, high blood pressure and diabetes mellitus (Engin, 2017). It is also popularly known that cardiac adiposity alone has caused many heart failures, significantly through the induction of abnormal myocardial functioning (Ebong et al, 2014). Also, there are devastating chronic effects of high body fatness on the bone health on all forms of obese individuals and leading to reduction of bone mass, its mineral content and strength (Mosca et al, 2014). Again, a 2017 systematic review of evidence on the effects of body fatness on child and adolescent periodontal health found a positive link between adiposity and gum disease in children (Martens, De Smet, Yusof, & Rajasekharan, 2017).

White adiposity therefore present itself in the body in different forms which have different or sometimes collective effects on the health of individuals at different age groups. Body fatness could either be classified as general or based on the body's compartment were it is found, in that instance there is total body fat, central fat, visceral fat and muscle fat (Denton & Karpe, 2016). Each of these regional fat depot have their consequences on health and wellbeing by either collectively or independently inducing the risks of diet related chronic diseases.

2.1.3 Total fat mass/total body fat (TBF)

Also known as total/whole adiposity is a body composition component for both normal and overweight people as it serves as proxy to good health. Since it is a stored fat, it is found in the adipose tissue and serve several purposes in the body. Some of these include energy generation, cushioning and insulation of the body's vital organs (Gariballa et al, 2019).

By the fact that age, sex and activity level show difference in TBF and percentage fat, Jeddi et al. (2014) further realized the association between TBF and anthropometry (weight, height and BMI) and ethnicity, though there was a gap in their study design since it was only cross-sectional and did not establish causality. That notwithstanding, some of these correlates have also been proven and presented different aspects of association with the use of diet as an independent variable on body fatness levels.

It was found in a systematic review of 26 studies which sought to find the association of body fat with extremely processed foods. More than half (54%) of the studies in the systematic review, found a positive association between ultra-processed foods (43%) and soft drinks/sugar sweetened beverages (57%), these interestingly occurred in studies that used more sophisticated methods such as the dual-energy X-ray absorptiometry (DXA) for the determination of adiposity (Costa, Del-Ponte, Assunção, & Santos, 2018). Whiles confirming the significance in the methods of body composition measurement, Howe, Black, Wong, Parnell, and Skidmore (2013), also in the study to determine the influence of adolescent dietary pattern on body composition alluded a 4% decrease in fat mass index (FMI) with the consumption of foods with higher factor loadings of breakfast cereals, milks and white bread. Subsequently, their fruit and vegetables food pattern also greatly affected total adiposity but not BMI or central adiposity using waist circumference and waist-to-hip ratio measures. It was also conclusive that sugars and sweets pattern did not associate with total fats but was associated with both BMI and central adiposity, where a difference was drawn between adolescent who were dieting and their counterparts who were not dieting. The cascading effects of dietary habits during childhood and adolescent prospective adiposity has been studied in the United Kingdom by Ambrosini et al. (2012), mostly through high intakes of energy, fat and low fibre intakes.

In the lives of humans, WAT is more prevalent than the BAT, though the difference in the ratio of WAT to BAT varies with respect to genetic background, sex, age, nutritional status, and environmental conditions of the people (Frontini & Cinti, 2010).

After controlling for age and sex, Drenowatz (2014) established a low but significant correlation between body fat and diet quality. Their study proved a significant correlation coefficient of -0.177 (<0.001). With a clear gender difference, males with high body fat were likely to consume less diversified diet (-0.204) as compared to females (-0.154) though they were both significant p (0.004, 0.027) respectively. They further admitted their low correlation may have been caused by the use of healthy eating index instead of the use of the WHO dietary diversity score to determine diet quality. There appear to be similar findings by Gertraud (2020). In their study also adult women had higher dietary diversity scores compared to men and their scores however were inversely associated with adiposity in both sexes, in this case too women had lower risks for accumulating viscera fat compared to men.

These findings are worth noting because of their importance in the management of excess body weight, implying that body fat distribution is a critical feature to consider when advising individuals with overweight about the health effects of their regular diets, as the metabolic consequences of visceral adiposity may lead to chronic conditions in the future.

2.1.4 Muscle fat mass

Muscle fat mass is seen as the solid or semisolid mass located beneath the skin and delicate organs like the kidneys. Shocks absorbance, energy reservation and insulation against cold weather are the basic functions the muscle fat offer to the body. The essentiality of muscle fat mass in the human physiology is lost when it is reduced whether through poor dietary practices, eating disorders (anorexia) or through a specific exercise regime (Bajeret al, 2015). Muscle fat mass accumulation is however a positive trend to health either in the short or long terms. It also help strengthen the body, influence whole-body metabolism, and associated with low risk of chronic kidney disease development (Jhee et al, 2020).

After puberty, girls tend to accumulate more muscle fat than boys, this has been demonstrated in study involving 11–13-year-olds; girls increased muscle fat by 78% as against a 19% increase in boys (Fox, Peters, Sharpe, & Bell, 2000). Moreover, girls had more muscle fat in a study of 11–20-year-old adolescents from Japan. Also girls had more abdominal muscle fat in a sample of British 12–14- year-olds (Benfield et al., 2008). Whole-body muscle fat was also higher in pubertal adolescent girls in an MRI study of 5–17-year-olds in the United States (Shen et al., 2009) whiles taking exception from their counterpart males with low muscle fat. With few exclusions from Lee, Kuk, Hannon, and Arslanian (2008) and Lê et al. (2011), where pre-pubertal male muscle fat was higher than females, another study by Brambilla et al (2006) reported a no sex difference in muscle fat of adolescents. It is because of the varied sex differences in the plausibility of muscle fatness that Craig, Reilly, & Bland (2015), in their study of risk factors for overweight and over fatness in rural South African children and adolescents recommended pre-adolescent/adolescent females may be the most purposeful goal for future interventions aimed at preventing obesity.

Diet selection and consumption is among major influencers of the muscle fat mass of the adolescent group. Daily sugar intake has been found by Mollard et al. (2014) to be higher in adolescents with higher muscle fat than their colleagues with lower muscle fat (149g/l compared with 12g/l, p=0.03). They further observed elevated levels of consumption of highly processed snacks including soda drinks in adolescents with ‘muscular obesity’ showed by 37% compared to a 13% muscular fat measured, p=0.02.

In another study, observed effects of eating frequency on the body fat composition of children. In their result, frequent eaters presented low levels of muscle adiposity than the infrequent eaters despite a high energy levels consumed by frequent eaters. The observation was that, they devoted much of their time to physical activities after insisting on frequent eating pattern, this however is contributory to a favourable body composition in the younger population as they are growing up.

Socioeconomically however, the prevalence of high adiposity increased in boys who were from high to medium socioeconomic household category (p=0.015) whiles there was no significant association in girls. Meanwhile when they were observed over a 2-year study period (2000-2002), girls aged above 14 years had increased fat percent irrespective of their affiliation to high or low socioeconomic household categories (Moreno et al., 2005). To add to this, rural adolescents have been found to show high muscular mass and fitness than their age groups in the urban location where they rather show high muscle fat than muscle strength (Sylejmani et al., 2019).

2.2 Adolescent's nutritional status

The result of whether or not one consumes correct amounts and types of nutrients have a bearing on their nutritional status. Adequate nutritional status for that matter is a reflection of healthy body composition on one hand and absence of physical signs of nutrient deficiency, thus one have adequate nutrient stores and are in balance, on the other hand (Hart, 2016).

Maintaining a healthy weight, a balanced diet and taking any special diet considerations into account, all ensure an ideal nutritional status. Inadequate food intake in terms of quantity and quality coupled with physiological changes sometimes cause undernutrition whiles excess in intakes are likely to lead to over nutrition (Debnath, Mondal, & Sen, 2019). Disproportionate financial and food resources at the population level, socioeconomic/cultural diversity and inaccessibility to adequate healthcare facilities are the major contributing factors of malnutrition (e.g., undernutrition/overweight-obesity) (Mawa & Lawoko, 2018). Malnutrition is henceforth broadly divided into under/over nutrition. Whiles over nutrition is demonstrated by overweight/obesity, undernutrition is made up of four cardinal forms of malnutrition. They are; thinness/wasting, stunting, underweight and micronutrient deficiencies.

2.2.1 Underweight

Malnutrition, defined as underweight, is a significant public health problem amounting to high risks of morbidities and mortalities across age groups, with highest bearing on women and children. Low weight-for-age is used to define underweight; shown in either stunted or wasted victims or both (WHO, 2020). Not only is this form of malnutrition prevalent among the poorer populations (WHO, 2018), recurring infectious diseases pose a risk in urban settings (Viana et al., 2020). The impacts of underweight on health are such that both food intake and absorption of nutrients are derailed. If a child or an adolescent is victimized, their linear growth is subject to faltering and their micronutrient stores also reduced. Underweight or low BMI-for-age subsequently has negative impact on recoveries following acute illnesses (den Hoed et al., 2017).

According to the WHO growth reference for child and adolescents, weight for age greater than -2 SD below the median of the population reference for children and adolescents are referred as moderate underweight and above -3 SD interpreted as severe underweight. Mild underweight is between -1 and -2 SD. Between 1 SD below the median and 1 SD above the median also depict healthy weight whiles more than 1 SD to 2 SD above the median shows overweight and finally obesity shown as SD above 2 of the median (WHO, 2006).

Over one million adolescents died through preventable deaths in 2015 globally, caused mainly through malnutrition or acting as risk factor (WHO, 2016). The global report further stressed that most of the deaths were found in Africa (45%) and the Southeast Asia (26%), where 19% and 30% of the world's adolescents reside respectively. Aside environmental causes of mortality, one-third of adult deaths are attributable to consolidated adolescent determinants such as underweight (Patton et al., 2016).

About one in every ten under five children (13%) in Ghana in 2017 were underweight (GSS, 2018). This prevalence had reduced slowly from the 2014 prevalence of 15% (GSS, 2015). The slow reduction of child underweight is a global situation. This is because of the marginal decreases recorded over the long period between 1975 and 2016 among girls from 9.2% to 8.4% and 14.8% to 12.4% in boys between 5 and 19 years, irrespective of a 75 girls and 117 million boys who were globally underweight (Abarca-Gómez et al., 2017).

In sub-Sahara Africa (SSA), 25% of children less than five years were found to be underweight (WHO, 2016) as well. Evidence of adolescent underweight (26%) is very much elaborated in Ghana by Manyanga, El-Sayed, Doku, and Randall (2014), Mogre, Gaa, and Abukari (2013b) in the Northern region, Gyamfi et al. (2019) in the Ashanti region and other areas of the country.

Whiles determining the differences in the nutritional status of school age students (SAC) in the Kwahu Afram Plains of the Eastern region of Ghana, Tandoh, Mills-Robertson, Wilson, and Anderson (2019) found that age serving as an independent variable has influence on underweight. They further reiterated that the existing economic activities (farming and fishing) of children drew some difference in their underweight status ($p=0.03$). Probably because of the impact of helminthiasis infection being higher in the fishing (33.8%) than farming (10.7%) communities ($p<0.001$). But on the opposite view, Kwotua (2019) did not establish the relationship between residence of students and their underweight status ($p=0.810$), in the adolescents and SAC. Rather, they found enough evidence to conclude that the academic grade of the adolescent or SAC is related to their level of thinness ($p<0.001$). Specifically, lower (lower primary) and higher graders (vocational) had normal body weight compared to the upper primary (7.41%) and JHS (4.71%) counterparts. Also, not only did their household sizes fell short to determine their thinness ($p=0.332$), ethnic differences supported it ($p=0.765$). In Tamale, despite Mogre, Gaa, and Abukari (2013a) found difference in thinness to be higher in boys than girls, they did not change with snacking behaviour. What was intriguing was the existence of significant difference between bedtimes of eight to nine pm ($p=0.0112$) and after nine pm ($p=0.0375$) where most were thin (41.5%), but not before eight pm. There was also a large percentage difference (p=0.0215) between thinness (p=13.9%) and overweight/obese (34.2%) SAC and adolescents who took TV watching at their leisure times, but not the same for their folks who read (p=0.7678) and play football (p=0.2358) at leisure time. All of Mogre and colleague's associations in their cross-sectional study were hinged on their overall (moderate/severe) thinness prevalence of 29.8%. Subsequently, they attributed their gender differences in thinness to the disparities between SAC and adolescent disparities.

To contribute to some of the assertions made by Mogre and colleagues, Tando et al. and Kwotua, at different geographical locations, Gyamfi et al. (2019) in Ashanti-Bekwai municipality also observed among JHS and SHS students that, the Basic schoolers were predominantly (11.3%) underweight than senior high schoolers (8.6%). After modelling underweight against possible determinants, there was higher odds of students who commute to school with bicycles than those who go by car. In the basic schools, students were 2.18 (1.01-4.71) times likely to be underweight when their means of going to school is bicycle than their colleagues who go by cars (1.54(0.79-3.00)). Similarly, in the high schools, underweight students were 0.61(0.18-2.01) likely to use bicycle than 0.58(0.23-1.15) who come to school in vehicles. They also reported that snacking before bed rather than before breakfast increases underweight chances in both schools. After making these assertions however, Gyamfi et al. could not substantiate the reasons why these two determinants (means of going to school and snacking behaviour) could lead to underweight, but they sort to explain their effects on underweight/obesity explicitly.

In this review of thinness prevalence and its determinants among age groups, it was found among several literatures that, there exist heterogeneity in the predictors of underweight.

This diversity move from sociodemographic to dietary through physical activity, hence serving as independent predictors.

2.2.2 Stunting

Stunted children are the common nutritionally impoverished group among their peers in the community, to the extent that when nutritional status data are viewed, substantial proportion of children are often hit by stunting (Atsu, Guure, & Laar, 2017). Stunting, if not emanating from congenital causes, could be directly caused initially by the poor density of weaning foods during the early years of a child's life Henry (2019), poverty and dearth of nutritional quality among others (Kek, 2016).

Also described as poor linear growth, stunting is the growth failure in a child that has undergone a steady consecutive buildup of the consequences of inadequate nutrition and/or repeated infections (Webb & Bhatia, 2005)**,** they are short for their ages; an index of their height and age (WHO, 2010), and have the likelihood of acquiring high irreversible physical and cognitive retardation, with a devastating generational effects (WHO, 2020).

It has been estimated that, 21.3% (144 million) children globally were stunted in 2019, though this number has reduced by 55.5 million in 19 years (2000-2019), more than half (54%) of the affected children live in Asia and 40% in Africa (WHO, 2019), buttressing the evidence that, across LMICs there had been decrease from 36.9% (95% uncertainty interval, 32.8–41.4%) in 2000 to 26.6% (21.5–32.4%) in 2017 (Ausloos & Collaborators, 2020). Taking a retrospection to the year 2000, West Africa alone has seen a reduction in the level of stunting from 36% to 27.7%. Aside this regionally insignificant pace of reduction in childhood stunting over the period, evidence from Ghana does not differ from the sub-region.

In Ghana, 18% of the childhood population have been found to be stunted, reiterating that almost one in 5 children are cognitively and linearly impoverished (GSS, 2018). Out of the thirty percent malnourished children reported in the Ghana Multiple Indicator Cluster Survey MICS, 2011, 27.5% were stunted and was more prevalent than the other forms of malnutrition such as wasting (7.7%), underweight (17.3%) and over-weight/ obesity (2.4%).

It is imperative to note the prospective effects of stunting on the child. This is what the WHO described as "poor cognition and educational performance, low adult wages, lost productivity and, when accompanied by excessive weight gain later in childhood, an increased risk of nutrition-related chronic diseases in adult life" (WHO, 2014). In effect, the devastation that can be caused by stunting on a country is overwhelming.

2.2.3 Wasting

Wasting defined by a weight for height z-score of less than -2 standard deviation of the mean of the WHO child growth standard also refers to a child who is too thin for their height, they often are underweight and it is estimated that severely wasted children between 6 and 59 months of age are 9 to 12 times more likely to die than are their healthy counterparts and that, about 13 percent of childhood death are caused by wasting (Black et al., 2013; Stobaugh et al., 2019).

Wasted children are described to be suffering from acute form of undernutrition, mostly occurring from inadequate dietary intakes or recurring infectious disease episodes, more importantly diarrhoeal infections. Wasting has severe negative impact on the child's immune system, such that they could be exposed to increased severity, duration of and/or susceptibility to infectious diseases and an increased risk for mortality (WHO, 2010). In both 2017 and 2019, the childhood wasting level globally was rife, showing that in 2017 51 million out of about 678 million and 47 million out of about 680 million in 2019 children under the age of five were wasted (WHO, 2019; Unicef, 2018). It is important to note that more than two thirds and more than one fourth of all these wasted children subsequently live in Asia and Africa. But in Africa, out of the 12.7 million wasted under five children, most of them (4.8 million) live in West Africa.

One in every 10 children under five in Ghana have been found to present wasting, representing 7% of children within that age bracket (GSS, 2017). Prior to MICS's report in 2017, 5% wasted children under five had been recorded in 2014 by the GDHS, when comparing the two wasting prevalence, all things being equal, there has not been impressive performance in reducing this form of malnutrition nationwide. The severity of wasting in Ghana is predominant in the Northern region with 9% prevalence in composite moderate and severe wasting indicators, and 2% severe wasting level (GSS, 2017). In the then Brong Ahafo region, the GDHS found severe wasting to be 0.4% and moderate wasting to be 4.5% of children under five.

Aside these national data, individual publications on child and adolescent wasting are available. In 2018 Ali et al., also established in Sunyani (Bono regional capital) among 246 under five children a wasting prevalence of 5.3%.

2.2.4 Overweight/obesity

Overweight and obesity are the other forms of malnutrition on the positive side of the energy balance equation, acting in conjunction with other risks to cause non-communicable diseases (NCDs) (Gouda et al., 2019). In as much as overweight/obesity is of a global public health concern, higher income and low income; sub-Saharan African and Asia's poorest countries undergoing nutrition transition are currently being threatened (Popkin, Adair, & Ng, 2012).

The effects of obesity on health is more than what is already known, Djalalinia, Qorbani, Peykari, and Kelishadi (2015) in their communication on the different aspects of health predominantly affected by the existence of obesity, outlined that aside the dimensions of physical and mental health, which are often what is mostly addressed, stigma, discrimination, ridicule, impaired eating behaviour and reduced spiritual well-being were also mentioned. List of chronic health defects including some cancers, diabetes, CVD and bone diseases, which are some of the leading causes of death are at the same time related to obesity (Hruby & Hu, 2015).

Globally, childhood and adolescent (5-19years) prevalence of obesity has increased to 14% in 2016 from 1% in 1975. At the same time overweight/obesity increased from 4% to 18% (WHO, 2020), and under five children estimates in 2019 to 5.6% corresponding to 38.3 million (WHO, 2019). In the African region, irrespective of the existing high levels of undernutrition, the trends in over nutrition is also not encouraging. This could be seen from the analysis of data from the Global Burden of Diseases Study (GBDS), by Chooi, Ding, and Magkos (2019), they presented an increased trend from 18.5% to 34.5% overweight between 1980 and 2015, and 6.2% to 12.7% obesity. These increased trends correspond to the changes in dietary selections, physical inactivity and the likes.

However, in Ghana, the prevalence of obesity in adolescent girls between the 15 to 19 year brackets was 9%, whilst the highest prevalence was fifty-six and was among between 40 and 49 years of age. In effect, overweight/obesity was 40%, showing a 10 percentage point increase in the space of six years (2008-2014). Whiles adolescent males of the same age group above were comparatively very low (1.7%) in their overweight/obesity status, they showed some similarities in the way their BMI increased with their wealth and where they resided (GSS & Macro, 2015).

In forecasting some of the factors that could interpret obesity among University students in Tamale, for general overweight/obesity, the consumption of fruits and vegetables in more than three times of a week could predict up to 26% risk, but not for vigorous PA participants (Mogre, Nyaba, Aleyira, & Sam, 2015). In another model, they also listed the consumption of staples such as roots and tubers and either intake of alcoholic or sugar sweetened beverages more than thrice a week predicted abdominal obesity. Demographically also, being a male rather than female could make one record a lower average BMI so as being generally overweight/obese (5.9%) in male's vs 25.8% in females $p<0.05$. Similarly, abdominal adiposity percentage varied among males (0.8%) and females (40.9%), irrespective of the wide differences between male (354) and female (198) samples. Mogre et al's conclusions thereafter was in concordance with other findings in Lazio-Italy, where males were twice as likely to be overweight/obese than females, thus risk of 2.03 within a 1.19-3.46 CI. In their study however, (Galfo, D'Addezio, Censi, Roccaldo, & Martone, 2016), found an interesting and more important dimension of collinearity between overweight/obese and geographical dispensation of adolescents. Urban dwelling adolescents were less likely to be obese than their counterparts residing in non-urban areas. Their evidence as well showed a twice likelihood of an adolescent in a non-populated area to be overweight/obese than their counterparts from metropolitan areas.

In Ethiopia where there were 10, 4.2 and 14% prevalence of overweight, obesity and it's composite among students; school type, gender, sedentariness and snacks and sweets consumption were found to determine overweight/obesity. Twenty-three percent of private schoolers than their colleague's public schoolers (7.9%) were overweight/obesity whiles associating private school status to higher wealth category. Unlike earlier literature reported in this write up, females (27.6%) rather than males (4.9%) were overweight/obese. Sitting for more than three hours in a day by participants gave a 6.1(3.45-10.87) plausibility for overweight/obesity. Snacking one or more a day could also lead to a 4 (1.86-8.66) odds of being fat, so as consuming a sweet food in the preceding week of the study. After adjusting however, in a multiple regression, there was a three times higher odds in private than public schools and over five times higher among females than males. Meal frequencies of more than three daily has also been found to be risk factor in body fatness (4.0, 1.26-12.95). These findings therefore compelled Shegaze et al. (2016) to conclude by admonishing the need for parental involvement in the reduction of adiposity risks.

2.3 Risk factors for adiposity

2.3.1 Genetic risk factors

Beyond the exposure of different caliber of individuals to any existing obesogenic environment, their differing body mass and adiposity could be explained by some complex evidence of genetic contributions. Though likelihood of genetic heritability of body weight is subject to inconsistency at certain times, change in phenotype of a trait as a result of genes in a specified environment has shown ratios of 0.71 and 0.86 Silventoinen, Magnusson, Tynelius, Kaprio, & Rasmussen (2008). It is worth mention that, not only do children inherit their obesity gene from their biological parents through a normal physiologic process, certain genetic disorders ring a predisposing alarm to the victims and subsequently develop high body fat stores in their later life.

Some of these endogenous monogenic or syndromic risks referred to by Mason, Page, and Balikcioglu (2014) include; Trisomy 21, Prader-Willi syndrome, Albright's hereditary osteodystrophy, Cohen syndrome, Bardet-Biedl syndromes, Alstrom syndrome, and WAGR (Wilms' tumor, aniridia, genitourinary anomalies, and retardation). On the contrary, these forms occur after infancy compared to the monogenic risks occurring within the first year of the child's life including; leptin deficiency, leptin receptor mutations, proopiomelanocortin deficiency, preproconvertase deficiency, and melanocortin 4 receptor mutations and lastly through hormonal disorders such as hypothyroidism, growth hormone deficiency, Cushing's syndrome, hypothalamic obesity, polycystic ovary syndrome, and hyperprolactinemia.

These critical observations made relating to heritability and obesity could be seen as linking the human gene through a complex relationship to factors such as the existing nutrient environment, overfeeding, exercise and interactions to medications. In Virginia, US when genetic and binge eating were modelled for a possible contribution of genetic factors to either one or both, it was found that when put together both obesity and binge eating increased moderately (0.41, CI:0.23-0.59) whiles obesity alone showed quite a high effect level (0.80, CI:0.72-0.88) and later concluded that those findings were possibly not solely a direct relation between genetics and the two phenotypes but environmental factors could one way or the other have some impact (Bulik, Sullivan, & Kendler, 2003). These evidence have shown resemblance to the use of different study designs to establish gene-environment interactions and obesity. For example, multiple studies using case-control designs have shown the effect of carbohydrate intakes on obesity risk through beta-2 adrenergic receptor (ADRB2) of women with Glu27 allele (Martínez et al., 2003) and there is also increase in the risk of obesity in children and adolescence in Spain through the action of the fat mass and obesity (FTO) polymorphism when participants were classified into cases and controls by their exposure to saturated fat intakes (Moleres et al., 2012)**.** In a case only study too, obese individuals showed varying interactions of dietary fiber intake and its role in the fatty acids absorption to their adiposity levels (Gatto, Campbell, Rundle, & Ahsan, 2004)**.** In a cohort study such as the nurses' health study, Hruby et al. (2016) and a randomized control trial by Sacks et al. (2009) they both showed evidence of the effects of a genetic trait on weight status, where Gatto and co saw increase in weight gain Sacks and co saw some effects of gene functioning on weight reduction among subjects.

There is compelling observations made across the studies reviewed, and this could suggest that genetic factors could implicate the pervasiveness of obesity across age groups though most literature in nutrigenomics accept that one-handed observations of the gene without effective scrutiny of the environment could likely mislead our interpretations.

2.3.2 Behavioural risk factors

The behavioural pattern of obesity risk ranges through a number of solely modifiable factors and are mostly individually controlled yet they may be influenced by the environment and enabling infrastructural endowment of the community in question. These factors can also act independently and cause obesity but their confluence aptly worsen the situation. To mention a few, dietary practices commonly referred as food choices, physical activity levels and sedentariness are noted risk factor.

2.3.3 Food choice as behavioural risk factor for adiposity

Behavioural attitude towards food decision making and selection are formed and present the likelihood to persist during the adolescent age period (Perez-Cueto et al., 2017)**.** The combined or independent psychologic, sociologic, economic and sensory influencers of an individuals' selection of what to acquire and consume describes the concept of food choice (Perez-Cueto, 2019). The adolescent is most often exposed to a wide variety of foods usually due to their constant change in environment, their relationships with peers and the use of social media networks Klassen, Douglass, Brennan, Truby, & Lim (2018), presenting them with both healthy and unhealthy foods to select from. Current food choice of adolescents is one that has been described by the nutrition transition Shaikh, Patil, Halli, Ramakrishnan, and Cunningham (2016) and further observed in the northern Ghana by Abizari and Ali (2019) among adolescent students as high sugar diets on one hand and a traditional healthy diet on another.

Making a choice of what to consume significantly suggest the inputs being made by an individual towards the energy balance equation; the equilibrium between what is consumed and expended. Excess of intake over energy use suggest tissue storage as adipose whiles excess of usage over uptake also predict weight loss (Norat et al., 2015). Adolescence are on the verge of eating diets dominated by high energy foods thus exceeding 225-275 kcal per a 100g which put them at risk of overweight/obesity (Fogelholm, Anderssen, Gunnarsdottir, & Lahti-Koski, 2012). Unlike evidence of protectiveness found in whole grain meals, fiber rich foods, reduced salt diet, against unwanted waste gain, high intake of refined grains, sweets and desserts have been mentioned as some of the predictors of weight gain, and for refined (white) bread in predicting larger increases in waist circumference (WC) (Fogelholm et al., 2012).

Interestingly, among Polish, the increase in consumption of sugar sweetened beverages among adolescents has been found to rise with adolescent age (Myszkowska-Ryciak, Harton, Lange, Laskowski, & Gajewska, 2019), whiles they also continuously rely on fast food consumption, similarly, age was seen to increase the likelihood of children's' breakfast skipping behaviour. When young consumers choose to eat outside of their homes, the foods they consume are often known to be energy-dense, micronutrient-poor and often high in saturated and trans-fatty acids and processed starches, Jaworowska, Blackham, Davies, and Stevenson (2013); these therefore risks their chances of growing fat and subsequent poor health outcomes because of some observations made in Ghana, United States of America, China and other countries about the possible excess in the daily energy requirement after fast foods are consumed between seventy and one twenty percentage points of a sedentary adult who did not consume other meals and snacks within the day of assessment (Roberts et al., 2018).

It is well established that choosing home prepared foods rather than purchasing takeaways or fast foods significantly reduced the consumption of high energy/sugar dense foods such as soda or carbonated drinks, crispy biscuits, cakes and other pastries, and barbecues whiles encouraging children/adolescent consumption of fruits and vegetables on the daily bases leading to an improvement in their food choices and eating behaviours accordingly (Garcia, Reardon, Hammond, Parrett, & Gebbie-Diben, 2017)**.** To reemphasize Ada et al's observation, in the US, there was an inverse relation between home food consumption and obesity among children and adolescences (Holston, Cater, Tuuri, & O'Neil, 2018).

On the contrary unhealthy food behaviours among adults decreased with age, the odds of consumption decreased with increasing age from 4.3 to 3.1, demonstrated by age group of adults less than 30years and 30-29years bracket respectively, but in this case yet a significant difference in average BMI was measured between unhealthy food eaters and their counterparts who made their food choices right (Bowman & Vinyard, 2004).

Since food choices are mediated by a wide range of individual and environmental factors that include food availability, accessibility, tastes and preferences, empowering the young consumer to make healthy food selection through the instigation of informed choices policies typically by the government through health, nutrition or wellness stakeholders remain a possible way to prevent unhealthy eating (Leng et al., 2017).

It is worth noting therefore, that identifying specific aspects of eating behavior, the food environment, or both are quantitatively important and can lead to effective public health interventions.

2.3.4 Snacking as a behavioural risk factor

A study by Phillips et al., (2004) among a cohort of adolescent girls between the eight and twelve years group in the USA found no association between consumption of energy dense snacks and both BMI status and body fatness level. Their findings showed; (Daily servings of EDS against BMI z-score, t=0.035, p=0.33 and percent of daily kcal: BMI z-score, t=0.0036 and p=0.11) and (Daily servings of ED against %BF, t=0.20, p=0.49 and percent of daily kcal: % BF, t=0.028, p=0.13). On the other hand, studies in Abuja showed 546 (35.2%) out of 1550 adolescent students between 10 to 19 years consumed carbonated drinks in the preceding 7 days before a survey to observe eating patterns and BMI status elaborated the relationship between the two variables (Otuneye, Ahmed, Abdulkarim, Aluko, & Shatima, 2017). It is important also to notice how those findings were in line with observations made in Sydney, Australia where snacking on sugar-sweetened beverages (SSBs) showed associations with common cardiometabolic health indicators; overweight (27%), obesity (5.9%) and WtHR≥0.5 (13.2%). Though they admitted that errors of self-reporting could impact accuracy, they saw among 30% of adolescents who consumed ≥1 cup of SSBs at any time of the day or on daily basis were overweight/obese but higher prevalence in those who consumed energy drinks.

Among the opposing findings made to contradict evidence such as mentioned by Philips et al and Otuneye is one reported in Durhan, USA by (Larson, Miller, Watts, Story, & Neumark-Sztainer, 2016) among 2793 adolescents where comparison was made by their snacking frequency in both home and outside home in relation to their weight status. They found that, energy-dense and nutrient-poor snacks measure by servings/day (r=0.059), frequency of snacking daily (r=-0.032) and away from home snacks (r=-0.029) were supported by enough evidence (p<0.001). In furtherance to that, conclusions drawn were based on the fact that overall adolescent consumption of snacks per day was high (4.3) and hence interventions targeting healthy growth and development and the prevention of chronic conditions in later life should consider tailoring healthy snack selections into daily foods and beverages consumption.

With the above observations on children and adolescent snacking and weight, other food specific suggestions by Maryam et al 2019 to serve as substitutes for unhealthy sugary snacks considered the intake of nuts and their products as a step to reducing health impacts of obesity and overweight in Iran's children and adolescents. To buttress this, it could be more sustainable when programmes go beyond behaviour modification to accommodate community-based prevention avenues including sporting activities to target the current obesogenic environment.

2.3.5 Environmental and socioeconomic risk factors

Environmental variables are undoubtedly related to obesity through the incongruity between food accessibility and PA opportunities Wall et al. (2012), and the complexity of the situation is sometimes socioeconomic disparities between populations (El-Sayed, Scarborough, & Galea, 2012). Man-made infrastructure including the streets, green spaces, sidewalks, water and sewage lines, electricity and other utilities providing the basic necessities for a healthy and functional life for all refers to the built-environment (Tengland, 2016), but on the negative side, when these environments reduce exercise spaces and create unhealthy food environment the end line is the manifestation of an obesogenic environment. Finding this balance is a complicated and challenging process, and one that is consistently being refined (Lindsay, 2015). Over the years, irrespective of the potential effect of the built environment on obesity, interventions have literally considered raking it into either short or long term plans of obesity reduction (Suglia et al., 2016).

In the USA the assertion that built environments greatly affect PA and obesity attributes of walkability muchly have been found to play roles in health behaviours. Where the standard environment for that matter could lower obesity risk in urban cities, middle urban cities often observe food environment as correlates of weight. Though rural communities did not present solid evidence in that direction, it was believed that both built and food environments could be determinants of normal weight in that social class (Xu & Wang, 2015).

In Ghana, the endorsement of the advertisement and marketing of junk foods is widespread, and whiles influencing students through their food environment, entrepreneurs in this venture through large billboards and sponsorship of some programmes organized by schools result in increasing the obesogenicity of these environments (Bonah, 2016).

Until recently, the US had their adolescent obesity pregrammes targeting adolescents with high socioeconomic status (SES) but not the less privileged, upon results showing similarities in obesity prevalence among the two groups and in some cases marked reduction in the high SEC children, interventions therefore have been dually focused (Frederick, Snellman, & Putnam, 2014). Within-country shifts in the incidence of obesity from the rich to the poor is more rapid in LMICS than it used to (Dinsa, Goryakin, Fumagalli, & Suhrcke, 2012).

2.4 Physical activity (PA) and sedentariness

Physical activity (PA) combined with healthy eating behaviours is one of the basic elements of a healthy lifestyle (Parikh & Stratton, 2011). The dual impacts of healthy diet and PA on adiposity and fitness are significant public health recommendations towards maintaining standard energy balance whiles regularly assessing changes in weight or in one's fat mass (Romieu et al., 2017), so for any sustainable/long-term weight control, the diet should be coupled with adequate PA.

It is admitted that regular physical activity stimulates the physical, motor, psychosocial development of children and adolescents (Duma-Kocan, Barud, Glodek, & Gil, 2017), and to some extent the regularity of PA can improve glucose tolerance, retain a good lipid profile and maintain muscle mass as well (Mann and Truswell (2017)**,** but these importance are not recently observed due to the rate of physical inactivity. The realization of the rapid reduction of human physical activity dates back to the 1980's, where changing dietary patterns of eating were accompanied by a drastic low physical activity and paving way for sedentariness across age groups of the population (Popkin et al., 2012).

In today's world, an extremely rapid pace of life is accompanied by elimination of fitness exercises and a reduction in physical activity Ponczek and Olszowy (2012), suggesting a major risk contributor to our ill health and causing a fifty-two percent rise in all-cause deaths, two times the level of heart and its related illness and increase in the level of obesity among young men and women (Warburton, Nicol, & Bredin, 2006).

The geographical disparities in the PA levels has been established, showing that levels of activities are often marginal in urban than in rural settlements where their occupations and daily routines require high mobility than the leisure type in urban dwellers (Anjana et al., 2014). This could also mean the younger population at the moment are liable to both acute and chronic morbidities as the transitioning from rural through urban slum and urban settlements pose a drastic reduction in the level of PA in both males and females, with an overwhelmingly higher duration of PA on weekly basis, an observed trend above the WHO recommendation of 150 minutes per week. Rural women, though performed most PA were malnourished whiles their counterparts in the urban settings were either over nourished or presented central obesity which was worst in men (Yadav & Krishnan, 2008). The Center for Disease Control and Prevention (CDC) in Canada, have enumerated several benefits of PA to the health of an adolescent. Their recommendation of at least sixty minutes of moderate to intensive PA daily could help in a number of ways by improving adiposity, cardiovascular health, mental health, academic achievement, musculoskeletal health, fitness, injuries, and asthma (Janssen, 2007).

Among some evidence of collinearity between PA and body fat composition are in two cohorts observed in India by Bowen et al. (2015), negative association was recorded between whole body fatness and rate of moderate to vigorous physical activity. In both groups, central adiposity where in line with body fat but on the contrary view, there was insignificant evidence of relativeness between PA and abdominal fatness though they admitted the effect of difference in age exposure, believing that when ones age is taking in a continuum and observed over time, diet and PA could result in varying body fat levels as was observed in the evidence from Bulgaria by Boneva-Asiova and Boyanov (2011), so they concluded that PA impact was two dimensional, thus on both obesity and fat distribution, importantly when time spent on the activity is considered.

In Tamale, university students who were either generally or centrally obese were shown to subsequently present low levels of PA. In their study, Mogre et al. (2015), found that two groups of students (those involved in vigorous PA and those with acceptable waist circumference (WC)) had lower risk of becoming overweight/obese than their counterparts though they accepted the impact of dietary contribution to adiposity risks. Mogre, Nyaba, and Aleyira (2014), in a similar study hypothesized the likelihood of overweight prevalence with light or moderate PA but not vigorous activity ($p<0.05$). Being a female student for that matter raises your risk of obesity though a major factor such as dietary determinants were not assessed within the school's food environment. So in both of their studies, Mogre and co suggested the need for policies targeting PA and the food environment of the school.

Previously, in China Lee et al. (2013) were interested in the effect of either aerobic (AE) or resistance exercises (RE) on body fat composition. Their evidence of causality over the three months period of the trial of obese adolescent girls showed drastic reduction in total body fat for both AE and RE groups whiles a 10% increase of total body fat was seen among the controls. Similar trends were observed for visceral adiposity but in this case there was a marked reduction among AR than the RE group. On the contrary, RE group recorded the maximum reduction in abdominal subcutaneous adipose tissue than in both the control and AE groups, though all three groups observed reductions with the minimum reduction occurring in the control arm of the study. Therefore, sedentary obese study participants could reduce their body fatness levels with AE or RE. So in all of these evidences given, sedentariness is implicated as a single factor leading to either excess weight gain or fat distribution.

BMI and WC which are used to determine nutritional status could have some association with PA levels. To check for the impact of PA initiated by a school on selected health status of schooling children, Kriemler et al. (2010) in Switzerland have realized the increase in skinfolds of children exposed to the school's monitored programme on PA for twelve months period. The controls on the other hand had increased BMI and not WC with the conclusion that in the young population, showing increase in adiposity when one is inactive, and making it a compulsory school extra curriculum would make PA by children yield health benefits all things being equal, but a long term observation of young students for five years had also shown a conflicting result of reduction in BMI or overweight/obesity in a developing economic environment like Ghana. In this study, average BMI between intervention and control did not attenuate but WC reduced marginally in the intervention group who also had improved fitness levels, reduced sedentariness and higher academic performance (Bhave et al., 2016).

Sedentary behaviour has professed some relationship with adiposity dynamics in children and adolescence. A one percent increase in sedentary time of adolescent could significantly lead to increase in fat mass index (FMI) of about 0.15 kg/m^2, in the same trajectory, introducing a single bout of PA in an hour within sedentary time of children and adolescent have a marginal reduction of FMI of 0.01 kg/m^2. There is also the likelihood of a negative association between sedentary time and BMI of children less than 10 years but a positive association for adolescents less than 16 years (Mann et al., 2017). To make these evidence more profound, Saunders et al. (2013) also stressed on the effects of even low bouts of less than 16 minutes on the adiposity levels with a direct effect on cardio metabolic health by gender differences. There however was a common admittance that such evidence must be as a result of a good study design such as a longitudinal design to better understand the time pattern and effect.

2.5 Dietary diversity of adolescents

According to the Food and Nutrition Technical Assistance (FANTA) (2016), dietary diversity is among several dimensions of diet quality. Other dimensions of diet quality may include nutrient balance and/or moderation, which diverse diets could still fall short. Unbalance diets have too high or too low quantities of the three macronutrients. Also diets lack moderation when they include excessive consumption of fats, calories, sodium or free sugars. Food group diversity does not ensure balance or moderation. Food group diversity also does not in itself ensure that the carbohydrates, proteins and fats consumed are of high quality. Dietary diversity is, however, associated with better micronutrient density (micronutrients per 100 calories) and micronutrient adequacy of diets. Therefore, dietary diversity could be defined as the number of food items or food groups consumed within a specified time by an individual to insure diet quality, variety, and nutrient adequacy.

Since adolescence is a crucial life period for growth, diet quality of this age group could present a great opportunity to prevent stunting and shape their nutritional status for future health benefits. In spite of this several studies have reported low levels of dietary diversity among adolescence. For example, in Ghana among rural and urban adolescent girls, less than half (44%) of the study respondents consumed adequately diversified diet (Gyimah 2021), consistent with a systematic review in Ethiopia 40% adolescence observed dietary diversity (Ayele, 2023) and in Burkina Faso less than one-third (25%) of the adolescents consumed a diversified diet (Godha, 2021). It was observed in the Ghanaian studies that more rural adolescents were eating less diversified diet than their counterparts in the urban area (67% vs 54%) this suggest low micronutrient intake implying that they may not have achieved enough for critical body functions.

Adolescent boys in a remote Indian community were found with low dietary diversity than girls although the mean scores were close (males;7 and female;8) (Nithya & Bhavani, 2018). The males were found to be consuming more of spices, condiments and nuts and sometimes chew tobacco which were not considered for the study as important food groups. Whiles Aurino (2017) observed higher dietary diversity among adolescent boys compared to girls, it was asserted that being more likely to be enrolled in school, adolescent boys may supplement the food received at home and increase their dietary diversity by accessing to food programmes or buying snacks from vendors at school or around the school premises.

Hirvonen (2016) also suggested that the rural-urban gap in children's dietary diversity in Ethiopia is due to differences in household wealth and parental education, as well as unequal access to health care. However, inferences from these results could not be conclusive. This is an observational study and therefore one should not attribute causality to these findings. It was therefore recommended that continuing the efforts to expand access to education and health care services (e.g., nutrition counselling) in the rural areas are likely to improve the quality of diets.

There is the possibility of parental socio-economic factors having impact on adolescent dietary intakes in several other observations. Whether mothers and/or fathers attain a higher educational level or the type of occupation they are involved could influence their wards diet. In the Witold (2011) study of eating habits of children and adolescents in Poland, there was an observed significant correlation between minimum meal intake of adolescents and their parents' educational status (chi square 682.7, p=0.000). Either one of the parents with at least primary education (32.2%) or higher education (34.2%) consumed ≥ 5 meals daily. A correlation between the number of daily meals and economic situation of the households was also found.

The least percentage of adolescents who did not meet the minimum dietary intake were predominantly among subgroups with very good and good economic status, and the highest found in the subgroup with poor economic status.

To examine the regional differences in diet quality score among adolescents in southern and northern European countries, evidence showed that both maternal and paternal occupational levels associated with diet quality in southern and northern Europe. However paternal educational status was more strongly correlated with all the diet quality components (namely diversity, quality, balance and meal index) in northern Europe than in southern Europe where all the interactions with maternal educational level were significant, except for the meal component (Béghin, 2014).

To establish the healthful or otherwise wrongful dimensions of individual and group level food intakes, the dietary pattern analysis has been recommended for its level of reliability by the FAO (FAO, 2018). Basically, dietary pattern analyses present the regularity of foods and/or food groups consumed over a given time frame. This has predicted diet-related indicators for health across age groups over the years (Tallman et al., 2020).

Making efforts to link socio-economic and demographic factors to the dietary pattern has been extensively investigated both in Ghana and elsewhere but not for the specific investigations into the body fat mass, fat percentage and fat index and its relationship to dietary pattern. Socio-demographically, Abizari and Ali (2019), demonstrated how there was a difference in adolescent student's dietary pattern when matched against their relationship with their carer's. A sugar preponderance pattern significantly related to wards leaving with their parents ($p<0.05$), but not the same for a traditional pattern. Students with pin moneys also were associated to the 'sweet tooth pattern', likewise the father's level of education and employment status against the nutritional status was not different between the two identified dietary patterns. Economically also, the wealth status of the house resulted in about three times plausibility of the sweet food than the regular food patterns. They further cautioned the need for nutritional education in order to influence positive dietary choices of adolescents.

In another Ghanaian setting, urbanized students have shown difference in nutritional status with reference to food pattern described as unhealthy, and at the same time changes in this pattern in higher socio-economic households (Alangea, Aryeetey, Gray, Laar, & Adanu, 2018). The pattern that was likely to be energy dense in the result was >1 AOR (CI 1.04-1.70) likely to be overweight/obese. Furthermore, starchy foods added to vegetables negatively related to the SES in that direction.

In South African adolescent students, mother's wealth index has demonstrated a significant relation between nutrients that were derived predominantly from animal sources of foods consumed by their wards. Students from the lowest wealth households were with the group that adhered to the consumption of a variety of foods from plant and animal sources, where it was termed as the mixed diet. At the same point, adolescents from the highest wealth group were following the pattern of animal food sources whiles concurrently their mothers were educated (Pisa et al., 2015). Their evidence is relevant and could possibly be accurate in the dietary pattern analysis due to the use of nutrient pattern analysis rather than the usual dietary pattern analysis that list foods to determine pattern. It therefore gives the opportunity to explore beyond the knowledge of the only food groups though with its own minor limitation of subjects recording the wrong nutrients when not in an assisted questionnaire method.

Olatona, Ogide, Abikoye, Ilesanmi, and Nnoaham (2020), in their study in Nigeria on adolescent diet pattern, their nutritional status and knowledge, reported increasing levels of fatty and/or salty snacks (70%), processed cereals (74%), carbonated beverages (47%) and only 10% adherence to a fruits and vegetables pattern. The allusion made to support these prevalence's of unhealthy food intakes by the adolescents was to the fact that they lived with their parents and were given enough pocket money. Already, the pattern suggest that the foods they consumed mostly were eating as snacks which adolescents exercised their own discretion in their food selection when they are out of their homes, probably resorting to fast foods and unhealthy snacking. Olatona et al. (2020), concluded that the future risks of these poor dietary patterns are highly preventable, hence mass advocacy is needed to reduce the widespread in Nigeria.

When it was determined that girls had increased body fat through bioimpedance and skin folds assessments, their counterpart boys only presented high body mass index levels though it was conversely lower compared to the females BMI. In this study in Brazil, de Andrade Previato and Behrens (2018) after describing the common dietary pattern of the adolescents as 'obesogenic food pattern' accepted the fact that both study groups were exposed to similar food environment but 75% of males were involved in sport activities daily as against females ($p=0.001$) and could account for the difference in the body fatness levels among the two groups. In assuming the same male-female difference in body composition, Movassagh et al (2017) also refuted the similarity in the dietary pattern, whiles observing a change in the body composition as there was prospective change in dietary pattern from childhood through to adolescence. Marked variation was observed between males and females' scores of the dietary pattern as they transition from childhood through adolescence to adulthood whiles their adiposity levels followed suite. As the cohort grew, the females predominantly followed the vegetarian pattern characterized by dark green vegetables, legumes and nuts, fruit juice and whole grains (34.1% in children, 41.7% in adolescence and 44.4% in adults, $p<0.05$), consequently these increases in the level of consumption of vegetarian pattern exacerbated the fat mass of females where in children the two extreme measures of fat in Kg was 10.6±7 and 11.8±5, in adolescence 12.5±6 and 16.7±9, and adults 24.6±14 and 18.0±7. Both high-fat/high-protein and the western-like dietary patterns caused similar increases in their fat and BMI levels. Furthermore, western-like pattern changed significantly (p=0.001) in males whiles corresponding to a 64.7% and 34.4% increase in fat mass and BMI respectively. They had the reason to believe that implementing healthy dietary practices early in life coupled with adequate physical activity that seek to involve females could mitigate against risks of adulthood diet-related diseases, so increase in fruits and vegetables, whole grains and low-fat milk are some of the proactive recommendations.

Intra-abdominal fat has been previously studied and known to have link with diseases (Silveira et al., 2013). Independent of weight status or overweight/obese status, VAT and muscle fat increased with sugar-based beverages Odegaard et al (2012), implying that SSB could lead to adiposity and subsequent disease over time. Albeit adolescence aged between fourteen and eighteen from California who consumed high SSB had less than 10% increase in their VAT compared to their colleagues in the low SSB category, their findings were significantly different.

2.6 Body composition and disease risks

For the dual benefits of research and care for the ill, having the requirements needed to study, diagnose and manage obesity and its future morbidities including the most common types such as diabetes and cardiovascular are significant in recent times (Duren et al., 2008). There is escalating levels of comorbidities of diabetes alone when BMI is high, such example has been observed in Ghana at the Korle-Bu Teaching Hospital in Accra where among 261 diabetic patients with peripheral arterial disease (PAD) equally had the highest BMI levels (Yeboah et al., 2016). It has also been highlighted among south Asians by (Flowers et al., 2019) that, though the modelling of body composition measures with the risk of type two diabetes showed only moderate evidence, the fact that adipokines such as adiponectin and resistin are mentioned as the two main causes of insulin resistance (the precursor for type two diabetes) adiposity henceforth could be implicated all things being equal.

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study was conducted in the Berekum municipality, which is among the 12 municipal and district assemblies in the Bono region. The Municipality covers a total land area of about 863.3 sq.km and bordered to the North-east and North-west by Tain District and Jaman south municipal respectively, South-west by Dormaa East District and to the South-East by Sunyani West District. The GSS projected 159,950 population in the Berekum municipal in 2019. Males constitute 46.2% and females represent 53.8%. More than half (65.5%) of the municipality's population live in the urban areas, and has a sex ratio of 85 males to a hundred females (85:100). About 42% of the population of the municipality is youthful (0-14 years). The average household size in the municipality is 4 persons per household. Children constitute the largest proportion of the household structure accounting for 40.4%.

Berekum is a peri-urban area dominated by the private informal sector (86.6%), which is further distributed as 43.4% engaging in skilled agricultural, forestry and fishery works, 22.4% as service and sales workers, 12.8% in craft and related trade. The municipality has 243 basic schools (kindergarten (96), primary (93), JHS (74)), 8 SHS, a Teacher Training College, and a Nursing Training College. The municipality also has two hospitals, a health centre, seven privately owned maternity homes, seven private clinics and three Community Health Planning Services (CHPS).

Berekum is one of the municipalities in the Bono region aside Dormaa that has observed rapid urbanization in the past, this is prominent in the fast infrastructural growth and physical developmental activities (Kyere, Addaney, & Akudugu, 2019).

3.2 Study design

An analytical cross-sectional design at the school level was conducted in this study. Adolescent students from various schools were considered as the target population. Quantitative methods were used to enable the collection of both discrete and continuous data about body composition and its determinants.

A cross-sectional design was the most appropriate design for this study, because of its ability to measure exposure and outcome simultaneously, thus adolescent's exposure to diet, socioeconomic characteristics, physical activity and subsequent outcome of body fat percentage and BMI variations. It is also useful for identifying specific foods and nutrients that are far from optimal, particularly poor or good dietary patterns and disparities in diet between specific subgroups of the adolescent population.

3.3 Study population

The study comprised adolescent pupils (males and females) between the ages of 10 and 17 years who were students in the 93 primary and 74 Junior High Schools distributed across the peri-urban and rural settings of the Berekum municipality.

Inclusion criteria of schools: Schools were included when their minimum grade is class four and/or enroll JHS students during the time of assessment.

Inclusion criteria of students: Students between ages 10 and 18 inclusive, physically well and without visible deformity of the limbs.

Exclusion criteria of students: adolescent above 18 years or below 10 years and children with amputated limbs or any form of swollen feet were not considered for questioning and assessment.

3.4 Sample size calculation

A minimum sample size was calculated using the Cochrane formula for cross sectional study (Cochran, 1963). Calculating the sample size (n), involved a z score associated with the confidence level (95%), estimated prevalence of distribution of body composition (50%) and the level of precision (5%).

$$s = \frac{z^2 * p\,(1-p)}{e^2}$$

Where:

s= sample size

p= 50%, estimated proportion of distribution of body fat composition

e=5%, margin of error allowed

z=1.96, standard normal deviation value corresponding to 95% confidence level

Therefore, s= 385, upon calculation of a 10% (39) possible non-responsive rate, data was collected on 424 adolescent students within the study area.

3.5 Sampling technique

A multi-stage cluster sampling technique was used to draw educational circuits and subsequently select corresponding schools and respondents for the study. Six out of the 12 educational circuits in the municipality were randomly selected as clusters for this study. The 12 circuits are listed in table 2.1 below.

Table 2.1 list of educational circuits in the Berekum municipality

1	Ahenbronoso
2	Berekum
3	Biadan
4	Fetentaa
5	Jamdede
6	Jinijini north
7	Jinijini south
8	Kato
9	Kutre
10	Mpatase
11	Nsapor
12	Senease

Six circuits were primarily selected as the basic sampling units to obtain the sample size of 424, for each of the selected circuit, two schools were selected from which students were sampled randomly. In all, 12 schools were selected and at least 35 students were further selected randomly from each school to make up the total of 424 respondents. Respondents were selected from both upper primary and JHS.

In the following table, the selected circuits, schools and number of respondents selected has been listed; table 2.2.

Table 2.2 list of educational circuits, schools and number of respondents

Circuit	Schools	Number
Berekum	St. Augustine Basic school	37
	Freeman Methodist school	37
Senease	All for Christ School	35
	Senease R/C Schools	35
Ahenbronoso	St. Monica's Basic School	35
	Adventist Basic School	35
Biadan	Methodist Primary and JHS	35
	Glory Preparatory and JHS	35
Kutre	Impacts Educational Complex	35
	Kutre R/C Basic School	35
Kato	Presby Basic School	35
	Golden Child Academy	35

3.6 Data collection

3.6.1 Measurement of body fat and weight

Omron karada scan body composition monitor was used to measure weight, fat percentage and muscle fat using bioimpedance analysis method. Using both palms and soles, an extremely weak current of 50 kHz and less than 500µA was used to determine the amount of body fat tissue.

Omron karada scan body composition monitor, model HBF-701 is an effective device that allows the accurate analysis of various physical factors such as body weight, body fat percentage and visceral fat level. Body weight was measured to the nearest 0.1 kg by the same device.

Before the actual measurement of body composition, personal data including age and gender of respondent was keyed in. A clean barefoot was stepped onto the foot electrodes. Body weight was recorded from the device screen after the indicator flashed twice to show that weight has been determined. After weight determination, a measured height in cm was also keyed in and respondent with their palms firmly holding the handle electrodes, and arms extended straight to align a 90^0 to the body. Body fat and muscle fat percentages were read and recorded. In all measurements the assessor repeated recordings more than ones for the recorder.

Additionally, the device also measures BMI when height of the respondents were manually inputted. Through the internal equation of the impedance analyzer body fat and muscle fat percentages were estimated and classified based on cutoffs described in the operations manual of the device. An adolescent was categorized as follows in table 2.3 demonstrated by (Kagawa et al., 2007) per their gender.

Table 2.3: body fat composition classifications

	Body fat percentage		**Muscle fat percentage**	
Classification	**Gender**		**Gender**	
	Male	Female	Male	Female
Low	5.0%-9.9%	5.0%-19.9%	50%-32.8%	5.0%-25.8%
Normal	10.0%-19.9%	20.0%-29.9%	32.9%-35.7%	25.9%-27.9%
High	20.0%-24.9%	30.0%-34.9%	35.8%-37.3%	28.0%-29.0%
Very high	≥25.0%	≥35.0%	37.4%-60.0%	29.1%-60.0%

Source: www.Manualslib.com

3.6.2 Measurement of height and calculation of BMI-for-age Z-scores.

A microtoise fixed to the wall was used to measure standing body height (stature) to the nearest 0.1 cm using. The respondents stood (without shoes) on a horizontal platform with their heels together in a Frankfurt plane horizontal. The respondents were encouraged to draw themselves to full height without raising the shoulders, with hands and arms hanging relaxed, and with the feet flat on the ground. Measurement was done by two interviewers and recorded upon a second announcement of the measured value to the supporting interviewer.

Using data from the WHO reference (2007) which is the reconstruction of the 1977 National Center for Health Statistics (NCHS), BMI for age z-scores for adolescent's thinness, overweight and normal were calculated using the WHO anthroplus software (Onis et al., 2007). Thinness describe as z-score <-2, or <-3 –severe thinness, normal as z-score>-1 to <+1 and overweight as z-score >+1 SD.

3.6.3 Measurement of physical activity

Physical activity was determined using a modified 7day recall questionnaire referred to as the global physical activity questionnaire (GPAQ) adopted and used by Craig et al., (2003). It originally involved 16 component questions designed to elaborate the number of days and amount of time in the previous week one involved in the three domains of physical activity (activity at work, travel to and from places and recreational activities). This domain was further elaborated by these common domains; vigorous activity, moderate activity, light intensity and sitting.

Metabolic equivalents (MET) was calculated for moderate, vigorous and walking. For moderate physical activity, MET value assigned was 4.0, 8.0 for vigorous and 3.0 for walking (WHO, 2007). METs for adolescents was calculated as; MET value × duration of activity × number of activity/week. Also the following trail was used to categorize moderate/minimal PA and health enhancing PA (HEPA); if vigorous PA is ≥ 3 and time spent ≥ 20minutes OR moderate PA is ≥ 5 OR walking ≥ 30 minutes OR total MET ≥ 600METmin/week. For HEPA; if vigorous PA≥3 and MET for vigorous PA ≥1500MET/minute/week OR total MET≥3000 (WHO, 2007).

When respondents failed to meet the two criteria above they were classified as physically inactive.

3.6.4 Measurement of dietary diversity

Dietary diversity was measured using the FAO 24-hour dietary diversity questionnaire (Kennedy, Ballard, & Dop, 2011). The questionnaire consisted of 10 groups of foods, which covered every food taken in a day prior to the data collection. In addition, the questionnaire had single question about any food or fast food consumed out of the house. Dietary diversity scores of food groups were a count of food groups that a respondent had consumed from, during the previous 24 hours. Scoring was between 0 and 10 (0-none and 10-consummed from all food groups). Even though 16 food groups were initially asked during the data collection, it was aggregated into 10 food groups during analysis according to the (FAO, 2021). Cereals, starchy roots, tubers and plantain were aggregated into Grains, white roots and tubers, and plantains; other vitamin A rich fruits and vegetables group was an aggregation of vitamin A rich vegetables and tubers and vitamin A rich fruit; meat, poultry and fish was an aggregation of fish and seafood, fleshy meat and organ meats and legumes, nuts and seeds was interpreted as pulses.

The 16 food groups for the calculation of dietary diversity score were; cereals; white roots and tubers; vitamin A rich vegetables and tubers; dark green leafy vegetables; vitamin A-rich fruits; other fruits; organ meat; flesh meats, eggs; fish and seafood; legumes, nuts and seeds; milk and milk products; sweets; spices condiments and beverages and oils and fats.

3.7 Data analysis

Data was analyzed using statistical package for social sciences (SPSS) software version 25. Results were presented using tables to simplify and enhance reporting. In all analysis, a p-value less than 0.05 was considered for statistical significance.

Descriptive statistics was used to categorize body composition measurements into high and low values with the corresponding frequencies and percentages. BMI-for-age z-score, total fat percent and muscle fat percentage were calculated and categorized.

Chi-squared test was used to establish bivariate associations. Factors with $p \leq 2.0$ at the bivariate analysis level was included in a logistic regression model for test of probability of those associations.

3.8 Ethical consideration

Permission was sought from the ethical review board of the University for Development Studies. Additional clearance was taking from the Committee on Human Research, Publication and Ethics of the Kwame Nkrumah University of Science and Technology, College of Health Sciences (Ref. number: CHRPE/AP/243/20). Informed consents from the Ghana Education Service, guardians of respective adolescent students were sought before all types of data was gathered. Hence all information regarding the research was made available to all the parties involved in the research.

Both the respondents and their guardians were allowed to give their approval signed/thumb printed on a consent form or give a verbal approval for assessment. They were assured that information gathered from them are mainly for academic purposes and hence their privacy would be safeguarded.

CHAPTER FOUR

RESULTS

4.1 Sociodemographic characteristics

Four hundred and nine questionnaires were completed and included in the data analysis (409) out of 424 questionnaires administered to adolescent students in the Berekum municipality. There was therefore a 96% response rate.

More than half (54.3%) of the study participants were aged between 13 and 16 years (mean ± SD = 13.88 ± 2.18), females (53.3%) and went to government schools (51.3%). Schools were predominantly located in the Peri-Urban settings (55.7%). Also, more than three-quarters (94.1%) of the adolescence resided in homes with at least 10 household members, and 53% were also Junior High School students with the remaining in the upper primary. They were mostly Bono by tribe (88%) and lived in the same house with parents (64.1%). Most children lived in smaller family types (60.6 %) than in larger families (39.4 %) (Table 4.1).

Table 4.1: Sociodemographic characteristics

Variable	Frequency	Percentage (%)
Age of respondents (Means ± SD)		
10-12 years	131	32.0
13-16 years	222	54.3
17-19 years	56	13.7
Mean ± SD **age**	13.88 ± 2.18	
School type		
Government	210	51.3
Private	199	48.7
Location of school		
Peri-Urban	228	55.7
Rural	181	44.3
Grade of respondents		
Class 4	48	11.7
Class 5	79	19.3
Class 6	66	16.2
Form 1	64	15.6
Form 2	55	13.5
Form 3	97	23.7
Gender of respondents		
Male	191	46.7
Female	218	53.3
Ethnicity		
Bono	360	88.0
Ashanti	25	6.1
Others	24	5.9
Father's education		
Basic education	215	52.6
Secondary/tertiary education	166	40.6
None	28	6.8

Father's occupation		
Farming	175	42.8
Trading	75	18.3
Civil servant	48	11.7
Others	111	27.1
Mother's education		
Basic education	270	66.0
Secondary/tertiary education	95	23.2
None	44	10.8
Mother's occupation		
Farming	133	32.5
Trading	222	54.3
Civil servant	27	6.6
Others	27	6.6
Living in the same house with parents		
Yes	262	64.1
No	147	35.9
Family head		
Father	219	53.5
Mother	81	19.8
Grandparent	98	24.0
Others	11	2.7
Family type		
Nuclear	248	60.6
Extended	161	39.4
Family size		
Up to 10 members	385	94.1
More than 10 members	24	5.9

4.2 Nutritional status and Dietary diversity

Generally, most adolescence had normal weight (66%), 13% were thin and about 21% were either overweight or obese.

The average number of times adolescents ate in the day prior to the survey was 3.46 ± 1.11 times. Most adolescent students (64.3%) ate three meals a day though they were mostly consumed in a weekday (82.9%) rather than a weekend (17.1%), and mostly not days characterized as 'ceremonial' (61.4%).

The average dietary diversity score for respondents was found to be 6.40±1.79. Also, it was found that 65.8% had high dietary diversity, and 34.2% reported low dietary diversity (Table 4.2).

Table 4.2: Nutritional status and dietary diversity

Variable	Frequency	Percentage (%)
Nutritional status (BAZ used)		
Normal	270	66.1
Thin	55	13.4
Overweight/obese	84	20.5
Mean ± SD BAZ	0.16 ± 0.09	
Diet frequency		
3 meals a day	263	64.3
At least four meals a day	146	35.7
Mean ± SD	3.46 ±1.11	
What day was the previous day?		
Weekend	70	17.1
Weekday	339	82.9

Variable	Frequency	Percentage (%)
Was yesterday a 'ceremonial' a day?		
Yes	158	38.6
No	251	61.4
Dietary diversity score		
Means ± SD	6.40±1.79	
Low dietary diversity (DDS<5)	140	34.2
High dietary diversity (DDS ≥5)	269	65.8

4.3 Physical activity (PA)

Weekly average metabolic equivalence of moderate and vigorous physical activity was 756.9 ± 1,284.9 minutes per week and 2,621.5 ± 4,435.3 minutes per week respectively. Also, almost half (46.2%) of the respondents practiced 'health-enhancing physical activity' (HEPA) whiles 44.7% where moderately active, but 9.1% were physically inactive. More than two-thirds (67%) of the respondents also were not involved in extra classes after school, and those involved in extra class averagely spent less than 3 hours a session (2.83 ± 1.04 hours), usually less than 5 days in the week (75.8%). (Shown in table 4.3).

Table 4.3: Physical activity

Weekly physical activity(METs min./week)	mean±SD	
Mean MET of walking	840.9±1,809.9	
Mean MET of moderate PA	756.9±1,284.9	
Mean MET of vigorous PA	2,621.5±4,435.3	
Total weekly MET	4,216.5±5,749.9	
	Frequency	**Percentage**
Physically inactive	37	9.1
Moderately/minimally active	183	44.7
Vigorous physical activity/HEPA	189	46.2
Do you do extra classes?		
Yes	132	32.3
No	277	67.7
Number of days student engaged in extra class (132)		
<=5 days	100	75.8
>5 days	32	24.2
Mean ± SD per week	5.02±1.18	
How much time spent on classes? (hours)		
<=3hours	89	67.4
>3hours	43	32.6
Mean ± SD	2.83 ± 1.04	

Note: if vigorous PA is ≥3days/week and time spent ≥20 minutes OR moderate PA is≥5 days/week OR walking≥30 minutes OR total MET ≥600 MET-minute/week----(moderate PA)

If vigorous PA is ≥3 days/week and MET of vigorous PA ≥1500 minutes/week OR total MET ≥3000 MET-minute/week----(vigorous/Health enhancing PA)

4.4 Body fat composition

Twenty percent of the adolescents had low general body fat whiles 52% were normal and 28% had high/very high BF. Per their muscle fat, 71.4% measured very high, 6.4% were low and 22.2% were normal (Shown in Table 4.4).

Table 4.4: Body fat composition

Fat composition	Frequency	Percentage
Total fat percentage		
Low	82	20.0
Normal	212	51.9
High/Very high	115	28.1
Muscle fat percentage		
Low	26	6.4
Normal	91	22.2
High/Very high	292	71.4

4.5 Bivariate analysis of sociodemographic characteristics and body fat

It was found that there was statistically significant difference in the mean body fat of adolescent students taking their age into consideration (M±SD; 19.07±7.03, $p<0.001$), with mean adiposity increasing with age. Students from private schools likewise demonstrated a significantly high mean fat percent than their counterpart's government schoolers (23.05±9.60 vs 19.77±7.93, $p<0.001$). Also, mean body fat increased alongside the increase in the student's grade from class 4 to JHS 3 (16.55±7.12 vs 26.43±10.49). Also, urban schoolers significantly presented high body fat compared to those in the rural setting (23.32±9.70 vs 18.90±7.12). Although, the findings did not show significant difference in body fat of students based on their parent's educational background, there was a mean difference per their maternal occupation whereby adolescence of trading mothers showed high mean body fat (23.07±9.66, <0.001). (Table 4.5)

Table 4.5: Student sociodemographic factors and body fat composition

Variable		**Body fat percentage**	
Age of respondents	**N (%)**	**Mean ± SD**	**P value**
10-12	131	19.07±7.03	<0.001[a]
13-16	222	21.81±9.38	
17-19	56	24.96±9.67	
School type			
Government	210	19.77±7.93	<0.001[b]
Private	199	23.05±9.60	
Location of school			
Urban	228	23.32±9.70	<0.001[b]
Rural	181	18.90±7.12	
Class of student			
Class 4	48	16.55±7.12	<0.001[a]
Class 5	79	20.22±6.80	
Class 6	66	20.99±7.44	
Form 1	64	20.22±8.21	
Form 2	55	20.05±8.81	
Form 3	97	26.43±10.49	
Gender			
Male	191	16.68±6.87	<0.001[b]
Female	218	25.47±8.49	
Ethnicity			
Bono	360	21.19±8.94	0.283[a]
Ashanti	25	21.21±9.82	
Others	24	24.18±7.39	
Living in the same house with parents			
Yes	262	21.13±8.81	0.490[b]
No	147	21.77±9.14	
Father's highest education			
Primary	33	20.49±11.20	0.851[a]
JHS	182	21.48±8.07	
SHS/SSS	127	21.85±9.22	
Tertiary	39	20.25±10.61	
None	28	21.02±7.66	

Father's occupation			
Farming	175	21.94±8.28	0.157[a]
Trading	75	22.50±7.80	
Civil servant	48	20.97±11.58	
Others	111	19.86±9.20	
Mother's education			
Primary	69	20.95±6.81	0.741[a]
JHS	201	21.89±9.57	
SHS/SSS	78	20.29±9.87	
Tertiary	17	21.51±6.11	
None	44	21.48±8.00	
Mother's occupation			
Farming	133	18.92±7.52	<0.001[a]
Trading	222	23.07±9.66	
Civil servant	27	21.20±7.20	
Others	27	19.55±7.63	
Family type			
Nuclear	248	21.40±9.11	0.919[b]
Extended	161	21.31±8.65	
Family head			
Father	219	21.43±8.91	0.419[a]
Mother	81	20.25±9.06	
Grandparent	98	22.34±8.86	
Others	11	19.70±8.76	
Family size			
Up to 10 members	385	21.22±8.88	0.182[b]
More than 10 members	24	23.73±9.45	

[a] ANOVA

[b] Independent t-test

4.6 Bivariate analysis of sociodemographic characteristics and muscle fat

In addition to age, parent's occupation and family type and size, grade of students did not show significant difference in the average muscle fat composition of assessed adolescents in the current study. Contrary to that, gender (Male=37.74±5.73 vs Female=32.52±3.59), school type (government=35.84±5.32 vs private=34.03±5.30), parental educational status assumed a significant difference in their muscle fat levels. (Table 4.6)

Table 4.6: Student sociodemographic factors and muscle fat composition

Variable		Muscle fat percentage	
Age of respondents	**N (%)**	**Mean ± SD**	**P value**
10-12	131	34.44±3.06	0.174[a]
13-16	222	35.00±5.54	
17-19	56	36.04±8.22	
School type			
Government	210	35.84±5.32	0.001[b]
Private	199	34.03±5.30	
Location of school			
Urban	228	34.47±5.52	0.04[b]
Rural	181	35.57±5.15	
Class of student			
Class 4	48	34.16±3.68	0.240[a]
Class 5	79	34.69±2.50	
Class 6	66	34.82±3.77	
Form 1	64	35.68±4.33	
Form 2	55	36.29±7.42	
Form 3	97	34.44±7.51	
Gender			
Male	191	37.74±5.73	<0.001[b]
Female	218	32.52±3.59	
Ethnicity			
Bono	360	34.93±5.45	0.587[a]
Ashanti	25	35.92±4.47	
Others	24	34.40±5.27	
Living in the same house with parents			
Yes	262	35.37±5.28	0.037[b]
No	147	34.22±5.49	

Variable		Muscle fat percentage	
	N (%)	Mean ± SD	P value
Father's highest education			
Primary	33	35.35±5.94	0.010[a]
JHS	182	35.65±5.15	
SHS/SSS	127	33.53±5.36	
Tertiary	39	35.78±5.61	
None	28	35.38±5.078	
Farming	175	34.72±5.28	0.422[a]
Trading	75	34.50±4.17	
Civil servant	48	34.94±5.79	
Others	111	35.66±6.04	
Mother's education			
Primary	69	34.86±4.93	0.966[a]
JHS	201	35.05±5.24	
SHS/SSS	78	34.74±6.41	
Tertiary	17	35.70±3.14	
None	44	34.79±5.56	
Mother's occupation			
Farming	133	36.15±5.84	0.019[a]
Trading	222	34.31±5.18	
Civil servant	27	34.47±5.40	
Others	27	34.91±3.60	
Family type			
Nuclear	248	35.23±5.72	0.208[b]
Extended	161	34.54±4.81	

Variable		**Muscle fat percentage**	
	N (%)	**Mean ± SD**	**P value**
Family head			
Father	219	35.39±5.22	0.090[a]
Mother	81	34.74±6.29	
Grandparent	98	33.96±4.93	
Others	11	36.95±3.90	
Family size			
Up to 10 members	385	35.04±5.43	0.208[b]
More than 10 members	24	33.62±4.37	

[a] ANOVA

[b] Independent t-test

4.7 Correlation analysis

Pearson correlation for BMI and body fat percentage was found to be highly positive and statistically significant (*r*=0.763, p<0.001), implying that the body fat of adolescents increased with their BMI. However, muscle fat marginally showed a negative correlation with BMI (*r*= -0.308, p<0.001). (Table 4.7)

Table 4.7 Correlation matrix for BMI and body composition

Variables	*r*-value (Significance)	
	Body fat percentage	Muscle fat percentage
BMI	0.763(<0.001)	-0.308(<0.001)
Body fat percentage	1	-0.663(<0.001)
Muscle fat percentage		1

Correlation is significant at the 0.01 level (2-tailed).

4.8 Determinants of body fat composition

4.8.1 Determinants of high total body fat

In a logistic regression, factors including gender, location of school and mother's occupation were found to have a significant effect on high body fat (p <0.05). Compared with females, male adolescents had 2.5 odds of having high body fat [OR=2.5; CI (1.3-5.1); p=0.007]. Also, schooling in urban locations had a 4.0 odds of presenting high body fat than rural schoolers [OR=4.2; CI (2.1-8.5); p<0.001]. Students whose mothers were civil servants significantly had 11.3 odds and those whose mothers were traders had 5.3 odds of having high body fat compared to their counterparts whose mothers were into farming [OR=11.3, p=0.017 & OR= 5.3, 0.011]. Finally, dietary diversity of the study group did not affect their body fat levels. (Table 4.8.1).

Table 4.8.1: Multinomial logistic regression of the determinants of high total body fat

Variables			95% CI of AOR	
	OR	P-value	Lower	Upper
Sex				
Male	2.563	0.007	1.292	5.082
Female	Ref			
School type				
Government	0.888	0.724	0.460	1.716
Private	Ref			
School location				
Urban	4.242	<0.001	2.119	8.493
Rural	Ref			
Living in same house with parents				
Yes	1.301	0.405	0.700	2.418
No	Ref			

Fathers occupation				
Trading	1.384	0.508	0.528	3.627
Civil servant	0.687	0.445	0.263	1.799
Farming	Ref			
Mother's occupation				
Civil servant	11.317	0.017	1.537	83.303
Trading	5.279	0.011	1.474	18.899
Farming	Ref			
Family head				
Father	4.683	0.188	0.471	46.563
Mother	3.200	0.336	0.299	34.241
Grandparent	Ref			
Family size				
Up to 10 members	0.682	0.500	0.224	2.075
More than 10 members	Ref			
Dietary diversity				
High dietary diversity (DDS ≥5)	0.428	0.908	0.746	1.732

4.8.2 Determinants of high muscle fat

Apart from school location (OR=0.572, p=0.027), factors such as age, living with parents in same house and parents occupation had insignificant odds of determining ones high muscle fat level (Table 4.8.2)

Table 4.8.2: Multinomial logistic regression of the determinants of high muscle fat.

Variables			95% CI of AOR	
	OR	P-value	Lower	Upper
Age				
10-12	1.139	0.717	0.563	5.082
13-16	1.744	0.099	0.901	3.375
17-19	Ref			
Gender				
Male	0.673	0.100	0.419	1.079
Female	Ref			
School type				
Government	1.036	0.882	0.647	1.659
Private	Ref			
School location				
Urban	0.572	0.027	0.349	0.937
Rural	Ref			
Living in same house with parents				
Yes	1.238	0.388	0.763	2.009
No	Ref			
Father's education				
Primary	1.123	0.840	0.364	3.646
JHS	1.684	0.260	0.680	4.174
SHS/SSS	1.132	0.792	0.451	2.841
Tertiary	1.421	0.547	0.453	4.453
None	Ref			
Mother's occupation				
Farming	2.721	0.070	0.921	8.033
Trading	0.684	0.440	0.261	1.792
Civil servant	Ref			

CHAPTER FIVE

DISCUSSION

5.1 Sociodemographic characteristic

The current study analysed responses from 424 adolescent students from an interview-based and anthropometric assessments questionnaires. Among the sociodemographic variables assessed were age, school type and location, grade of students, their gender, family head, their ethnicity, family type and size and parents educational and occupational statuses. These sociodemographic variables were assessed as baseline for the purpose of assessing the body fat composition and its determinants among adolescent school children in the Berekum municipality of Bono region.

Female population in the current study group was dominant (54%) and was similar to findings presented by (Abizari & Ali, 2019) in the Northern region in a school-based survey to determine dietary pattern. On the contrary in the Bono regional capital (Sunyani), studies by (Ali et al., 2018) showed a higher male group (52.4%) than females. For age distribution, there was a slight disparity in the mean age compared to the current study (mean ± SD = 13.88 ± 2.18) vs (15.6 ± 2.0 years) in Abizari et al's work, usually due to the exclusion of upper primary students in their study, that has shown an obvious increase in the mean age. Concurrently, mothers and fathers of assessed students were predominantly basic school leavers. This is very common to a typical Ghanaian setting whereby most people have acquired basic education, emphatically in the Bono region.

There was a predominant number of father's involved in agricultural works (54.3%). This may represent the reality because Berekum is noted for its agricultural activities as was described in the 2010 population and housing census, 43.4% were engaged in skilled agricultural, forestry and fishery works. There was however a variation in the number of household members in the current study and the one measured by the Ghana Statistical Service in 2010; thus 10 vs 4 persons per household respectively. The wide difference could be anticipated to be caused by respondents in the current study's inability to understand the meaning of a household as group of people eating from one pot, they may have counted all the occupants of their household which could account for this observation.

5.2 Determinants of body fat composition

The current study recorded a 28% high/very high percentage body fat, 52% normal body fat and 20% low. It further showed male and female difference in mean body fat percentage; male 16.68±6.87 vs female 25.47±8.49, $p<0.001$. Gender difference in body fat however has been observed in studies in Ghana by (Asante et al., 2021; Nyakotey, Ananga, & Apprey, 2020) and (Vuvor & Harrison, 2017) and elsewhere by (Bawadi et al., 2020; Hawkes et al., 2011). Genetically, females hold more fat than males, for example an active female normally would have 12% to 24% body fat whereas males possess 14% to 17% (Jasik & Lustig, 2008). This natural difference could be attributed to the higher estrogen production in females during their pubertal period than males. Estrogen triggers fat accumulation in the depots of gluteal cells, hips, lower abdomen and thighs. For instance, increasing mean body fat percentage along the pubertal growth spurt is emphasized by Jeddi et al. (2014), whereby females had increased percentage fat compared to males, with hormonal differences as the predicted cause. It is however not conclusive to say that females highly diversified diet from the current study may be contributing to their subsequent high body fat compared to males with low dietary diversity.

Furthermore, school location was able to significantly predict one's high body fat status. Adolescents in the urban dwelling schools have shown over 4 odds of having high percentage fat. Means of transportation to school, school food environment and parental occupation in urbanized schools could be linked to the high odds. Most children in urban areas are commonly transported to schools by passive transport which increases time spent sitting than walking; a recipe for weight gain (Thorp, Owen, Neuhaus, & Dunstan, 2011). To reaffirm this assertion, observation in China was that commuting to school by children was predictive of lower BMI and %fat. Children who commuted via active modes had lower scores of all indicators of obesity than those who used passive transport. Commuting was associated with lower odds of being obese and lower odds of having depressive symptoms compared with children using passive transport (Sun, Liu, & Tao, 2015). Private schools in the urban study location commonly have school buses compared to government schools, this may however contribute to the difference in energy expenditure among the two groups of adolescence accessed.

Urban school food environment is likely to be dominant with highly processed foods and sugary beverages which has been described to increase ones chances of having high percentage fat (Howe, Black, Wong, Parnell, & Skidmore, 2013). Odegaard, et al (2012) similarly stressed that, body fat increased with sugar-based beverages (SBB), implying that SSB could lead to adiposity and subsequent disease over time among adolescents.

As was observed in the current study, age was a common factor for the changes that occurred in adolescent body fat. During adolescence, whiles boys tend to add more lean mass and less body fat, girls put on more body fat than boys during adolescence and this is normal and healthy. When an adolescent is growing, their body tends to lose lean tissue, muscles, and vital organs such as the liver and kidney may also lose some of their cells. The bones may lose some of their minerals and become less dense. Tissue loss reduces the amount of water in your body. As a result, the amount of body fat increases steadily when they are growing. This may partly lead to the age differences in the changes observed in adolescent body fat.

For the adolescent muscle fat, significantly males had higher mean muscle fat than females, whiles higher muscle fat may over-shadow the actual muscle mass, having higher muscle fat has positive effect on total body weight and may be disguised for a dense lean mass in adolescents. Aside accumulation of muscle fat explained by hormonal imbalance such as rise in cortisol levels (Bajer, Vlcek, Galusova, Imrich, & Penesova, 2015), the current study apart from significantly explaining that females had high mean increase in muscle fat, attending private school and/or located in an urban setting increased ones mean muscle fat percentage.

In conformity with an assertion made by (Odegaard, Choh, Czerwinski, Towne, & Demerath, 2012) that muscle fat increased with sugar-based beverages in Nigerian adolescents. Whiles in adult population dietary diversity may be linked to diet quality and for that matter leading to weight reduction (de Oliveira Otto et al., 2018), there was a contradiction in the current study whereby eating more than five food groups rather increased ones muscle fatness levels. The variety from which the adolescents choose were predominantly foods that were either high in sugar or fat yet have been put in several forms to make them appealing to consumers and since most of the study respondents were from the urban center they may be readily available for purchase and consumption.

The findings from this study demonstrate higher percentage of the study sample consume highly diversified diet (65.8%), which suggest that respondents may have their diets concentrated with all the known macronutrients including carbohydrate, fat and protein. Since excessive intake of these nutrient may suggest high body fat (Wang, Storlien, & Huang, 2002), the current study may want to allude to the fact irrespective of not showing significance diet may contribute to the current body fat, probably using other methodologies such as dietary pattern or DXA provide advanced knowledge.

5.3 Adolescent physical activity

School going adolescents may very often be involved in sporting activities at school leisure hours and at homes, these activities are often dominated by continues running over a period, and contributing to vigorous PA levels as observed in the current results whereby almost half of the study respondents practiced vigorous physical activity whiles 44.7% where moderately active.

In the current study there was an observed high physical activity both moderate and vigorous compared to the findings by Adilson et al among 105 Lower, Middle, High Income countries albeit most adolescents did not engage in PA up to 3 days/week. It is interestingly easy to juxtapose the current study with the one by Adilson and co all because in both studies males were predominantly represented yet it is difficult to understand where the difference in physical activity could emanate from. It is however important to note that whether vigorous or moderate PA, the goal is to obtain good health outcomes and it is recommended that these practices are encouraged to be sustained among the young adults so as to make it their lifestyle.

Comparing the current studies to the observations made in Poland by Jozef et al 2012, there was just about two thirds of adolescents involved in moderate to vigorous PA. The two findings contradict and in one way or the other the observations by Jozef is not different from what is widely observe in European Union countries whereby approximately two thirds adolescents do not attain the recommended level of PA (Woynarowska et al, 2005).

At all levels, any form of healthy exercise prescription is found to be healthy through weight regulation and physiology. The fact is that it goes a long way to make adolescents healthy and should be encouraged.

5.4 Dietary diversity of adolescents

The basis for emphasizing dietary diversity is mainly due to nutrition deficiency and the importance of increasing food and food group variety to ensure nutrient adequacy.

The average dietary diversity score for adolescent students in the current study was found to be 6.40±1.79 which was consistent with Aurino (2017) and (Nithya & Bhavani, 2018). Also, it was found that 65.8% had high dietary diversity, 31.3% with moderate dietary diversity and 2.9% reported low dietary diversity. Unlike other observations of overall low dietary diversity made by (Wiafe et al, 2023), (Ayele, 2023) and (Wemakor & Laari, 2018) , it could be suggested that higher dietary diversity of adolescent in the Berekum municipality may result from the peri-urban nature of the settlement certainly because in the municipality variety of foods are marketed in the central business area and in deed most of the schools even though are government they are located within the peri-urban area making adolescents have ready access and for that matter select from several food groups.

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Adolescents in the urban dwelling schools have shown higher odds of high percentage body fat but not muscle fat. BMI was also significantly higher in urban schools. Means of transportation to school and parental occupation in urbanized schools could be linked to body composition of adolescents.

Forty-six percent of the respondents engaged in health-enhancing physical activity' (HEPA) whiles 44.7% were moderately active, but 9.1% were physically inactive.

The average dietary diversity score for respondents was found to be 6.40±1.79. Also, it was found that 65.8% had high dietary diversity, and 34.2% reported low dietary diversity

Factors such as schooling in urban locations and students whose mothers were civil servants showed higher odds of high adolescent body fat rather than those whose mothers were into farming and trading.

RECOMMENDATIONS

1. School health activities must be redirected to include constant monitoring of physical activities among adolescent students.
2. Yearly nutrition surveillance is recommended for the school age adolescent group to understand their nutritional situation to guide nutrition policies for the age group.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

UNIVERSITY FOR DEVELOPMENT STUDIES
SCHOOL OF ALLIED HEALTH SCIENCES
DEPARTMENT OF NUTRITIONAL SCIENCES

BODY FAT COMPOSITION AND ITS DETERMINANTS AMONG ADOLESCENT STUDENTS IN THE BEREKUM MUNICIPALITY

Consent: Hello, good morning/afternoon. We are representatives from the University for Development Studies. We are doing a research on **body fat composition and its determinants among adolescent students in the Berekum Municipality**. You are among the students selected to respond to questions in an interview about the topic. You are to be involved in about 25 minutes of assessment and interview. Your participation is very much appreciated and voluntary.

We would be very grateful if you accept for us to proceed with the interview else you can opt out. Please you can now tell me whether you accept or not.

Accepted: ________________

Rejected: ________________

Identification

1) Questionnaire number: _______________
2) Interview date: ____/_____/2020 (mm/dd/yyyy)
3) School type: 1. Government 2. Private
4) School name: ____
5) Location of school: 1. Urban 2. Rural
6) Interviewer name: ___________________________________sign: __________

SECTION A: SOCIO-DEMOGRAPHY

1) Pupil's name: ____
2) Class of pupil: 1) Class 4 2) Class 5 3) Class 6 4) JHS 1 5) JHS 2 6) JHS 3
3) Pupil's date of birth: ____/_____/______ (mm/dd/yyyy)

4) Age of pupil: ______________

5) Sex: 1) Male 2) Female

6) Ethnicity: 1) Bono 2) Ashanti 3) Fante 4) Safwi 5) Dagomba 6) Others (specify) ____________

7) Father's highest educational level completed:

1) Primary 2) JHS 3) SSS/SHS 4) Tertiary 5) None 6) Others (specify) ________________

8) Father's occupation: 1) Farming 2) Trading 3) Civil servant 4) Others (specify) ____________

9) Mother's highest educational level completed:

1) Primary 2) JHS 3) SSS/SHS 4) Tertiary 5) None 6) Others (specify) ________________

10) Mother's occupation: 1) Farming 2) Trading 3) Civil servant 4) Others (specify) ____________

11) Do you live in the same house with your parents? 1) Yes 2) No

12) How do you describe your family type? 1) Nuclear (only parents and siblings) 2) Extended (parents, siblings and other relatives)

13) What is your family size? ______________ (Count yourself and family members living together)

14) Who is your family head? 1) Father 2) Mother 3) Grandparent 4) Others (specify) ____________

SECTION B: 24 HOUR DIETARY INTAKE

1) What day was yesterday? 1) weekend 2) week day
2) Was yesterday a normal day? 1) Yes 2) No (**note:** days characterized by weeding's, outdooring's, funerals etc. are not normal days)
3) How many times did you eat any kind of food yesterday? (Either home or outside) ______________
4) In the past 24 hours, mention all foods and drinks you took either home or outside **(during day and night yesterday)**.

Meal	**Description of dish/dishes**	**Ingredients**	**Place of consumption (home, school, street)**
Breakfast			
Snack before lunch			

Lunch			
Snack after lunch			
Dinner			
Snack after dinner			

From the meals mentioned, indicate whether the pupil, ate the following food groups during the past 24hours either at home or outside home.

	Food groups	Examples	0=No 1=Yes
1	Cereals	Corn/maize, rice, wheat, sorghum, millet or other grains and grain products (biscuits, banku, mansa, TZ, akple, kenkey etc)	
2	Starchy roots, tubers and plantain	Cassava, cocoyam, yam, plantain (fufu, ampesi, plantain chips, etc)	
3	Vitamin A rich vegetables and tubers	Carrot, pumpkin, sweet potatoes (orange flesh) , squash, red sweet pepper etc.	
4	Dark green leafy vegetables	Kontomire, cabbage, lettuce/kale, spinach, cassava leaves, alefu, ayoyo, bra soup, cucumber, okro leaves, green beans, green pepper, 'asahaa', etc.	
5	Other vegetables	Tomato, onion, eggplant, garden eggs, okro, solanum (kwahu nsuswaa) and other locally available vegetables.	
6	Vitamin A rich fruits	Ripe mango, apricot, watermelon, ripe pawpaw, pink or red grape, avocado, tangerine etc and 100% fruit juice made from these or other available vitamin A rich fuits.	
7	Other Fruits	Banana, orange, pineapple, dates, berries, apple	
8	Flesh meats	Beef, goat, chicken, lamb, guinea fowl, turkey, duck, other birds, rabbit, khebab, pork, bush meat	
9	Organ meat	Liver, kidney, heart, gizzard, or other organ meats, or blood-based foods	
10	Eggs	Eggs from chicken, ducks, guinea fowl etc.	

11	Fish and sea food	Fresh or dried fish or shellfish, all kinds of fish; amane, nsesaawa, keta school boys, 1 man 1000	
12	Legumes, nuts and seeds	Dried beans, dried peas, lentils, nuts, seeds or foods made from these (waakye, groundnut soup, akatowa nkwan, soya, peanut butter, palm nut soup, boiled or roasted groundnut	
13	Milk and milk products	Milk, cheese, yogurt, or other milk products; waagashi	
14	Oils and Fats	Oil, fats or butter added to food or used in cooking	
15	Sweets	Sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies, cakes, amudro, sobolo, ice cream etc	
16	Spices, condiments, beverages	Spices (black pepper, red pepper, salt), condiments (bouillon cubes, dawadawa), coffee, tea, milo	

SECTION C: ONE WEEK PHYSICAL ACTIVITY ASSESSMENT

What to note in answering the following questions,

- Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal
- Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

Now answer the following questions;

1) Has COVID 19 change your physical activities? 1) Yes 2) no (**if No, skip question 5a**)

2) If yes has it affected the type of physical activities you do? 1) Yes 2) no

3) If yes has it affected the frequency of physical activities you do? 1) Yes 2) no

4) If yes has it affected the time you spend on physical activities? 1) Yes 2) no

5a) During the last 7 days, on how many days did you do **vigorous** physical activities like heavy lifting, digging, jogging, playing football or fast bicycling? **Think about *only* those physical activities that you did for at least 10 minutes at a time.** None _______ or ________________days per week

5b) How much time in total did you usually spend on one of those days doing vigorous physical activities? __________**hours** __________**minutes**

6a) **Again, think *only* about those physical activities that you did for at least 10 minutes at a time.**

During the last 7 days, on how many days did you do **moderate** physical activities
like carrying light loads, bicycling at a regular pace, or tennis? **Do not include walking.** None _______ or ________________days per week

6b) How much time in total did you usually spend on one of those days doing moderate physical activities? __________**hours** __________**minutes**

7a) During the last 7 days, on how many days did you **walk** for at least 10 minutes at a
time? This includes walking at school and at home, walking to travel from your home to town, and any other walking that you did solely for recreation, sport, exercise or leisure.

None _______ or ________________days per week

7b) How much time in total did you usually spend walking on one of those days??
__________**hours** __________**minutes**

The last question is about the time you spent sitting on weekdays while at school, at home, while doing school work and during leisure time. This includes time spent sitting at a desk, visiting friends, reading, traveling on a bus or sitting or lying down to watch television.

8) During the last 7 days, how much time in total did you usually spend ***sitting*** on a **week day? _________ hours _____________ minutes**

9) Do you engage in extra classes during school days or weekend? 1) Yes 2) No **(if no, skip to Section D**)

10) If yes, how many days do you go for classes in a week ______________

11) On average how long does the classes take in a day ______ Hours______ Minutes. (hours: minutes)

SECTION D: MORBIDITY HISTORY

1. Did you get diarrhea in the past two weeks? (Diarrhea means having loose watery stools more than 3 times a day?). 1) Yes 2) No

2. Have you had Fever/Malaria (High temperature with shivering/ suspected malaria in the past two weeks?) 1) Yes 2) No

3. Have you had any other sickness in the last two weeks? 1) Yes (specify) ______________ 2) No

SECTION E: ANTHROPOMETRIC MEASUREMENTS

1. Age _______________ years

2. Weight ________________ kg

3. Height ________________ cm

Record the following measures from the BIA scale

4. BMI __________________ kg/m^2

5. Total fat __________ %

6. Muscle fat _________kg

APPENDIX 2: ETHICAL CLEARANCE

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES

SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/243/20

17th July, 2020.

Mr. Wisdom Peprah
Department of Nutritional Sciences
School of Allied Health Sciences
University for Development Studies
TAMALE

Dear Sir,

LETTER OF APPROVAL

Protocol Title: ***"Body Fat Composition and its Determinants among Adolescent Students in the Berekum Municipality."***

Proposed Site: ***Basic Schools, Berekum Municipality, Bono Region.***

Sponsor: ***Principal Investigator.***

Your submission to the Committee on Human Research, Publications and Ethics on the above-named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 30th December, 2019 from the Berekum Municipal Education Directorate (study site) indicating approval for the conduct of the study at the Municipality.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning **17th July, 2020 to 16th July, 2021** renewable thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you, Sir, for your application.

Yours faithfully,

Rev. Prof. John Appiah-Poku.
Honorary Secretary
FOR: CHAIRMAN

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