Variations In Body Composition Among Adult Males With Different Lifestyles

A Thesis presented to the
Department of

NUTRITION AND FOOD SCIENCE

UNIVERSITY OF GHANA, LEGON

By

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In partial fulfillment of the requirements for the award of a degree in

MASTER OF PHILOSOPHY

in

NUTRITION

May 2001

DECLARATION

This research was conducted by me under the supervision of Dr. WB Owusu of the Nutrition and Food Science Department, University of Ghana, Legon

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DEDICATION

To Nana Yaa and Awura Adjoa ,

and to the HAWK, you…

ACKNOWLEDGEMENT

I am most grateful to God Almighty for giving me strength to do the things I do. I am also grateful to my supervisor, Dr. WB Owusu, whose guidance has led to the completion of this thesis.

I also express my sincere gratitude to all the men who willingly took part in this study, and to Mr. Henry K. Adi (librarian) Nutrition and Food Science Department, University of Ghana, Legon, for his assistance at various stages of this work. Special mention must also be made of Mr. F.K Tayie and Dr. Tano-Debrah (lecturers in the Department of Nutrition and Food Science, University of Ghana) for their extreme kindness during the data analysis segment of the thesis. To the Follow-up team, Screening team and Office Staff of the MGRS/ WHO Project I say thank you for your wonderful support and concern.

To Akpene, Kwame, Tobias, Eugene, Vivienne, Tanefa and Paa Kow Micah, I say a "Big Thank You" for your prayers, concern and support.

More importantly, to my family for their encouragement, support and the confidence they reposed in me during these most trying moments, I say a big 'Ayeekoo'. Those not mentioned are not forgotten; God Bless you all !!!

ABSTRACT

Knowledge about body composition is essential when one considers nutritional status, body weight, and health. Excess body fat is associated with chronic diseases such as diabetes mellitus, coronary heart diseases and strokes, while underweight or under-nutrition in adults can result in reduced work capacity and affect productivity. Both conditions exist in developing countries. Research on body composition is widespread in developed countries. Literature is, however, not readily available on the trends in body composition in developing countries. This study was carried out with the aim of investigating trends in body composition among adult males and how they are influenced by age, socio-economic status (measured by the mean grade point system), energy expenditure, energy intake, and energy balance.

Information on age, socio-economic status, energy expenditure, and energy intake were obtained using questionnaires, while anthropometric measurements were taken using standardized procedures. Measures of body composition were derived using various equations from which Upper-arm Fat Estimate (UFE), Fatmass (FM), Total Skinfold Thickness (TSKF), Percent Body Fat ($BF\%_{DER}$ and $BF\%_{LEAN}$), Body Mass Index (BMI) and Waist-Hip Ratio (WHR) were used as indicators of body fat, while Lean Tissue Mass (LTM) and Bone Mineral Content (BMC) were used as indicators of fat-free mass.

The mean age of the study population was 35.4 years. From regression analysis, age was found to be a significant determinant of both fat mass and fat-free mass. Ten men were found to have accumulated abdominal fat (WHR > 0.98), and the minimum age for this group was 42 years. Socio-economic status was also found to be a significant predictor for all the indicators of body composition.

Construction workers had the highest mean energy expenditures (4005 kcal/day), and the lowest mean energy intakes (3432 kcal/day). On the contrary, office workers had the lowest mean energy expenditure and the highest mean energy intake. Construction workers also had the least values for mean FM, LTM, and BMC (8.45 kg, 51.67 kg and 3.94 kg, respectively). Office workers had the highest mean FM (11.61 kg), while drivers had the highest values for LTM and BMC (53.52 kg, and 5.01 kg, respectively).

Men who were in the low socio-economic group had the smallest energy balance (-134.3 kcal), with those in the high socio-economic group having the highest (positive) energy balance (1346 kcal).

Energy expenditure, energy intake, and energy balance were significant determinants for UFE and TSKF, while their influence in predicting FM, $BF\%_{DER}$, $BF\%_{LEAN}$, LTM, and BMC were not significant ($\beta \cong 0.00$).

Age and socio-economic status were significantly related to all indicators of body composition. Occupation had a marked effect on energy intake and energy expenditure, and also on FM, LTM, and BMC. The expected result between energy expenditure and energy intake and some indicators were not seen and this could have been due to reliance on the memory of the respondents for information as they might have over- or under-estimated their energy intake and expenditure.

GLOSSARY OF ABBREVIATIONS

AGR – Android- Gynoid Ratio

Bal Energy Balance

BF – Body Fat

BF%$_{(DER)}$ – Percent Body Fat (using the equation by Deurenberg et al.(1991))

BF% $_{(LEAN)}$ - Percent Body Fat (using the equation by Lean et al .(1996))

BIA – Bioelectric Impedance Analysis

BCM – Body Cell Mass

BMC – Bone Mineral Content

BMD – Bone Mineral Density

BMI – Body Mass Index

CHDs – Coronary Heart Diseases

CRONOS – Cross Cultural Research on Nutrition of Older Subjects

CVDs – Cardiovascular Diseases

CT- Computer Tomography

DEXA – Dual Energy X-ray Absorptiometry

DPA – Dual Photon Absorptiometry

ECW – Extra Cellular Water

Exp – Energy Expenditure

FFM – Fat-Free Mass

FFQ – Food Frequency Questionnaire

FM – Fatmass

GH – Growth Hormone

HDL – High Density Lipoprotein

IAAT – Intraabdominal Adipose Tissue

Int- Energy Intake

LBM – Lean Body Mass

LTM – Lean Tissue Mass

MRI – Magnetic Resonance Imaging

MUAC – Mid Upper Arm Circumference

NCDs – Non- Communicable Diseases

NIDDM – Non-Insulin Dependent Diabetes Mellitus

PEM – Protein Energy Malnutrition

PWS – Prader- Willis Syndrome

SAAT – Subcutaneous Abdominal Adipose Tissue

SES – Socio- economic Mean Grade Point

TBBM – Total Body Bone Mineral

TBW – Total Body Water

TOBEC – Total Body Electroconductivity

TSKF – Total Skinfold Thickness

UFE – Upper-arm Fat Estimate

UME – Upper-arm Muscle Mass

UWW – Under-Water Weighing

WHO – World Health Organization

WHR – Waist-Hip Ratio

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CHAPTER ONE

INTRODUCTION

Excess body fat is associated with chronic diseases such as hypertension, Non-Insulin Dependent Diabetes Mellitus (NIDDM), strokes, and myocardial infarction (Rush et al.,1997). In adults, Intra- Abdominal Adipose Tissue (IAAT) or visceral fat has been identified as the specific fat depot related to adverse health outcomes (Goran et al.,1997). These conditions are costly to manage and difficult to treat. The process of modernization and economic transition has seen most developing countries (including Ghana) move towards industrialization. This has brought improvements to standards of living and services available to more people. It has also had a number of negative consequences that have directly or indirectly led to adverse nutritional and physical activity patterns that influence body composition, hence the risk of diseases. According to WHO (1998) reports have also indicated that unlike women, men show minimal variation in Lipoprotein Lipase (LPL) activity or fat cell size. Premenopausal women have quantitatively more LPL and high LPL activity in the gluteal and femoral subcutaneous regions which have large fat cells. These differences explain the tendency for premenopausal women to deposit fat preferentially in the lower fat depots. The higher level of IAAT in men compared to premenopausal women seems to explain in part the greater prevalence of dyslipidemia and coronary heart diseases in men than premenopausal women (WHO, 1998).

In developing countries, poverty is regarded as a major cause of low-level nutrition, and where dietary insufficiency is rife among the adult population, productivity is likely to go down due to reduced work capacity. This condition will further adversely affect food availability, aggravate undernutrition and potentially compromise immunocompetence.

Morbidity rates are bound to increase and financial resources have to be channelled to reduce disease incidence at the expense of other household needs such as good nutrition. Therefore, both overnutrition and undernutrition have the tendency to lower productivity and adversely affect the quality of life.

1.1 Rationale for the Study

Knowledge about body composition is essential when one considers nutritional status, body weight and health. Body composition studies are also relevant to various aspects of clinical nutrition, selected areas within many medical specialties, and components of exercise sciences (Nelson et al.,1996).

Through body composition studies, significant variations in components of the body have been found among different ethnic and racial groups (Ellis, 1997; Wang et al., 1994). Body composition studies have also been carried out to investigate the increased prevalence of obesity with age beyond 25 years (Benade et al., 1996). Some studies have identified body compositions that are compatible with optimum athletic performance (Kerr et al.,1995). Work has also been done on the development of prediction equations for various components of body composition, for sex, different age groups, racial and ethnic groups (Ellis, 1997; Lean et al., 1996). Several studies have also been carried out on the relationship between total body fat, fat distribution, and the risk of Non-Communicable Diseases (NCDs) ([illegible] et al., 1997; Spiegelman et al.,1992). Some work has also been done on pathologies resulting primarily in changes in the amounts, proportions, or quality of body mass or specific organs, and those in which changes in body composition are secondary to and conditioned by the disease (Solomons and Mazariegos, 1996). Most of the work has been done on body composition in developed countries. Although variations in body composition have a marked effect on the risk of NCDs (excess body fat) and potentially influence work capacity and affect quality of life, information on such relationships is not available in Ghana. The main objective of this study therefore was to investigate the variations in body composition among adult males and how they are influenced by their socio-economic status, age, energy intake and energy expenditure. The specific objectives were to:

i) Investigate the trends in body composition among adult males.

ii) Study the association between body composition among adult males and;

  a) Age (b) Food (energy) intake (c) Physical activity (occupation) and

  d) Socioeconomic status

CHAPTER TWO

LITERATURE REVIEW

2.1 The Need for Body Composition Studies

The study of body composition is of relevance in a variety of situations. Furst and Leweling (1996) reported that injury, sepsis, malnutrition and dietary intake, all had important effects on body composition and therefore on therapeutic efforts and modalities.

According to Durnin (1995), body composition studies have a clear relevance in many clinical situations: general medicine; in anesthetics and therapeutics where some quantitative information always seemed to be desirable because of the high fat solubility of many anesthetics and drugs. In surgery, the degree of obesity or of wasting may be important to assess, perhaps in a longitudinal fashion, to monitor progress. In obstetrics, may be worthwhile to assess fat gain during pregnancy as an indication of the possible long-term effect of adding too much adipose tissue to her body. In epidemiology, with particular relevance to Cardiovascular Diseases (CVDs) and other medical conditions, body composition studies are also very relevant when one considers the distribution of fat in various ethnic groups. It is useful in assessing the nutritional status and the relationship of body composition and diet to the way of life in general and specifically to physical activity.

In Sports Science, Kerr et al. (1995) reported that body composition studies were necessary in attempting to relate physique to athletic performance. Before any meaningful conclusions could be drawn from body composition studies involving patients and individuals in various physiological sub groupings, it is necessary to study body composition in healthy individuals and the factors that influence it.

2.2 Models of Body Composition

In relation to the increasing concern about weight and health, body composition studies have become very important. The human body is made up of various different components, and based on this observation various models have been proposed for body composition. Durnin (1995) stated that Fatmass (FM) and Fat-free Mass (FFM) could be measured when considering body composition. Further, depending on certain correlates of body composition, for example age, FM, FFM, total body water and calcium (mineral mass) may be considered. Based on the criterion of metabolic activity, hence energy demand and comparative size, a four- compartment model of body composition has been proposed. For this the body is divided into Lean Body Mass (LBM), Body Fat (BF), body water and mineral mass, mainly bone (Williams, 1993).

Conlisk et al (1992), Kushner and Hass (1988), also reported on the two-compartment model comprising FM and FFM.

Body composition research is a branch of human biology that has 3 inter-connecting areas: body composition and their organizational rules, measurement techniques and biological factors that influence body composition (Wang et al., 1992). Wang et al. (1992) reported that although there was an accumulation of information on body composition that was extending human biology knowledge, there were certain limitations of the field. For example, there were many mathematical models that described relationship among different body components, which suggested the existence of a quantitative association describing the relationship among body compartments in equilibrium. Another limitation was from the reconstruction of human chemical components and body composition, from elements estimated in-vivo by neutron activation analysis, which seemed to suggest that a relation existed not only between individual components, but between different levels of body composition as well. They further stated that the model involving FM and FFM failed to answer the question whether lipid-free body mass, LBM and fat-free body mass belonged to the same or different body compartments. They therefore proposed a comprehensive model of human body composition consisting of five distinct levels of increasing complexity, in which each level had clearly defined components that comprise total body weight. The five levels were; atomic, molecular, cellular, tissue systems and whole body systems.

According to Tanphaichitr and Leelahagul (1995), body weight is the sum of FM and FFM whereas the chemical model consists principally of triglyceride, protein, water and minerals and some carbohydrates such as glycogen.

2.3 Components of Body Composition

The two-compartment model (which states that total body weight consists of fat mass and fat-free mass) and the four-compartment model (that "breaks up" the body into body fat, lean body mass (total body water, body cell mass and mineral mass) are the two most widely researched.

2.3.1 Fatmass and Body Composition

The importance of body composition has been extensively investigated for a number of reasons including the relation between body fat and a number of Non-Communicable Diseases (NCDs) including non-insulin dependent diabetes mellitus (NIDDM), hypertension and dyslipidemia.

Body fat: Total body fat consists of subcutaneous adipose tissue in general (under the skin), Intra-abdominal [illegible] Tissue (IAAT), subcutaneous abdominal adipose tissue and fat around specific [illegible] and organs (Goran et al., 1997).

Body fat varies widely depending on individual level of fatness or leanness. It serves as a measure of the number and size of adipocytes. In adult males, total body fat may account for [illegible] of total body weight. This figure could be slightly higher in females (Williams, [illegible]

In considering [illegible] absolute fat mass, Spiegelman et al. (1992) found that Absolute Body Fat ([illegible]) [illegible] relative body fat [% body fat (%BF)] provided two different representations of [illegible] fatmass.

Adipose [illegible] primarily composed of storage fat mainly in the form of triglycerides. Although [illegible] less metabolically active in terms of energy and nutrient requirement. Adipose [illegible] plays an important role in hormone metabolism (e.g. synthesis of estrogen in post-menopausal women) (Willett, 1989).

According [illegible] (1995), fatmass was relatively simpler to measure. In many situations a [illegible] assessment of the absolute or relative mass of fat in the human body was useful [illegible] needed to remember that what was being measured was the total mass [illegible] and that the structure which incorporated this lipid, that is the adipocyte [illegible]ous or connective tissue, together with the water content of the tissue, [illegible].

2.3.1.1 Body Fat and Health

When considering body composition in terms of health, fat is a very important compartment. Obesity [illegible] defined as a condition of abnormal or excessive accumulation of adipose tissue, to the extent that health is impaired (WHO, 1998). Solomons and Mazariegos (199[illegible]) identified obesity as a combined gain of both fat and lean tissue since the carriage of extra weight leads to additional development of musculature. Extra body fat is associated with [illegible] diseases such as hypertension, NIDDM, strokes and myocardial ischemia (R[illegible]h et [illegible] 9[illegible]).

According to [illegible]delli et al. (1997), the distribution of body fat is an important predictor of metabolic alterations and cardiovascular morbidity and mortality. It has been demonstrated that abdominal obesity has been associated with hyper-insulinaemia, hyper - triglyceridaemia, [illegible] concentration of High Density Lipoprotein (HDL) and hypertension.

Through [illegible] composition studies, Caprio et al. (1996) reported that the accumulation of [illegible]abdominal fat is linked to metabolic complications such as hyper-insulinaemia, insulin resistance, hypertension and NIDDM which are known risk factors for CVDs.

When [illegible] body fat (obesity and overweight) and health, it is necessary to consider the distribution of body fat. Evidence suggests that the health risk associated with obesity relates not only to total adiposity, but also to the regional distribution of adipose tissue. Individuals [illegible] predominantly android (upper body) distribution of body fat, usually measured [illegible]t-hip-ratio (WHR), experience greater rates of blood lipid disorders ([illegible] diseases (CHDs) and NIDDM (Ross and Rissanen, 1994).

One of the [illegible] important developments in understanding health risks associated with overweight [illegible] is the measurement of body fat distribution. The two types of fat distribution are [illegible] abdominal (android, upper body or male) type and the gynoid (lower body or female) [illegible] former has a higher Android-Gynoid Ratio (AGR) and WHR. Prospective studies [illegible] shown a clear-cut and highly significant increase in the risk of death, and/or increase [illegible] the risk of diabetes, hypertension, heart attack, and strokes with increase in [illegible]. Fat distribution was therefore a more important risk factor for morbidity and [illegible] than simply being overweight (Bray, 1990).

In a case-[illegible] study involving 14 obese adolescent girls (with average BMI of 30 ± 1.3), and 10 [illegible] controls (average BMI 21.7 ± 0.5), using anthropometric and magnetic [illegible] methodologies, Caprio et al. (1996) found a positive association [illegible] or intraabdominal fat mass and triglycerols, and an inverse relationship with [illegible] cholesterol in the obese adolescent girls. These results confirmed the fact that IA [illegible] than subcutaneous fat was known to be associated with cardiovascular risk [illegible] both pediatric and adult populations.

2.3.2 Lean Body [illegible] and Body Composition

Lean body mass [illegible] a major compartment of active fat-free cell mass, and also a major determinant [illegible] metabolic rate (BMR), energy and nutrient needs. In healthy adults, this [illegible] up to 40-70% of total body weight. It is responsible for almost a[illegible] in the body (Williams 1993). Lean body mass (LBM) is extremely [illegible] includes bone, muscle, extra cellular water, nervous tissue and all cells other than [illegible]tes. Knowledge of LBM and total body mass can be helpful in the deter[illegible] compartment by difference (Willett, 1989).

Body Cell Mass: [illegible] part of LBM composed of cells, made up predominantly of muscle. It excludes [illegible]ellular water and bone minerals. It is the compartment of LBM which is m[illegible] of energy utilization and is usually determined by measuring total intr[illegible] potassium (Willett, 1989).

Body Water: [illegible] part of LBM, and it constitutes about 50% to 65% of body weight. It is known [illegible] large proportion of body water is found in the LBM (since water conte[illegible]sue is very low) and that muscles contain more water than other body tiss[illegible] lean persons have higher proportions of body water than do fat perso[illegible] 19[illegible]).

Body Mineral Mass: [illegible] component of LBM is mainly found in the skeletal structure and usually [illegible] of gross body weight. Calcium is the predominant mineral in this co[illegible] constitutes about 75% of total body mineral mass in bone and other bod[illegible] (Williams, 1993).

2.4 Body Composition Measurement Methods

2.4.1 So[illegible] Body Fat assessment methods

Densito[illegible] mainly for estimating fat mass (FM). The principle for densitom[illegible] f an individual submerged in water is directly related to that person[illegible] After correcting for the amount of air in the lungs, the remainin[illegible] the contribution of FM and FFM. The proportion of separate compart[illegible] determined using standard equations (Williams, 1993). Densitometry (hydrostatic w[illegible] become the generally accepted “gold” standard for measuring percent [illegible]) due to its high accuracy compared to other body fat determination methods ([illegible] et al. [illegible]).

Densitometry has been a widely used method in sports science for the assessment of body fat ([illegible]). However, in order to make a prediction of percent body fat from body [illegible] assumed that the body was composed of two compartments, i.e., fat and non-[illegible] that the densities of each were the same for all individuals. In addition, [illegible] significant variations in the density of FFM constituents occurred in bone due to [illegible]. For this reason, body fat would be under-estimated in an athlete ([illegible]) with a high bone density and over-estimated in individuals with low [illegible]. For example, one study recorded negative percent body fat values for a Can[illegible] team in which the players were known to have relatively high bone densities [illegible]

[illegible] association between fat distribution, IAAT and the metabolic complications [illegible] need has arisen for accurate quantitation of regional body fat, to assess [illegible] contribution of upper body subcutaneous fat, leg (lower body) and intraabd[illegible] fat [illegible] sources of circulating free-fatty acids.

Dual Energy X-ray Absorptiometry (DEXA): This is usually used to measure FM, FFM, and bo[illegible]. The [illegible] principle of dual energy absorptiometry is based on the differe[illegible] of photons from two energy levels from a radio nuclide (Dual Photon [illegible] (DPA) or from an x-ray source (Dual-Energy X-ray Absorpt[illegible] (W[illegible]ers et al.,1994).

In [illegible] the body composition has to be measured using DEXA have to lie on a nar[illegible] are taken. It is therefore not applicable for excessively large individuals [illegible] cannot fit onto the narrow table. It is also not applicable to critically [illegible] patients and the exposure to radiation makes the method unsuitable for pregnan[illegible] children (Williams, 1993).

[illegible] direct methodologies include visual imaging scans, under which we have Magnetic [illegible] Imaging (MRI) and Computer Tomography (CT), both applica[illegible] determination.

J[illegible] reported that although DXA alone was capable of determining regional [illegible] it could not differentiate abdominal fat from subcutaneous abdomin[illegible] , taking anthropometric measurements (including body circumf[illegible]mography and DEXA scans, they concluded that DEXA measur[illegible] were highly correlated with computer tomography measur[illegible]rd) and that the addition of DEXA to a single slice of CT mad[illegible] differentiat[illegible] between SAAT and IAAT.

I[illegible] independent of biological assumptions about the constancy of tissue d[illegible]ion which characterize body composition measurement method [illegible] Weighing (UWW) or densitometry (Wellens et al., 1994).

V[illegible] carried out a study on white adults with the aim of comparing estimate[illegible] by DXA, densitometry and TBW. They found that due to certain [illegible] individuals, DXA was not applicable to them. These individ[illegible] than 100kg, height greater than 193cm, width greater than 57.6 cm [illegible] of weight to stature greater than or equal to 0.72.

2.4.1.2 Indirect body fat assessment methods

Bioelectrical Impedance Analysis (BIA): This is an indirect method for determining total body fat, body water (BW) and LBM. When using BIA, small electrical currents are introduced into the body. The impedance to the flow of current resulting from resistance and reactance is then measured. Lean tissue contains more water and electrolyte, and thus it produces low resistance to the flow of current, while bone and fat produce high resistance electrical pathways because they contain low amounts of fluid and electrolytes (Brylowski, 1992).

Anthropometry: Anthropometry involves the measurement of size, weight and proportions of the human body (Williams, 1993). It has a number of advantages over other body composition measurements. It is non-invasive and does not adversely affect human performance. Its use also involves inexpensive equipment and it is relatively fast (Kerr et al.,1995). Measurements taken in anthropometry include weight, height, skinfold thickness (at various sites) and circumferences of various body parts (e.g. arm span, mid upper arm circumference, chest, hip and waist).

Various indices (e.g., Body Mass Index (BMI) and waist-hip ratio) can be derived from these measurements, which can serve as indicators of body composition. Various equations have also been developed to predict body composition, using more accurate methods of body composition determination (e.g., under-water weighing for body fat determination) together with anthropometry.

2.4.1.2.1 **BMI as a measure of body fat**

BMI is a simple index of weight-for-height that is commonly used to classify overweight and obesity in adults. It is calculated as the weight in kilograms divided by the square of the height in metres (kg/m^2). Individuals with BMI less than 18.5 are classified as underweight, those between 18.5 and 24.9 are considered to be within the normal range while BMI greater than or equal to 25 is classified as overweight. In terms of obesity, individuals can be classified as pre-obese, obese class I, obese class II and obese class III if they have BMI ranges; 25 29.9; 30 34.9; 35 39.9 and greater than or equal to 40.0 respectively (WHO, 1998).

BMI as a predictor of body fat, has some advantages over other predictive methods. BMI requires only a weighing scale and stadiometer, and the measurements are easy to perform with little between-observer variance. BMI in developing countries is generally much lower than in western societies (Deurenberg et al., 1997).

A study carried out by Deurenberg et al. (1997) tested whether the relationship between body fat and BMI differed between a Caucasian population (Dutch) and an Asian (Chinese) one. The study involved 205 Chinese and 189 Dutch subjects divided into various age groups. They were weighed under water to determine their body density, from which Body Fat (%BF) could be calculated. Body fat was predicted from BMI using age- and sex-specific prediction models. One of their findings was that there was an increase in body fat with age, and this was more pronounced in the Caucasians than in the Chinese who were more physically active.

Khan et al. (1996) found that BMI was significantly correlated with other anthropometric measures of body fatness. They found that heart diseases, diabetes, chronic respiratory diseases, respiratory signs and symptoms or musculoskeletal complaints, were not more prevalent in overweight and obese men than in lean and underweight men regardless of smoking status. They attributed the lack of a stronger and more consistent relationship between obesity and morbidity in their sample of adults to their relatively young age as well as their small sample size (23 out of 114 men and 26 out of 174 women were older than 45 years).

Certain observations by some earlier studies have, however, demonstrated some unreliability in BMI for predicting body fat (Wang et al., 1994). Racial differences and the absence of updated anthropometric reference literature for Asian adults, led Wang et al. (1994) to study the correlation between BMI and percent body fat (% fat), measured by Dual Photon Absorptrometry (DPA) in whites and Asians with wide ranges of age and body fatness. This study involved 1657 volunteers (445 whites and 1212 Asians), ranging in age from 18 to 94 years, with BMI of 15 - 31 kg/m^2. The investigators observed that whites were taller, heavier, and had higher BMI than Asians, while the Asians were significantly fatter than whites of both sexes. The differences in estimated % fat between whites and Asians, however, varied by BMI in different directions for males and females. Percent body fat increased with BMI for males but decreased with BMI for females. Based on these results, Wang et al. (1994) stressed the necessity for race-specificity in the methods for estimating body composition by anthropometric methods. They therefore presented 2 levels of BMI-based anthropometric methodologies for estimating percent fat in whites and Asians. The equations based on BMI alone required less technical expertise, but gave relatively large systematic error of the estimates which could be used in field studies.

In a study to determine the relation between densitometrically determined BF % and BMI, taking age and sex into consideration, Deurenberg et al. (1991) used 1229 subjects (521 males and 708 females), and found a negative correlation between height and %BF among the adults. This negative correlation was more pronounced in the older age groups (those greater than 56 years). They, therefore attributed it to the relatively older age of their subjects.

2.4.1.2.2 Skinfold thickness as measures of body fat

Body fat consists of subcutaneous fat, intraabdominal fat and fat that surrounds various organs (e.g., kidneys). One of the commonest methods for assessing fatness in human beings, especially in field investigations, is by the use of skinfold thicknesses (Durnin et al., 1997).

Rolland-Cachera et al. (1997) have reported that while skinfold thickness measurement and BMI predicted fatness and body shape, it did not give the proportion of fat to lean body mass. Regression equations gave these proportions, but they applied only to subjects who had the same characteristic as the populations on which the equations were based.

Willett (19[illegible]) also stated that skinfolds were probably the most widely used method ([illegible] weight and height) to measure body composition in epidemiologic studies. In addition, [illegible] had conceptual appeal because it provided a direct measure of body fat.

Fat was abundant subcutaneously, with considerable amounts also around the kidney, heart and in the abdominal cavity and between muscles (Jelliffe and Jelliffe, 1989). Caliper measurements only gave an estimate of superficial and accessible fat as manifested by a double layer of fat and skin. This observation reduced the accuracy of skinfold thickness as a measure of body fat.

In [illegible] to find out whether there was the need to be very precise in the location of sites for skinfolds, Durnin et al. (1997) picked skinfolds from the biceps, triceps, subscapular and suprailiac. Additional sites are the abdominal, front thigh and medial calf (Kerr et al., 1995). Durnin et al. (1997) investigated whether picking up the skinfolds at sites which were slightly different from the recommended ones would influence the [illegible] body fat determinations. A group of 98 adults (45 males and 53 females) were involved in the study and skinfold thicknesses were measured at the biceps, triceps, s[illegible]iliac and subscapular sites on the right side of the body. In addition to measuring skinfolds at the standard sites, the following variations were also done:

Biceps: m[illegible] level of the tricep skinfold, and not over the mid-point of the belly of the biceps muscle.

Triceps: [illegible] 20mm above and below and 20mm to the right of the standard reference site.

Subscapular: [illegible] below the reference location and immediately superficial to the tip of the scapula.

Suprailiac: measured at the reference location, just below the iliac crest and also taken as a vertical [illegible] skinfold, and 20mm anterior to this location at an angle of 45°

Various [illegible] were made of the rightly and wrongly taken measurements in different [illegible]. Although many of the combinations were significantly different from each other, the actual difference was comparatively small and of little practical importance [illegible] this finding and the reported imprecision of the quantitative bases from which [illegible] thickness is calculated from skinfolds, Durnin et al. (1997) concluded that the [illegible] caused by picking up the wrong skinfold was really of minimal importance

W[illegible] compared anthropometric measurements between Asians and whites. I[illegible] study, skinfold measurements were made at the triceps, biceps, chest, umbilicus, [illegible] iliac, subscapular and thigh. From this study, Wang et al. (1994) concluded [illegible] necessary to have race-specific methods and equations for assessing body com[illegible] anthropometric methods. They also provided equations that required the addi[illegible] skinfold thickness measurements which could provide more accurate [illegible] clinical studies.

Co[illegible] Willett (1989) reported that a small difference (2.5cm) in the site of m[illegible] triceps skinfold for example, resulted in a 50% difference. Furtherm[illegible] such as the manner in which the skinfold was picked, and the depth of [illegible] contributed less to the variation observed in the use of skinfold. Consideri[illegible] however, they contributed significantly to the inter-observer variations [illegible] reported in skinfold measurements. This relatively high degree of error va[illegible] measurement placed some limitations on its use in monitoring changes [illegible] over time.

[illegible] ness in nutritional status and body composition assessment, skinfold [illegible] few problems attributed to their use. Since 1950, more than 100 equa[illegible] body fat from skinfolds have been reported in the literature. The problem [illegible] is that they are population specific and based on the densitometry technique, which in turn is based on some assumptions (Kerr et al., 1995). According to Kerr et al. (1995), most sports scientists thus preferred to use the raw skinfold data reported as skinfold sum other than predicting body fat.

Other major limitations in the use of skinfolds as measures of body fat include the fact that not all fat (e.g., intraabdominal and intramuscular fat) is accessible to the calipers and that the distribution of subcutaneous fat can vary considerably over the body (Willett, 1989).

2.4.1.2.3 **Waist-Hip measurement and body fat**

Abdominal fat accumulation (obesity) is an important predictor of metabolic aberration and cardiovascular morbidity and mortality (Tam et al., 1999, WHO, 1998, Goran et al., 1997, Kodali et al., 1997 and Ross and Rissanen, 1994).

According to WHO (1998), abdominal fat mass could vary dramatically within a narrow range of total body fat or BMI. This, together with the fact that for any accumulation of total body fat, men had on average twice the amount of abdominal fat than what was found in premenopausal women, made it an alternative method to BMI necessary in identifying individuals at increased risk from obesity-related illnesses due to abdominal fat accumulation.

Goran et al. (1997) reported that when assessing visceral fat accumulation, and when examining it in relation to disease risks, it was important to consider the strong inter-relation among IAAT, SAAT and total fat mass. Hence in order to perform comparative studies among subgroups of the population, and to examine unique effects of IAAT on adverse health effect, it was important to identify an index of visceral fat accumulation that was independent of total and subcutaneous fat.

According to Tam et al. (1999), it was generally recognized that fat distribution, as ascertained from the ratio of waist-hip circumference, was an important prognostic indicator of the occurrence of hypertension, CHD, stroke, diabetes and gall bladder disease.

In their review, Kodali et al. (1997) also reported that waist-hip ratio (WHR) was an indirect index of abdominal adiposity and was positively related to both systolic and diastolic blood pressure. Waist-hip ratio greater than 1.0 in men, and greater than 0.85 in women has become accepted as clinical cut-off points for identifying patients with abdominal fat accumulation (WHO, 1998).

In a case-control study to determine the role of fat distribution in hypertension, Kodali et al. (1997) used 162 males (74 cases) and 168 females (84 cases) and found that male cases had WHR of 0.98 ± 0.01 compared with 0.94 ± 0.1 for female cases, while male controls had WHR of 0.93 compared to 0.92 for female controls. From the higher WHR observed in cases than controls, Kodali et al. (1997) concluded that abdominal obesity had a role in the inception and progression of diseases. Their study also showed that for similar BMIs, cases had higher WHR than controls, thus suggesting that for any degree of overweight, individuals with higher WHR were more prone to hypertension.

2.4.2 FFM assessment methods

The measurement of LBM (FFM) usually involves 2 assumptions: that water is distributed only to this compartment (as water content of adipose tissue is very low); and that the concentration in lean tissue mass is constant among persons. From animal studies, the fraction of water in lean tissue mass has been estimated to be 0.732. This constant proportion of FFM has been found not to be perfectly correct, as it varies depending on the state of hydration, and relative sub-components of this mass (Willett, 1989).

2.4.2.1 Direct methods of assessing FFM

Wellens et al. (1994) reported that the inclusion of Dual Energy Absorptiometry method, which can be used for skeletal, as well as soft tissue estimates of total and regional body composition had given non-invasive methods of body composition determination further recognition. According to them, DEXA had the ability to discriminate between 2 substances in a given system and minimize errors from soft tissue heterogeneity. It could also provide soft tissue measurements from which percent body fat and FFM were computed, and estimates of Total Body Bone Mineral (TBBM) were obtained. DEXA was also known to operate independently of biological assumptions about the constancy of tissue densities and the level of hydration that characterized methods such as densitometry or UWW and total body water.

For assessing LBM, hydrodensitomery has become the “gold” standard against which other techniques are validated. This method, however, is cumbersome, requiring knowledge of lung volume and is not suitable for studies involving young children (Young and Sinha, 1992).

2.4.2.2 Indirect methods of assessing FFM

Total Body Electroconductivity (TOBEC) is one of the methodologies for estimating FFM in infants and adults; the extent of electroconductivity is dependent on the amount and volume of electrolyte present. Water and electrolytes also reside exclusively in FFM, hence allowing estimation of this body compartment. Furthermore, the interpretation of total body electroconductivity signals in terms of FFM and TBW require the use of prediction equations, which were derived by relating TOBEC signals of individuals in a reference population, to the TBW, or FFM, which is measured by alternative methods (Cochran et al., 1989).

Deurenberg et al. (1989) found that a lower body weight acquired after long-term weight loss was difficult to maintain, and most people regained the lost weight quickly after a period of successful slimming. This prognosis of long-term weight loss could be due to a decrease in FFM during weight loss, associated with a decrease in Resting Metabolic Rate (RMR), leading to lower energy expenditure after weight loss.

Deurenberg et al. (1989) investigated the applicability of the bioelectric impedance method for determining changes in body composition during weight loss as compared with the densitometric method. They used 13 healthy obese individuals, measured their weight and height; bioelectric impedance, and body density. FFM was calculated from an equation that related the height, resistance and sex of the subjects. From the results obtained, Deurenberg et al. (1989) concluded that the bioelectric impedance method was not able to assess small changes in FFM, especially if they were due to changes in glycogen and its associated water stores, which could cause an under-estimation of FFM of approximately 1 -2 kg, depending on the size of the glycogen stores. They, however, recommended that if glycogen stores were constant (as in most western individuals), a correction factor could be introduced when the impedance method was being used to follow people during slimming exercises. The impedance method was, however, very useful in assessing the FFM compartment of body composition.

Certain anthropometric measurements have also been useful in estimating FFM in field studies. In a bid to establish the relationships for the 3 body composition compartments as functions of age and body size, Ellis (1997) generated various prediction equations, using weight and height measurements to estimate BMC, LTM, and FM, among a multiethnic young male population. The various equations for BMC and LTM generated using DEXA-measured body compositions explained between 93% and 96% of the observed variations respectively.

Using arm muscle area as a measure of FFM, Rolland-Cachera et al. (1997) generated an equation that related upper arm muscle estimate (UME) to total upper arm area (TUA) and Upper-arm Fat Estimate (UFE). The similarities between the results obtained from anthropometry and MRI encouraged the use of anthropometry in field studies involving body composition. The study was, however, carried out among children (1 month to 17 years), and hence the applicability of the results on adults could be limited.

In a study on the prevalence and functional correlates of obesity in an Egyptian village, Khan et al. (1996) used mid arm circumference, mid arm muscle circumference and arm muscle area as anthropometric indicators of lean mass. This study involved adults (114 men and 174 women).

2.5 Body Composition and its determinants

Body composition varies widely in individuals, depending on sex, age, food (energy) intake, physical activity, socioeconomic status, and to a lesser extent, race.

2.5.1 Age as a determinant of Body Composition

Advancing adult age is associated with profound changes in body composition. These changes are characteristic of senescence and analogous to those that occur with growth in earlier life. Adipogenesis increases and this is indicated by an increase in body fat, and body fat redistribution with age. Body fat tends to increase slowly between the ages of 25 and 45 years. In the mid-40s both males and females continue to accumulate fat mass until 70-75 years. Age has also been proven to be an independent determinant of relative fat mass (Tam et al., 1999). According to them, cross-sectional and longitudinal data have shown that advancing age is associated with body composition changes such as a decline in FFM, and an increase in FM. Furthermore, they pointed out in their review that FFM begins to decline gradually both in men and women primarily due to wasting of muscle, which begin in middle adulthood. In addition, the rate of loss of FFM with aging differed in men and women.

Rabe et al. (1996) also reported that aging was accompanied by changes in body composition and stature. They carried out a study on the elderly to examine the nutritional status by using BMI. They used 33 males and 36 females between the ages of 60 and 69 years. Their weights, heights and armspans were measured. Rabe et al. (1996) found some elderly who were chronically energy deficient with BMIs in the normal range (18.9-24.9 kg/m^2). They, therefore, proposed that height should be replaced by armspan to give a different Body Mass Index (BMA). This is because some elderly might suffer senescent and pathological shortening of stature by the time they attain the age of 70 years and beyond.

A study to determine absolute, and relative body fat, FFM, fat distribution (expressed as AHR) and abdominal circumference in the elderly population living in an underprivileged area in Vietnam, and to compare these with fat mass and its distribution in a middle-aged population living in the same socioeconomic area, was carried out by Tam et al. (1999). Two hundred individuals were divided into 2 age groups; 30-44 years and 60-74 year-olds. Each group consisted of 50 males and 50 females. Their weights, heights, armspans, skinfold thicknesses (biceps, triceps, subscapular, suprailiac), abdominal, hip and calf circumferences were measured. From their results, Tam et al. (1999) found that there was no difference between absolute body fat in the elderly group and the middle-aged group. They attributed this observation to a reduction in food intake and its ensuing undernutrition among the elderly. The results obtained were generally in agreement with the observation that AHR increased with advancing age. They, however, indicated that this increase could be at the expense of a reduction in hip circumference. The results were also in accordance with the reduction in FFM with age. This study, however, considered body composition and age in a lower socioeconomic community and did not take into consideration physical activity and food intake, which are vital determinants of body composition. The study also did not use the Cross-Cultural Research on Nutrition of Older Subjects (CRONOS) project protocol, which recommended the use of 600 individuals from rural areas, low socioeconomic urban communities, and middle-income urban communities.

According to Hale et al. (1996), various studies had reported a height loss with aging, due to compression of vertebrae, kyphosis, and osteoporosis (partly due to a reduction in body minerals). They also reported the existence of chronic energy deficiency among the elderly.

2.5.2 Energy expenditure (physical activity) as a determinant of body composition

The basic components of energy expenditure are basal metabolic rate, thermic effect of food and physical activity (Williams, 1993). For most people, the second largest component of total energy expenditure is the energy expended in physical activity (NRC, 1989).

Most publications on physical activity and its effect on body composition have been done with respect to obesity. According to WHO (1998), cross-sectional data on a number of studies had revealed inverse relations between BMI and physical activity. They indicated also that obese and overweight subjects were less active than their lean counterparts. Such correlation did not provide cause-and-effect relationships, and it was difficult to know whether obese individuals were less active because of their obesity, or whether their low level of activity caused their obesity. This view, however, conflicted with results of other studies, that suggested that low and decreasing levels of activity were primarily responsible for the development of obesity. For instance, obesity was absent among elite athletics, and those who gave-up sports frequently experienced increases in body weight and fatness.

Physical activity patterns have an important influence on the physiological regulation of body weight. Analysis of over 40 national physical activity studies worldwide showed that there is a significant relationship between the average BMI of adult men and their physical activity levels, with the likelihood of them becoming overweight being substantially reduced when individuals are physically active (WHO, 1998).

The concept of adaptation has arisen from the knowledge that undernutrition leads to reduction in the rate of metabolism. True adaptation could have 2 components; a reduction in physical activity and an increase in energy efficiency (Haggarty et al., 1997).

Dietz (1996) defined inactivity as a state in which bodily movement was minimal. In terms of energy expenditure, inactivity represented a state or behaviour for which energy expenditure approximated resting metabolic rate. Results from earlier studies pointed out the fact that a child's time spent watching television had an independent effect on the prevalence of obesity. Increased activity was inversely associated, whereas television viewing was directly and independently associated with the prevalence of obesity. Additionally, inactivity had some significant relationships with other adverse health practices such as consumption of less healthy foods or increased fat intake. Inactivity has also been associated with increased rate of cigarette smoking. These data suggest that inactivity tended to cluster with other health behaviours that had adverse effects on quantity and location of body fat.

Two strategies can be pursued to address the role of inactivity in the genesis of obesity or mortality from chronic diseases. The first is to increase activity and decrease inactivity (Dietz, 1996). According to Dietz (1996), recommendations from the Centre for Disease Control and Prevention and the American College for Sports Medicine, suggested that every adult should have 30 minutes or more, of moderate intensity physical activity in most or preferably all days of the week; the greatest impact will be observed in the most physically inactive at baseline.

In their study to compare the sensitivity of techniques for detecting small changes in body composition with strength training, Nelson et al. (1996) observed that programmes of regular physical activity, particularly strength training, had been reported to produce small but significant changes in skeletal muscles. They further reported on the effect of a one-year randomized control trial of high intensity strength training in post-menopausal women. The results showed that women who participated in the strength training programme had greater bone density than their sedentary controls.

The enlargement of skeletal muscles which resulted from strength training was also reported by Bosselaers et al. (1994).

The lack of clarity in the relationship between physical activity and body composition or body weight has been reported by Obazarnek et al. (1994). The relationships had been inconsistent and had generally not demonstrated a significant inverse relationship between physical activity and body weight or fat.

According to Obarzanek et al. (1994), these inconsistencies have also been reported in earlier studies comparing lean and obese children, and attributed this lack of consistency in the results to poor quantification methods of physical activity, particularly in children, or because the sample size in the previous studies could have been inadequate (between 20 and 300).

In a study to investigate the relationship between indices of body fat and physical activity and energy intake, a sample size of 2379 girls, aged 9 and 10 years (49% whites and 51% blacks), from three field centres were used. The obesity indices used were BMI and the sum of skinfolds (taken from biceps, triceps, subscapular and suprailiac). Physical activity was estimated using 2 instruments; a pictorial 3-day diary, depicting 24 physical activities commonly performed by children, and a physical activity-pattern questionnaire, which asked about physical activities performed both in and out of school. Information on energy intake was obtained using a consecutive 3-day food record, consisting of 2 weekdays and one weekend. From their results, Obarzanek et al. (1994) observed that television watching was directly associated with BMI and skinfold thicknesses in both black and white girls and hence concluded that television watching might be a stronger marker for sedentary behaviour that strongly impacted on energy balance. Additionally, however, to better define the relationship between energy intake, physical activity and body fatness, future longitudinal data analysis would help clarify differences in physical activity levels and energy intake between black and white girls (and children in general). Furthermore, with longitudinal data analysis, changes in energy intake and physical activity levels over time could be examined in the context of changing body fatness. This study was, however, carried out in a developed country and among girls only. The events that would determine energy balance among men in a developing country might therefore differ.

2.5.3 Energy intake and body composition

Most research papers on energy intake and body composition have involved obese individuals or centred on body fat content. A few papers have also been on re-feeding and body composition variations of malnourished individuals and the effect of nutrients on bone density.

Obesity has been regarded as a problem of nutrient imbalance. Initially, it was thought that excessive energy intake was the primary cause of obesity among obese individuals. However, some studies report that obese individuals consumed a minimal amount of energy per day. In some cases, obese individuals took in less and expended more energy in RMR and physical activity than normal weight individuals (Fatimah et al., 1996).

The shift in the composition of the diet to a higher contribution from fat in western countries has often been quoted as the reason for the increasing incidence of overweight (Westerterp et al., 1996). In their review, they cited experimental details to show that a change to a high fat diet could lead to an increase in body weight. They found that people in western countries tended to eat diets higher in fat, and hence they concluded that being overweight could be prevented by reducing the fat content of diets.

According to Horton et al. (1995), understanding how obesity developed was very necessary in the development of strategies for its prevention and treatment. They also further reported that individuals could be metabolically or behaviourally susceptible to weight gain.

Hill et al. (1994) proposed that behavioural susceptibility created the opportunity for positive energy balance to occur (for example, overeating and under-exercising), whereas metabolic susceptibility, determined the metabolic fate of the excess energy when the positive energy balances occurred. For example, individuals with a high metabolic susceptibility to obesity, would be inclined to accumulate more body fat but less glycogen during periods of positive energy balance, than would an individual with a lesser metabolic susceptibility to obesity.

A cross-sectional study carried out to assess energy and nutrient intakes associated with obesity among obese, normal weight, and underweight individuals by Fatimah et al. (1996), involved 385 adults (199 women and 186 men). The results showed that the average daily intake of the total sample was 1709.2 ± 637.3 kcal/day, and that the underweight individuals ate a greater portion of energy, carbohydrate, protein and fat than normal weight and obese subjects. The results also showed that the overweight individuals consumed slightly higher amounts of energy (1687 kcal) than the normal weight individuals, with the under-weight individuals consuming the highest (1912 kcal). These differences became less significant when the results were analyzed by group and sex. Fatimah et al. (1996) thus concluded that there was a trend for the obese to have energy intakes less than the under-weight subjects. This study did not, however, take into consideration the physical activity of the individuals, and this could have accounted for the lack of significance in the results.

In their study to determine how obese and lean individuals partitioned excess energy provided as carbohydrate or fat, Horton et al. (1995) assessed energy and nutrient balance during dietary challenges by combining indirect and direct calorimetry, as these techniques could be measured using body composition assessment techniques.

Sixteen individuals (9 lean) were used. Their usual food intakes were estimated using a 14-day weighed food diary and physical activity, using Caltrac accelerometers, and a whole-room calorimeter. They ate foods at their usual energy intake levels, while undergoing their usual physical activity routine. The subjects were then taken through two

14-day overfeeding phases involving carbohydrate and fat over-feeding. The results showed that diet composition could have an important effect on energy expenditure and body energy stores, when subjects were in positive energy balance. The results also demonstrated that more than 75% of excess energy consumed by the subjects were stored in the body and not expended, regardless of the nature of the excess. It was also revealed that for equivalent amounts of excess energy, fat led to more body fat accumulation than carbohydrate. Horton et al. (1995) thus concluded that all overeating could eventually lead to obesity, and that regardless of diet composition, most excess energy was stored in the body and not expended as heat. Excess dietary fat was stored with very high efficiency and that the body did not accurately respond to increased fat intake. Whereas fat over-eating would be predicted to lead to efficient storage of excess energy in all subjects, some differences were found to be seen in carbohydrate overfeeding.

A study to compare adiposity with dietary and physical activity patterns between ethnic Chinese youths living in Singapore, and their age and sex counterparts, living in California, was conducted by Wang et al. (1994). They used 1687 healthy volunteers (445 whites and 1242 Asians) aged between 18 and 94 years. They proposed a model to show that dietary patterns, which formed part of lifestyle, were influenced by the physical environment (climate and agriculture), social and economic constraints (availability and accessibility of food, ease of eating out and the role of women in family). Socio-cultural values ([illegible] on thinness and dieting and the importance of eating with family) also exerted some influence on dietary patterns. The model also showed that dietary patterns interacted with physical activity to influence lifestyles.

In a bid to gain a better understanding of the nature of the body composition and fat distribution changes that accompany short-term weight gain in anorexia patients, Orphanidou et al. (1997) carried out an observational cohort study, involving 26 malnourished underweight females aged 18 - 45 years. The patients' energy intakes were gradually increased from 5021kJ (1200 kcal) to a level in the range of 10042 - 14646kJ (2400 - 3500 kcal), that was more appropriate for their age and height. The patients were followed-up for a period of 6 months or until maximum weight was achieved, whichever occurred first. Measurements were taken at baseline and when the target-weight was attained and maintained for 2 weeks. Weight, height, skinfold thicknesses (from nine sites; triceps, chest, subscapular, axilla, abdomen A and B, iliac, thigh and calf, circumferences (also taken at 9 sites; arm, forearm, chest, hip, thigh A and B, waist A and B and calf). DEXA measurements were carried out at the subscapular, waist and thigh regions. Information was also sought on food intake and exercise behaviour. The study found that refeeding regimen of anorexia nervosa patients led to a significant increase in body fat weight. This weight gain included significant gains in total body fat, total LBM and total BCM; total body fat was the component that increased the most. Results obtained from skinfold thickness measurements indicated greater deposition of body fat in the central regions (chest, abdomen, hip and thigh) than in the extremities (arm and calf). Although there was a significant increase in WHR after weight gain, the gynoid fat distribution pattern was preserved (Orphanidou et al. 1997).

2.5.4 Socio-economic Status and Variations in body Composition

Another factor that is expected to have some influence on body composition is socio-economic or socio-demographic status.

Islam (1997) stated that nutritional status was dependent on food intake, which in turn, was dependent on income levels (SES), and that for these reasons, low level nutrition could be responsible for poor nutrition. He, however, stated that in reality, the situation could differ as certain aspects of nutrition could be influenced by factors other than food intake, and also that [illegible] of income or socio-economic status alone may not be the only determinant of nutritional status, which affected body composition. For example, spending a large proportion [illegible]'s income on food could have 2 possible reasons; either you are spending more [illegible] nutritional status, or food prices are so high that one has to spend more to get [illegible] amount of food.

According [illegible]k et al. (1995), SES is associated with the prevalence of obesity. A strong [illegible]itive association has been found in developing countries, whereas the effect was [illegible] clear in developed countries. From their study on socio-demographic de[illegible] of body fatness, a significant and positive association was found between education [illegible]d BMI in men (Grevink et al.,1995). Their study also showed that men of mid[illegible] household income had significantly low mean Waist- Hip Ratios (WHR) compared [illegible]e higher income counterparts. Other aspects of lifestyle examined in their study we[illegible] and marital status. Smokers had lower BMI than non-smokers, while marital st[illegible]tly associated with WHR in men after adjusting for age (they were close t[illegible]ting abdominal fat). From these results, Grevink et al. (1995) concluded that [illegible]ons [illegible]een cigarette smoking and the socio-demographic factors for body fatness (total and abdominal) in men were not consistent. They attributed this to a number of reasons which included the fact that the mean BMI for respondents in the study was very low (about 21 for both men and women), and that there were bound to be differences in socio-economic development or biological characteristics between an Asian and Caucasian population. These made comparison between them difficult.

CHAPTER THREE

METHODOLOGY

3.1 Study Design

The study was cross-sectional in design. Information on body composition and its determinants were collected simultaneously.

3.2 Sampling Strategy

3.2.1 Study Sample

Study participants included construction workers, commercial drivers, office workers and teachers aged between 25 and 50 years. A sample size of 280 men was used, based on a margin of error of 1.2 (based on the mean variability of measurements to be done. It was chosen based on the results of previous studies) and a 95% confidence interval.

3.2.2 Sampling

The Accra metropolitan area was divided into 3 clusters for the purpose of this study. Cluster A comprised Adenta, Madina, Legon and Achimota. Cluster B comprised Kwame Nkrumah Circle, Kaneshie, Mallam, Odorkor, Dansoman, Lartebiokorshi and Korle-Bu areas, while Accra Central, Osu, La and Teshie-Nungua township and environs constituted cluster C.

The establishments from which the men were sampled, within each cluster, were numbered after a survey around the areas. Eligible subjects were selected from the even-numbered ones. Within each establishment, eligible and willing subjects were picked by systematic random sampling (they were all numbered and every fourth individual was chosen to be part of this study).

3.3 Research Instruments, Measurement Methods.

Socio-economic status: Questionnaires were used to obtain information on age, level of education, household size and living conditions (Appendix I). The individuals were also asked about the type of toilet and bathroom facilities available to them, and also on their usual mode of transportation, and possession of other indicators of wealth (e.g., radio, television and other electronic household appliances).

Physical Activity Pattern: The men were made to provide retrospective information on their activity pattern on a very typical day, and their estimated duration (Appendix I).

Energy (food) Intake: A semi-quantitative food frequency questionnaire adapted from the one developed by Ireland et al. (1994) was used to obtain information on energy intake. The frequencies with which foods in the various groupings were eaten were obtained, together with estimates of portion sizes consumed. These responses were compared to the mean energy intake values obtained from three 24-hour food records, for two working days and a non-working day (Saturday or Sunday) (Appendix I). The comparison was carried out among 28 randomly selected respondents. The portion sizes were estimated using household measures and dummies.

Anthropometry: Body weight, heights, skinfold thickness, and various body circumferences were measured. All measurements were taken using standard procedures.

Weight: This was measured to the nearest 0.5kg using a Salter weighing scale. The subjects were relieved of all heavy objects such as keys, cellular phones, belts, wrist watches etc. The type of clothes worn by the individuals during weighing was noted and their weights subtracted from the overall weight of the individual (Appendix V).

Height: It was measured to the nearest 0.1cm using a Seca stadiometer, with the subject wearing no shoes, and standing straight on a horizontal surface, with heels together, shoulders relaxed, arms at the sides and head in the Frankfurt horizontal plane (Tam et al., 1999).

Skinfold thickness: Skinfolds were measured to the nearest 0.2mm using a Harpenden Skinfold Caliper. All skinfolds were measured on the left side of the body. Triceps skinfold was determined on the back of the left arm parallel with the axial line of the upper arm, over the triceps muscle, halfway between the acromial process of the scapula and the olecranon process of the ulna. The biceps skinfold was measured on the front of the left arm directly above the centre of the antecubital fossa. Subscapular skinfold was measured just posterior to the inferior angle of the left scapula. Supra-iliac skinfold thickness was taken with the person standing, and on the midaxillary line immediately superior to the iliac crest (Tam et al., 1999).

Mid-upper-arm circumference: This was measured to the nearest 0.1cm with a flexible non-stretch steel tape that was placed gently but firmly round the limb to avoid compression of soft tissue. Measurement was done on the left arm while it hanged freely. The tape was passed around the mid-point of the upper arm, located half way between the tip of the acromial process of the scapula, and olecranon process of the ulna (Jelliffe and Jelliffe, 1989).

Waist circumference was measured by passing a non-stretch tape around the waist at a position one inch above the umbilicus.

Hip circumference was measured by placing the tape around the level of maximum protrusion of the gluteal region (Kodali et al., 1997).

3.4. Data Analysis

Socio-economic Status: The [illegible] point system developed by Owusu and Orraca-Tetteh (1988) was used to classify the responses into high, middle and low socio-economic groups with the help of a cumulative frequency curve (Appendix II). Those below the lower quartile were in the low socioeconomic group; subjects within the interquartile range were in the middle socioeconomic group, while those above the upper quartile were in the high socioeconomic group.

Physical Activity: Resting energy expenditure (REE) of individuals was obtained by fitting their weights into WHO prediction equations: (15.3 X weight) + 679 (for those below 30 years) and (11.6 X weight) + 879, for those above 30 years (NRC., 1989). Activities in which the [illegible] engaged were categorized into: Resting, very light, light, moderate and heavy activities according to NRC (1989) (Appendix III). Each category had activity factors/unit units of activity accorded them. A weighted REE factor was obtained by multiplying activity as multiples of REE by the duration for which the activity was carried out. The mean weighted REE was then calculated. The energy expended on physical activity in kcal/day was obtained by multiplying the mean REE factor by the REE of the individual (NRC., 1989).

Energy Intake: The frequency responses were converted to daily equivalents as follows: Zero for foods that were never eaten or eaten less than once a month; 0.071 for those eaten between 1-3 times a month; 0.15 for once a week; 0.43 for 2-4 times a week; 0.80 for 5-6 times a week; 1.00 for those eaten once a day; 2.40 for 2-3 times a day and 5.00 for foods eaten more than thrice daily (Ireland et al., 1994). The weights of the estimated portion sizes were determined using a Seca kitchen scale (Appendix IV). The energy content of the foods consumed per day was obtained by multiplying the estimated weights by the daily equivalents and the energy content of the food obtained from energy values in food composition tables (Ireland et al., 1994).

Anthropometry: Derived [illegible] calculated for each individual included, Upper-arm Fat Estimate (UFE), Total Skinfold Thickness (TSKF), Fatmass (FM), BMI and WHR. Percent body fat, (for body [illegible]) and Lean Tissue Mass (LTM), and Bone Mineral Content (BMC) (for fat-[illegible]). They were calculated using various prediction equations (Appendix VI). The means and ranges were calculated with standard deviations. The extent to which body composition was affected by its correlates, either singly or in various combinations, was assessed using regression analysis. Regression analysis was used to determine which independent variables (age, socio-economic status, energy intake, energy expenditure and energy balance) were significantly associated with the indicators of body composition used in the current study. The analyses were done using Epi Info version 6.0 software and STATA (Texas, 1997). MS Excel '97 was used for the graphical presentation of the results.

CHAPTER FOUR

RESULTS

4.1 Population Characteristics

The means (± SD) of energy intakes, energy expenditure and anthropometric measurements and the derived variables for the men in the study are summarized in Table 4.1

Table 4.1: Summary of means (± SD) of measurements and derived variables on study population (n= 280).

Variables	Mean ± SD
Age (years)	35.4 ± 7.0
Energy intake (kcal)	3674.4 ± 424.3
Energy expenditure (kcal)	2863.3 ± 724.6
[1]Energy balance (kcal)	822.0 ± 942.3
Height (m)	1.69 ± 0.10
Weight (kg)	66.1 ± 5.8
Body Mass Index (kg/m^2)	23.1 ± 1.7
MUAC (cm)	30.2 ± 2.2
Triceps skinfold thickness (mm)	10.2 ± 2.0
Biceps skinfold thickness (mm)	6.3 ± 1.8
Subscapular skinfold thickness (mm)	11.6 ± 2.1
Suprailiac skinfold thickness (mm)	11.0 ± 2.1
Total Skinfold Thickness (mm)	39.1 ± 7.5
Upper-arm Fat Estimate (cm^2)	156.0 ± 40.8
Waist circumference (cm)	81.2 ± 5.4
Hip circumference (cm)	89.9 ± 3.3
Waist Hip Ratio (WHR)	0.90 ± 0.1
Fatmass (kg)	10.3 ± 2.9
[2]BF%$_{(DER)}$	19.7 ± 3.3
[3]BF%$_{(LEAN)}$	18.3 ± 4.5
Lean Tissue Mass (kg)	52.8 ± 5.7
Bone Mass Content (kg)	4.66 ± .08

[1]: Energy Balance= Energy Intake – Energy Expenditure

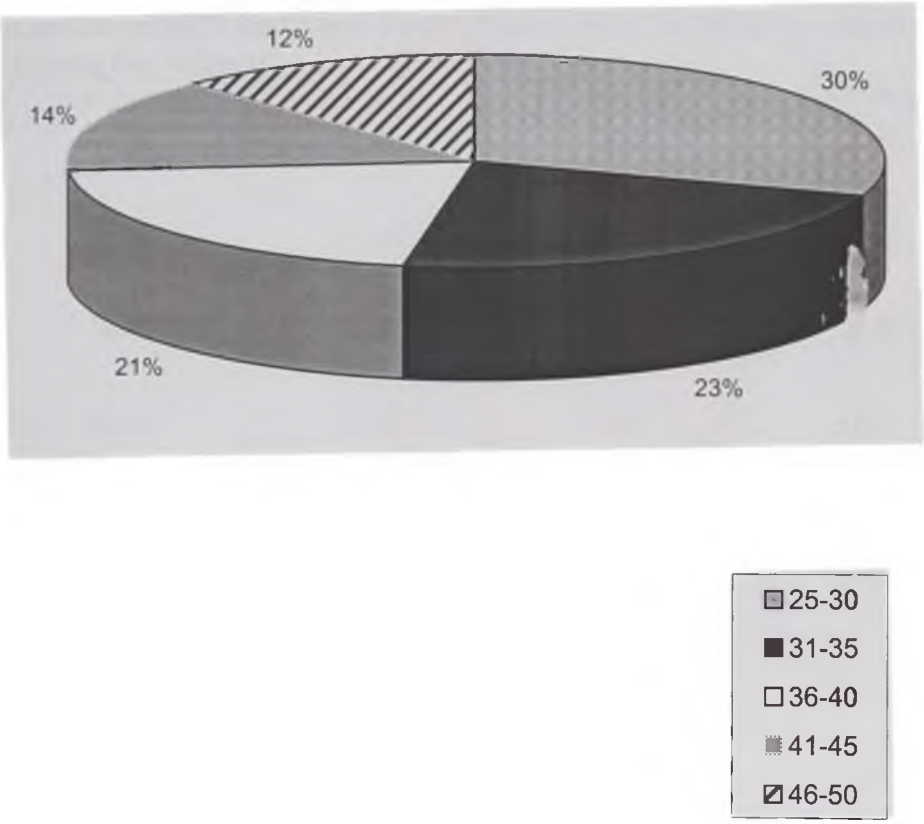
[2]:BF %$_{(DER)}$- Percent Body Fat using equation by Deurenberg et al.(1991).

[3]:BF %$_{(LEAN)}$ - Percent Body Fat using equation by Lean et al.(1996).

4.2 Age and Body Composition

The age distribution of the study population is summarized in Figure 1. Of the 280 men interviewed, 85 (30.4%) were between the ages of 25 and 30 years, 63 (22.5%) were 30 - 40 years, 40 (14.3%) were within the range 41 45 years, while 34 (12.1%) were 46 - 50 years.

Fig 1: Age distribution (years) among the study participants


12%
30%
14%
21%
23%
▨ 25-30
■ 31-35
☐ 36-40
▨ 41-45
▨ 46-50

From Table 4.2, a steady increase was observed in the means of Fatmass (FM) and Bone Mineral Mass (BMC), while similar values were observed for mean Lean Tissue Mass (LTM) with increasing age. Mean FM increased from 8.38 kg for men between the ages of 25 and 30 years, to 13.07 kg for those aged 46-50 years. Mean LTM ranged from 51.73 kg to 54.26 kg as the men advanced in age from 25 to 50 years. There was also a steady increase in mean BMC from 3.76 kg for men aged 25 to 30 years, to 5.99 kg for those aged 46 to 50 years.

Table 4.2: Mean values for Variations in Fatmass (FM), Bone Mineral Content (BMC), and Lean Tissue Mass (LTM) for different age groups among the subjects.

Age (years)	FM (kg)	BMC (kg)	LTM (kg)
25-30	8.38	3.76	51.73
31-35	10.00	4.37	53.26
36-40	10.66	4.93	52.54
41-45	11.92	5.49	53.35
46-50	13.07	5.99	54.26

4.3 Energy Intakes and Body Composition.

The responses obtained from the Food Frequency Questionnaires (FFQ) were compared to the average energy intake obtained using three 24-hour dietary recall method. For each of the respondents, one of the recalls was for a non-working day (Saturday or Sunday). The responses from the FFQ correlated positively and significantly with the responses from the 24-hour recalls ($r = 0.93$, $p<0.0001$; n-28) (Figure 2). The mean (SD) energy intake for the participants was 3674.4 kcal/day (424.3).

Fig 2: Scatter plot for energy intake, comparing FFQ and 24-hour recall.

From Table 4.3, energy intake correlated positively and significantly with all indicators of body composition, except percent body fat (BF $\%_{DER}$), derived from the equation for body fat. (Deurenberg et al., 1991)

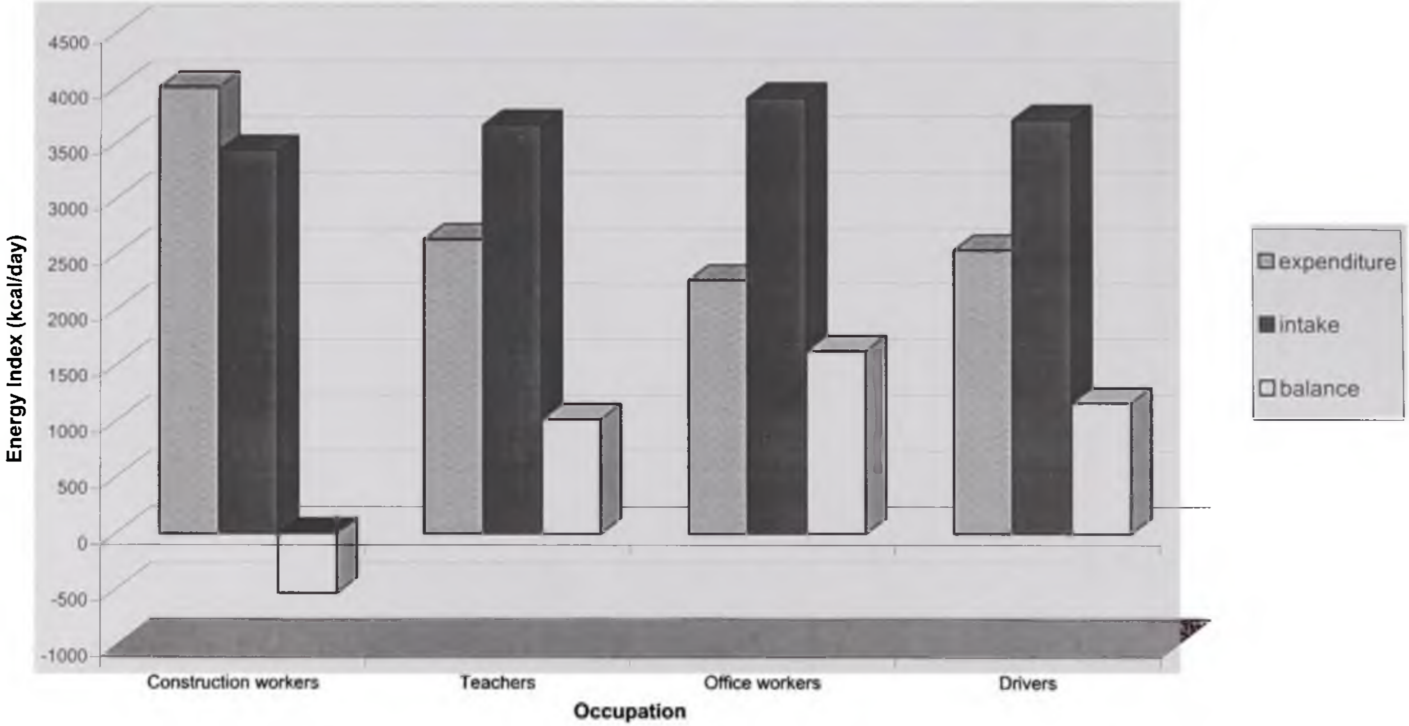
4.4 Energy Expenditure and Body Composition.

The mean energy expenditure of the study population was 2863.3 ±725.4 kcal /day and ranged from 1903.5 to 4644.2 kcal /day (Table 4.1). Energy expenditure correlated negatively and significantly with all indicators of body composition, except LTM (r= 0.06; p=0.31). The significant correlation coefficients ranged from –0.26 for fatmass to –0.51 for total skinfold thickness (4.3).

4.4.1 Occupation and Body Composition

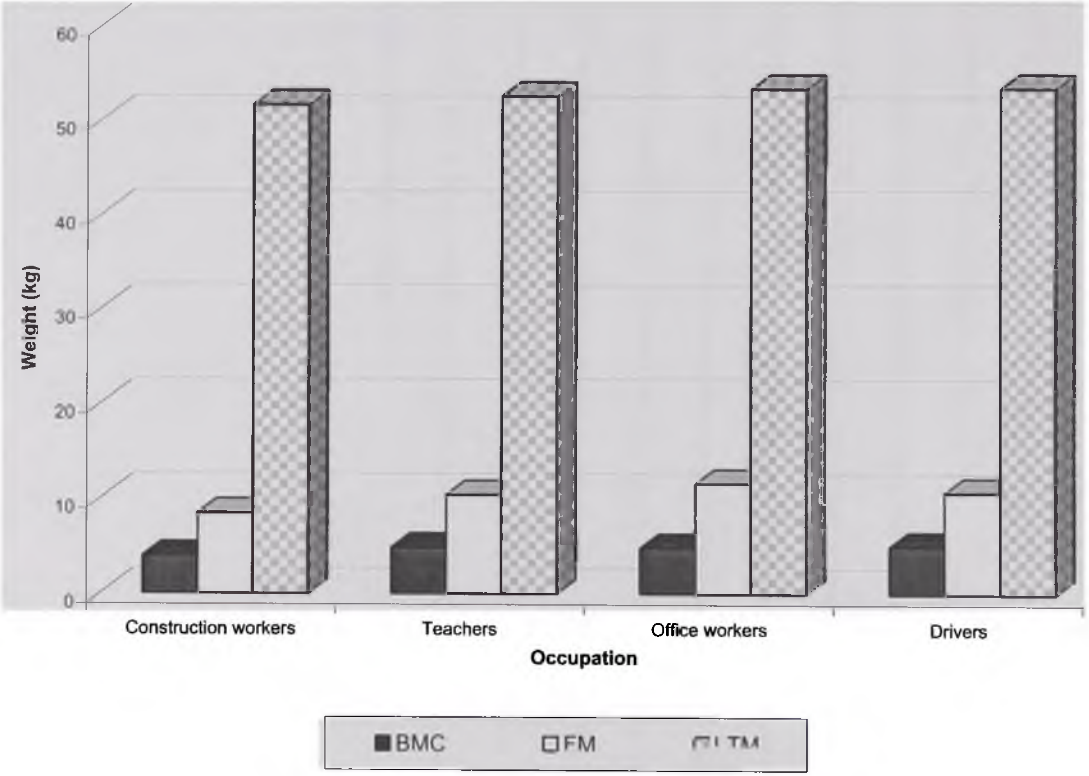
Construction workers had the highest mean energy expenditure of about 4005 kcal/day and the lowest mean energy intakes, which gave them the lowest mean energy balances (-529 kcal/day). The opposite situation was observed for teachers, office workers, and commercial drivers, with office workers having the largest mean energy balances (1633 kcal/day). These results are presented in Figure 3.

Fig 3: Variations in mean energy expenditure, energy intake, and energy balance among the subjects in the different occupational groups


4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Energy Index (kcal/day)
Construction workers
Teachers
Office workers
Drivers
Occupation
▨ expenditure
■ intake
☐ balance

The relationships between occupation and body composition are summarized in Figure 4. Construction workers had the least values for mean FM, LTM, and BMC (8.45 kg, 51.67 kg, and 3.94 kg, respectively.). Office workers, on the other hand had the highest mean values for FM (11.61 kg), with commercial drivers having the highest mean LTM (53.52 kg), and BMC (5.01 kg).

Fig 4: Variations in mean BMC, FM, and LTM for the subjects in the different occupational groups.

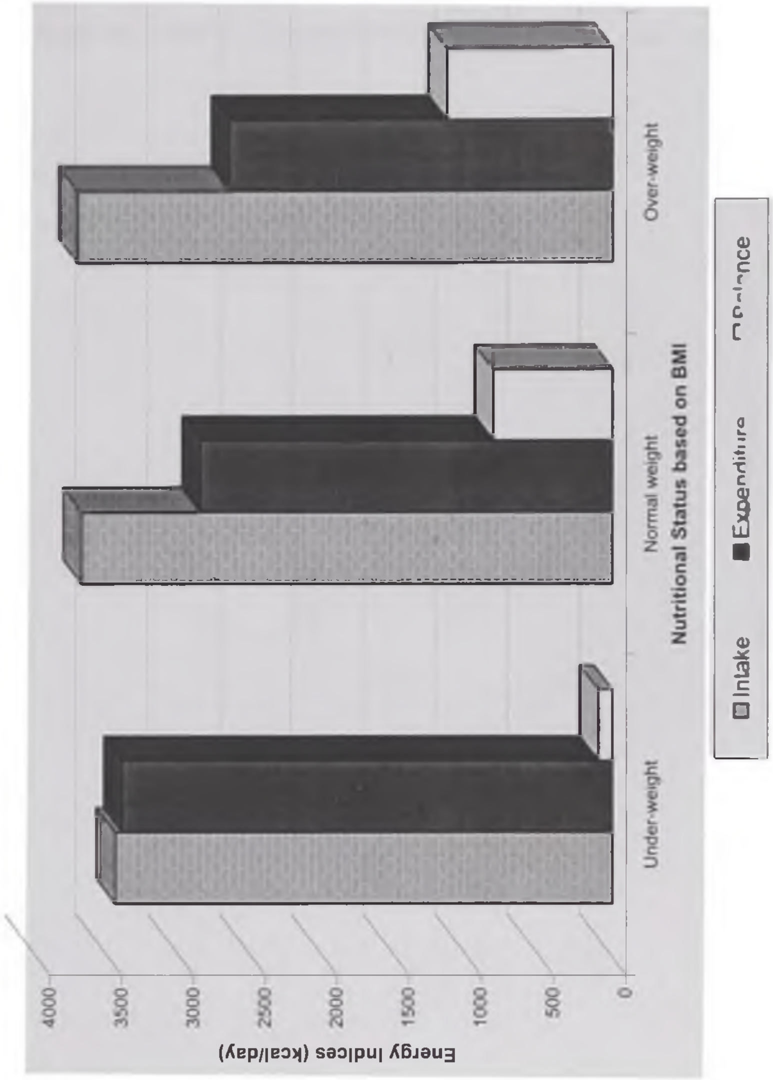

60
50
40
30
20
10
0
Weight (kg)
Construction workers
Teachers
Office workers
Drivers
Occupation
■ BMC
□ FM
▨ LTM

4.5 Energy Balance and Body Composition.

Energy balance is the difference between energy intake and energy expenditure (Appendix IV), and in this study the mean energy balance for the adult male population was approximately 822 ± 942 kcal (Table 4.1).

Energy balance correlated positively and significantly with all indicators of body composition, except LTM, whose correlation with energy balance was not significant at $\alpha = 0.05$ level ($p = 0.06$) (Table 4.3). The significant correlations ranged from $r = 0.28$ (for Fatmass) to $r = 0.52$ (for TSKF). Examining energy intake, expenditure and balance, for the BMI categories (under-weight, normal weight and over-weight), individuals who were categorized as overweight /obese had the highest energy intakes (3708.6 ± 521 kcal/day), lowest expenditures (2654.1 ± 651.3 kcal/day) and the largest positive balance (1142.5 ± 917.6 kcal), while the opposite trend was observed for males who were classified as underweight (Figure 5).

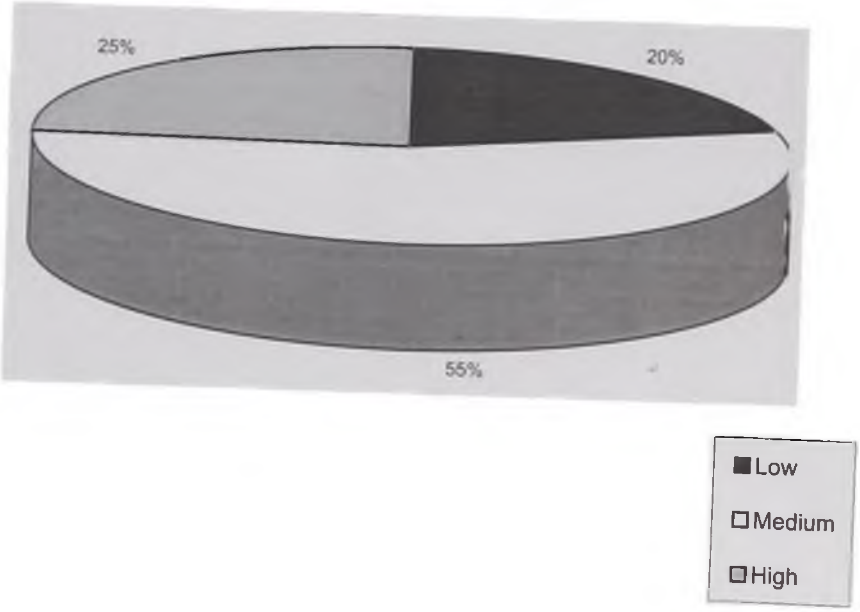
Fig 5: Mean energy expenditure, energy intake, and energy balance of under-weight, normal weight, and over-weight men in the study


Energy Indices (kcal/day)
4000
3500
3000
2500
2000
1500
1000
500
0
Under-weight
Normal weight
Over-weight
Nutritional Status based on BMI
▨ Intake
■ Expenditure
☐ Balance

4.6 Socio-economic Status and Body Composition.

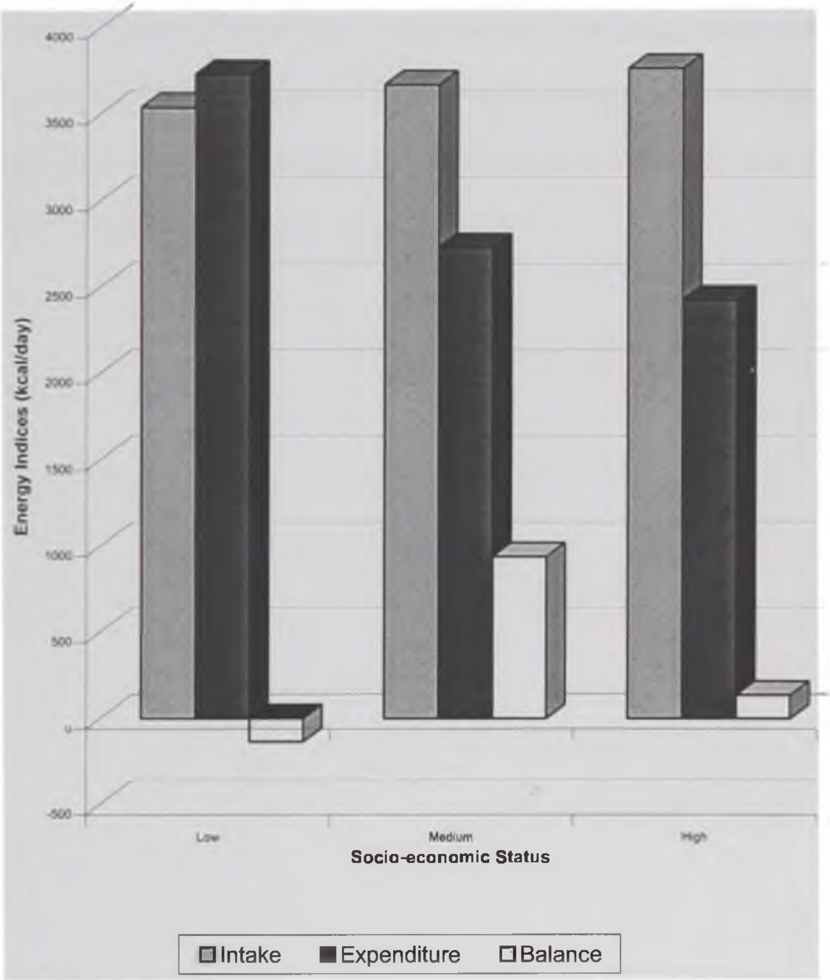
The socio-economic status of the respondents is presented in Figure 6. Fifty-seven (20.4%) of them were of low socio-economic status, 154 (55%), were of medium socio-economic status, while 69, representing 24.6% were in the high socio-economic group.

Fig 6: The socio-economic status of the study group.


25%
20%
55%
Low
Medium
High

Individuals of low socio-economic status had the lowest energy intakes (3539.6 ± 640 kcal/day), and the highest mean expenditure (3732.4 ± 372.5 kcal/day). Furthermore, these individuals had a negative mean energy balance (-134.3 ± 813.7 kcal). The opposite trend was observed for those in the high socio-economic group who had the highest intakes, lowest energy expenditures and the largest positive energy balances. The intermediate situation was observed for individuals in the medium socio-economic group (Figure 7).

Fig 7: Variations in mean energy intake, energy expenditure, and energy balance among different socio-economic groups.


Energy Indices (kcal/day)
4000
3500
3000
2500
2000
1500
1000
500
0
-500
Low
Medium
High
Socio-economic Status
Intake
Expenditure
Balance

4.7 Indicators of Body Composition and their Relationship to Various Determinants.

Correlations between determinants and indicators of body composition are presented in Table 4.3. The highest correlation was observed between age and BMC (r= 0.99). Energy expenditure correlated negatively and significantly with all determinants and indicators of body composition, except LTM (r=0.06; p=0.31). Correlation between age and energy expenditure; energy expenditure and LTM; energy intake and LTM and BMC were not significant at $\alpha=0.05$ level ($p>0.05$). Correlation between all indicators of body composition were positive and significant at $\alpha=0.05$ level, with the highest being between BF $\%_{(DER)}$ and BF $\%_{(LEAN)}$, (r=0.94).

Table 4.2: Correlation matrix for determinants and indicators of body composition

	Age (years)	SES	Exp (kcal)	Int (kcal)	Bal (kcal)	UFE (cm²)	TSKF (mm)	FM (kg)	BF % (DER)	BF % (LEAN)	LTM (kg)	BMC (kg)
Age (years)	1.00											
SES	0.39	1.00										
Exp (kcal)	-0.45	-0.59	1.00									
Int (kcal)	0.04 p=0.50	0.19 p=0.002	-0.33	1.00								
Bal (kcal)	0.36	0.51	-0.89	0.69	1.00							
UFE (cm²)	0.61	0.48	-0.43	0.28	0.45	1.00						
TSKF (mm)	0.62	0.56	-0.51	0.28	0.52	0.92	1.00					
FM (kg)	0.58	0.37	-0.26	0.15 p=0.02	0.28	0.81	0.80	1.00				
BF % (DER)	0.86	0.43	-0.39	0.11 p=0.07	0.35	0.80	0.80	0.91	1.00			
BF % (LEAN)	0.87	0.51	-0.48	0.18	0.45	0.87	0.89	0.82	0.94	1.00		
LTM (kg)	0.20 p=0.0007	0.18 p=0.002	-0.06 p=0.31	0.09 p=0.12	0.11 p=0.06	0.48	0.45	0.51	0.35	0.40	1.00	
BMC (kg)	0.99	0.40	-0.44	0.06 p=0.34	0.38	0.68	0.69	0.67	0.91	0.91	0.33	1.00

UFE- Upper-arm Fat Estimate; TSKF- Total Skinfold Thickness; FM- Fatmass; BF % $_{(DER)}$ - Percent Body Fat (Deurenberg et al., 1991); BF % $_{(LEAN)}$ - Percent Body Fat (Lean et al., 1996); LTM- Lean Tissue Mass; BMC- Bone Mineral Content; SES- Socio-economic; Int- Energy Intake; Exp- Energy Expenditure; Bal- Energy Balance. All p-values are less than 0.0001, unless stated.

4.7.1 Upper-arm Fat Estimate and its Determinants

Upper-arm Fat Estimate (UFE) correlated positively and significantly with age, socio-economic status (SES), energy intake and balance. It correlated significantly and negatively (r= -0.43) with energy expenditure (Table 4.3). Results of univariate and multivariate regression analysis for UFE and its determinants (age, SES, energy expenditure, intake, and balance) are presented in Table 4.4.

Table 4.4: Adjusted and unadjusted linear regression coefficients and 95% confidence intervals for predictors of Upper-arm Fat Estimate (UFE).

Variables	Univariate Regression Coefficient (95 % CI)	Multivariate regression Coefficients (95% CI)
Age	3.56 (3.01 4.11)	2.96 (2.39 3.52)[1] 2.97 (2.41, 3.54)[2]
SES	29.46 (23.20 35.73)	15.81 (9.35 22.27)[3]
Energy expenditure	-0.02 (-0.03 -0.01)	0.01 (-0.01 0.04)[4]
Energy intake	0.03 (0.02 0.04)	0.02 (0.01 0.03)[5]
Energy balance	0.02 (0.01 0.03)	0.01 (-0.01 0.04)[6]

[1] Adjusted for SES, energy expenditure, energy intake, and energy balance.
[2] Adjusted for SES, energy expenditure, and energy intake.
[3] Adjusted for age, energy expenditure, energy intake, and energy balance.
[4] Adjusted for age, SES, energy intake, and energy balance.
[5] Adjusted for age, SES, energy expenditure, and energy balance.
[6] Adjusted for age, SES, energy expenditure and energy intake.

From univariate regression analysis, the following coefficients were recorded: 3.56 for age, 29.46 for SES, -0.02 for energy expenditure, 0.03 for energy intake, and

0.01 for energy balance. These coefficients dropped to various extents when the determinants were adjusted for in multivariate models for predicting UFE.

4.7.2 Total Skinfold Thickness and its determinants.

From the correlation matrix (Table 4.3) TSKF was negatively and significantly related to energy expenditure (r=-0.51), while it was positively related to age, SES, energy intake, and energy balance (r= 0.62, 0.56, 0.28 and 0.52 respectively.).

The results of the univariate and multivariate regression analysis for TSKF and its determinants are summarized in Table 4.5.

Table 4.5: Adjusted and unadjusted linear regression coefficients with 95% Confidence Intervals (CI) for predictors of Total Skinfold Thickness (TSKF), Fatmass (FM), and Percent Body Fat (BF%$_{(DER)}$,BF%$_{(LEAN)}$).

Variables	Univariate regression coefficient (95% CI)	Multivariate regression coefficient (95% CI)
	TSKF	TSKF
Age	0.67 (0.57, 0.77)	0.51 (0.41, 0.60)[1]
SES	6.20 (5.11, 7.29)	3.38 (2.26, 4.50)[2]
	FM	FM
Age	0.24 (0.20, 0.29)	0.21 (0.17, 0.25)[1]
SES	1.60 (1.13, 2.06)	0.74 (0.30, 1.18)[2]
	BF%$_{(DER)}$	BF%$_{(DER)}$
Age	0.40 (0.38, 0.43)	0.38 (0.35, 0.41)[1]
SES	2.07 (1.55, 2.59)	0.52 (0.21, 0.83)[2]
	BF%$_{(LEAN)}$	BF%$_{(LEAN)}$
Age	0.57 (0.53, 0.61)	0.52 (0.48, 0.56)[1]
SES	3.43 (2.74, 4.12)	1.33 (0.94, 1.72)[2]

[1] Adjusted for SES

[2] Adjusted for age

The univariate regression coefficients for TSKF with age, SES, energy expenditure, and energy intake were 0.67, 6.20, -0.01, and 0.01 respectively. When energy expenditure and energy intake were adjusted for in the multivariate models for predicting TSKF, their relationships with TSKF became insignificant ($\beta \cong 0.00$).

4.7.3 Fatmass and its determinants.

Fatmass (FM) was significantly related to all the indicators of body composition used in this study (Table 4.2). It correlated significantly and positively with age, SES, energy intake, and energy balance (r= 0.58, 0.37, 0.15, and 0.28, respectively). It also correlated negatively and significantly with energy expenditure (r= -0.26).

Energy intake and energy balance were not significantly related to FM from the univariate regression analysis ($\beta \cong 0.00$). The summary of univariate and multivariate regression analysis for Fatmass and its determinants are presented in Table 4.5

From univariate regression analysis energy expenditure, energy intake, and energy balance were not significantly related to FM ($\beta \cong 0.00$ and $p>0.05$). Age had a crude regression coefficient of 0.24 which changed to 0.21 when it was adjusted for SES in the model for predicting FM, while the crude regression coefficient for SES changed from 1.60 to 0.74 when it was adjusted for age.

4.7.4 Percent Body Fat ($BF\%_{DER}$) and its determinants.

Percent Body Fat ($BF\%_{(DER)}$) was significantly related to all determinants of body composition used in this study except energy intake (r= 0.11, p= 0.07). It correlated positively with age, SES, and energy balance and negatively with energy expenditure (Table 4.3).

From the univariate regression analysis, energy expenditure, energy intake, and energy balance were found to be insignificantly related to $BF\%_{(DER)}$ ($\beta \cong 0.00$). The results of the univariate and multivariate regression analysis for $BF\%_{(DER)}$ and its determinants are presented in Table 4.4.

Age and SES had crude regression coefficients of 0.40 and 2.07 respectively, for predicting $BF\%_{(DER)}$. These coefficients changed to 0.38 and 0.52 respectively when age and SES were adjusted for in multivariate models for predicting $BF\%_{(DER)}$.

4.7.5 Percent Body Fat ($BF\%_{LEAN}$) and its determinants

From the correlation matrix (Table 4.3) $BF\%_{(LEAN)}$, correlated significantly and positively with age, SES, energy intake, and energy balance, while it correlated negatively and significantly with energy expenditure (r= 0.87, 0.51, 0.18, 0.45 and -0.48 respectively).

Univariate regression analysis showed that energy expenditure, energy intake, and energy balance were not significantly related to $BF\%_{(LEAN)}$. Regression coefficients from multivariate analysis for the prediction of $BF\%_{(LEAN)}$ are summarized in Table 4.5. Energy expenditure, energy intake, and energy balance were not significantly related to $BF\%_{(LEAN)}$ ($\beta \cong 0.00$, $p > 0.05$).

The results of univariate analysis showed that age and SES had coefficients of 0.57 and 3.43 for prediction of $BF\%_{(LEAN)}$ respectively, and these changed to 0.52 and

1.33, respectively, when age and SES were adjusted for in multivariate regression models for the prediction of $BF\%_{(LEAN)}$.

4.7.6 Lean Tissue Mass (LTM) and its determinants

The mean LTM for the study population was 52.8 kg and it correlated significantly and positively with age and socio-economic status ($r = 0.20$, and 0.18, respectively). The correlation between LTM and energy expenditure, energy intake, and energy balance were not significant at $\alpha = 0.05$ level ($p > 0.05$) (Table 4.3).

Results of univariate regression analysis also showed that energy expenditure, energy intake, and energy balance were not significantly related to LTM ($\beta = 0.00$) (Table 4.6).

Table 4.6: Adjusted and unadjusted linear regression coefficients with 95% Confidence Interval (CI) for predictors of Lean Tissue Mass (LTM), and Bone Mineral Content (BMC).

Variables	Univariate regression coefficient (95% CI)	Multivariate regression coefficient (95% CI)
	LTM	LTM
Age	0.11 (0.05, 0.17)	0.08 (0.02, 0.15)^1
SES	1.00 (0.37, 1.63)	0.68 (0.00, 1.36)^2
	BMC	BMC
Age	0.11 (0.10, 0.12)	0.11 (0.10, 0.12)^1
SES	0.48.(0.35, 0.61)	0.03 (0.00, 0.05)^2

^{1} Adjusted for SES

^{2} Adjusted for age

The univariate regression coefficients of 0.11 and 1.00 respectively for age and SES changed to 0.08 and 0.68 when they were adjusted for in multivariate models for predicting LTM.

4.7.7 Bone Mineral Content (BMC) and its determinants.

The study population had a mean BMC of 4.66 kg. Age, SES, and energy balance correlated significantly and positively with bone mineral content ($r = 0.99$, 0.40, and 0.38, respectively), while energy expenditure correlated significantly and negatively with it ($r = -0.44$). The correlation between BMC and energy intake was not significant at $\propto = 0.05$ level ($p = 0.34$) (Table 4.3).

Univariate regression analysis showed that energy expenditure, energy intake, and energy balance were not significantly related to BMC ($\beta \cong 0.00$). Table 4.6 presents results of univariate and multivariate regression coefficients for BMC and its determinants.

CHAPTER FIVE

DISCUSSION

5.1 Age and Body Composition

The mean age of the study population was 35.4 (SD= 7.0) years. Results of correlation and regression analysis showed that age was one determinant that profoundly influenced body composition (both fat mass and fat-free mass), and this was in agreement with the view of Rabe et al. (1996) that aging was accompanied by changes in body composition and stature. Adipogenesis was reported to increase with advancing age while fat-free mass decreased.

5.1.1 Age and Body Fat

Age has been reported to be an independent determinant of relative body fatness (Tam et al., 1999). From Table 4.2, an increase in mean fatmass was observed with age. This was further illustrated in the results of correlation between age and the indicators of body fat (i.e. Upper-arm Fat Estimate (UFE), Total Skinfold Thickness (TSKF), Percent Body Fat (BF $\%_{(DER)}$ and BF $\%_{(LEAN)}$) and Fatmass (FM) where age had high and significant correlation coefficients. This increase in body fat content with age could be due to the fact that adipogenesis occurs as one advances in age. According to Tam et al. (1999), body fat increases slowly between 25 and 45 years and that body fat accumulation could occur till 70 - 75 years.

From the univariate regression analysis (Table 4.4 and 4.5), age was observed to be significantly associated with all indicators of body fat (UFE, TSKF, Fatmass, and Percent Body Fat). For UFE, the model in which adjustment was made for SES, energy expenditure, and energy intake with age was found to be the most predictive equation; it explained 49% of the variance in UFE. The results of the current study also differed from the observation by Khan et al.(1996) who found no significant relationship between age and upper-arm fat estimate. Their study was however, carried out among men and women (114 men and 174 women) while the current study involved only men. The men used in their study were between 18 and 80 years. While those below 20 years could still be growing and laying down body tissues, those above 50 could be undergoing body composition changes associated with aging, e.g loss of fat-free mass and increase in adiposity.

For Total Skinfold Thickness (TSKF), BF $\%_{(DER)}$, and BF $\%_{(LEAN)}$, the model for which age was adjusted for socio-economic status was the most predictive. The regression equation for which age was not adjusted for any other independent variable was found to be the most predictive for Fatmass (FM). The model in which age was adjusted for SES was not statistically significant (p=0.081).

The model used for predicting percent body fat ($BF\%_{(LEAN)}$), using the equation by Lean et al.(1996) (Appendix IV) was generated using individuals between ages 18 and 81 years, while that used for Fatmass (FM) by Ellis (1997) was based on young males between the ages of 3 and 18 years. Considering the age ranges, and the influence of age on body fat content, the equation generated by Lean et al. (1996) appears to be more appropriate for the population subgroup selected for this study (25-50 years). This could be one of the reasons why the models generated with age (either singly or adjusted for other covariates) explained variances in body fat to larger extents for BF%$_{(LEAN)}$ (Lean et al., 1996) than for FM (Ellis 1997). The differences in variables used in generating the equations could also contribute to the differences in the amounts of variation explained (R^2). This was observed for BF%$_{(DER)}$ and BF%$_{(LEAN)}$ (R^2= 75% and 76% respectively). The equation for BF%$_{(DER)}$ (Deurenberg et al.,1991) (Appendix IV) was also generated using individuals between the age of 7 and 83 years. This equation included age, BMI and sex, while that developed by Lean et al. (1996) used waist circumference, triceps skinfold thickness and age.

Using Waist-Hip Ratio (WHR) as a measure of abdominal fat accumulation, the results showed that 10 men (3.6%) out of the 280 had accumulated abdominal fat (WHR>0.98). Out of these 10, the minimum age was 42 years (average age for the whole was 35.4 years) and this further confirmed the deposition of abdominal fat with age, as reported by Bray (1990).

5.1.2 Age and Fat free mass

Lean Body Mass (LBM) is considered to be the body compartment that is non-adipose and is therefore more metabolically active. It is generally made up of bone, muscle and Extra-cellular Water (ECW) (Willett, 1990). The Lean Tissue Mass (LTM), that was measured using the equation by Ellis (1997) (Appendix IV) measured non-bone Lean Tissue Mass (LTM). LTM correlated positively and significantly with age (r = 0.20, p=0.0007). This apparent weak but significant correlation could have been due to the fact that the equation was generated using a young population (3-18 years) and therefore less applicable to adults (25-50 years). Williams (1993) had stated that LBM kept on changing during one's lifetime. This continuous change in LBM with age could make the LBM component of body composition for 3-18 year old males differ significantly from that of adults 25 - 50 years. The lack of a clearer relationship between age and LTM could also be due to the heterogeneous nature of LTM (which includes muscle, ECW, nervous tissue and other non-adipocytes). This extreme heterogeneity could affect the accuracy of indirect methods of measurement of LTM, such as anthropometric measures.

Bone Mineral Content (BMC) is the other major component of LBM. Calcium (Ca) is the mineral element that is present in the body in the highest amount, constituting 1.5 2.0% of total body weight. Up to 99% of Ca is found in bone and teeth (Williams, 1993). This showed that BMC is very much dependent on the calcium content of the body. Using the equation by Ellis (1997) (Appendix IV), the mean BMC of the men in this study was about 4.66 ± 0.08kg, which meant that BMC constituted about 7% of mean body weight.

BMC correlated positively and significantly with LTM ($r = 0.33$, $p< 0.0001$), and this was in agreement with the observation of a high correlation by Ellis (1997). This could be an adaptive process since bone mass or strength has to increase in order to be able to cope with increasing body weight with advancing age. The high correlation between age and BMC ($r = 0.98$, $p< 0.0001$) could be due to a similar mechanism. Guthrie and Picciano (1993) had reported that adequate Ca intake during early adulthood could greatly improve BMC throughout adulthood and prevent loss of bone mass. This could therefore enhance the strength of bone later in adult life. The high correlation between age and BMC could therefore be attributed to an adequate Ca intake among the males in this study. The dependence of BMC on age was further demonstrated using regression analysis, where prediction equations generated with age alone explained 98% of variance in BMC; this did not change after adjusting for SES.

5.2 Energy Expenditure and Body Composition.

There was a negative and significant correlation between energy expenditure and all indicators of body fat content (Table 4.3). This observation was similar to the view of Dietz (1996), who showed that energy expenditure was inversely associated with excess body fat (obesity prevalence). This is explained by the fact that increased physical activity level could lead to a depletion of the body fat stores. From the regression analysis, energy expenditure was not significantly associated with FM, BF $\%_{(DER)}$ and BF $\%_{(LEAN)}$ ($\beta \cong 0.00$, $p \geq 0.05$).

The negative correlation between energy expenditure and LTM and BMC could however not be explained in the same way. According to Nelson et al. (1996), regular physical activity, especially strength training could produce significant changes in skeletal muscle size. The expectation was that muscles could enlarge (hypertrophy). This increase in skeletal muscle size could then be accompanied by a concomitant increase in BMC. The absence of a relationship between energy expenditure and fat-free mass and some indicators of body fat content could be due to a number of reasons. There is the possibility of an over- or underestimation of energy expenditure due to the reliance on the memory of the individuals for information on energy expenditure. There was also no means of validating the responses of the individuals on their energy expenditure, which was due to lack of the sophisticated ("gold") methods in validating self-reported energy expenditure responses. Obarzanek et al.(1994) reported that the lack of a clear relationship between energy expenditure and body composition observed in their studies could have been due to poor qualification in the self-reporting of physical activity. The equations for predicting FM, LTM and BMC were also generated using children (3-18 years) whose energy expenditure patterns could differ considerably from that of adults.

5.2.1 Occupation and Body Composition

The results in Figure 3 showed that construction workers had negative mean energy balances, and the least values for mean Fatmass and LTM (Figure 4). The fact that they were not meeting their energy requirements from their intakes meant that they had to resort to the use of body fat in storage for energy production, hence the observed low fat contents. Although construction workers also had the highest mean energy expenditure (they did a lot of manual work), they had the least mean LTM. This observation is not consistent with that of Nelson et al (1996). Their study showed an increase in lean body mass with increasing activity. This view was true for individuals who carried out strength training. From the physical activity accounts given by respondents in this study, strength training was not a major component of their daily activity routine. Although their energy expenditure was high, their energy intakes might have been relatively low. This could result in energy deficiency thus necessitating the use of body fat stores for energy production. The direct opposite situation was observed for office workers who had the largest positive energy balances.

5.3 Energy Intake and Body Composition

One factor that could directly influence body composition was energy ntake. It was expected that when there was an excess of dietary glucose, but more so from excess fat intake, new fatty acids were made from acetyl-CoA and incorporated into triglycerides for tissue stores. Body fat content could then be increased.

Individuals categorized as underweight (BMI < 18.5) had the lowest mean energy intake while those categorized as overweight (BMI > 24.9) had the highest mean energy intakes. It could thus be concluded that overweight individuals had high BMI because they were eating more food the excess energy, which was being converted to more body fat. They could also be expending less energy, which could lead to large positive energy balances.

Studies have, however, showed that food energy alone did not control body fat content, and hence BMI. Fatimah et al. (1996) reported in their study on energy, protein, fat and carbohydrate intake of underweight, normal weight and obese government workers in an urban area in Malaysia that underweight subjects had higher energy intakes than obese individuals. The obese individuals had higher energy intakes than their counterparts with normal weight Their study had food intake methodologies similar to that used in the current study; the 24–hour recall and FFQ. They, however, obtained a 7-day 24-hour recall and averaged it. The difference in results could be attributed to variations in food habits between Ghanaians and Malaysians. The positive and significant correlation between energy intake and indicators of body fat could also be due to the fact that, the more food energy one ate, the more the availability of excess energy to be converted to body fat for storage. This could occur if energy expenditure was lower than energy intake (resulting in prolonged maintenance of the body in positive energy balance).

The lack of significant correlation between energy intake and LTM and BMC ($p>0.05$) could be due to the fact that fat-free mass depended more on the body's intake of proteins and minerals rather than energy-giving ones. Furthermore the current study focused only on energy intake.

Energy intake was not significantly associated with FM, BF $\%_{(\mathrm{DER})}$, BF $\%_{(\mathrm{LEAN})}$, LTM and BMC. It was, however, significantly related to UFE and TSKF. When energy intake was adjusted for age, SES, energy expenditure and energy balance, in various combinations, its contributions in the regression equations for predicting TSKF were not significant (0.00, $p>0.05$). The model in which energy intake was adjusted for age and SES was the most predictive for UFE.

Information obtained for energy intake was heavily dependent on the memory of the respondents. This could have led to over- or underestimation of the frequencies and/or portion sizes of foods eaten. However, FFQ data correlated highly with 24-hour recall data ($r= 0.93$, $p< 0.0001$). The individuals might also be eating the energy-giving foods, for example, cassava, yam, rice etc. but their diet could lack micro-nutrients such as minerals and vitamins. These were needed to make the energy in these foods available to the body. Minerals and vitamins are the major sources of co-enzymes, and enzyme cofactors that play various roles along the pathway for releasing energy in food to the body. This means that eating a balanced diet could have an important association with body composition in adult males.

Horton et al. (1995) reported that the amount and composition of food eaten influenced body weight regulation, and that an individual with a high metabolic susceptibility to accumulating body fat (tendency to be obese), would be inclined to accumulate more body fat but less glycogen on a positive energy balance than an individual with a lower metabolic susceptibility to obesity. The variation in metabolic susceptibility to accumulating body fat among individuals could also account for the lack of a stronger correlation between energy intake and body fat.

5.4 Energy Balance and Body Composition.

Energy balance was determined by taking the difference between energy intake and energy expenditure. It correlated positively and significantly with all indicators of body fat (Table 4.3). Figure 5 also shows that individuals classified by their BMI as overweight had the highest positive energy balances while the underweight had the smallest (negative) energy balances. This is not surprising since excess energy reaching the body is converted to glycogen and body fat; the larger the positive energy balance, the higher the amount of fat that would be laid down for storage. The lack of significant correlation between energy balance and fat-free mass (LTM and BMC) was not very clear, since it was expected that LTM would increase as a larger and positive energy balance led to an increase in body fat and hence an increase in body weight.

Univariate regression analysis showed that the only indicator of body composition that was significantly associated with energy balance was UFE. The remaining indicators of body composition were not significantly associated with energy balance ($\beta \approx 0.00$, $p>0.05$). Energy balance is a result of energy intake and expenditure. The lack of a stronger relation between energy balance and some indicators of body composition could have been due to the reliance on memory to obtain information on both energy intake and expenditure. The reliance on memory could have led to over-estimation or under-estimation of energy intake and expenditure thus affecting the expected relation between energy balance and body composition.

Using energy balance to predict UFE, the regression equation in which energy balance was adjusted for age, SES, energy expenditure was the most predictive. This model explained 49% of the variance in UFE.

5.5 Socio-economic Status and Body Composition.

Socio-economic status was expected to influence body composition in a variety of ways, especially through energy intake and expenditure. It correlated positively and significantly with all indicators of body composition (Table 4.3). Figure 7 showed that individuals with low SES had the highest energy expenditures but lowest energy intakes, hence the lowest energy balances, in contrast to individuals in the high socio-economic category. Regression analysis also showed that SES was significantly associated with all indicators of body composition used in the study. All relationships between SES and indicators of body composition were significant, whether singly or adjusted for the other independent variables. For UFE, the model in which SES was adjusted for age and energy intake was the most predictive. For TSKF, FM, $BF\%_{DER}$, and $BF\%_{LEAN}$, the models in which SES was adjusted for age were the most predictive. They had relatively higher values for R^2 (51%, 31%, 76%, and 80% respectively).

These observations could be due to the fact that nutritional status is usually associated with food intake, which is in turn dependent on income (a function of socio-economic status). Hence, poverty (a potential indicator of low socio-economic status) could be regarded as a major cause of low-level nutrition. On the other hand, satisfactory nutritional status could be expected from high socio-economic status.

Islam (1997), however, pointed out that in reality, certain aspects of nutrition could be influenced by factors other than food intake. For instance, a household could be earning more or be in the high socio-economic class, but could be spending more on non-food items such as education, health and clothing. From the current study, however, it could be concluded that individuals in the high socio-economic group were taking in more food energy and hence were having high mean body fat contents.

Additionally, taking in more calories or maintaining a long-term positive energy balance with an increased metabolic susceptibility to accumulate excess body fat, would lead to high body fat contents. WHO (1998) reported that the process of modernization and economic transition in many developing countries, including Ghana, could lead to improvements in their living conditions or improved socio-economic status. Individuals of high socio-economic status tend to cut down on physical activity levels (e.g., relying on cars to move short distances rather than walk or using mechanized means of carrying out rather laborious and energy-demanding domestic activities, such as using blenders, vacuum cleaners and washing machines). If these reductions in physical activity accompany high food energy intakes, large positive energy balances could result. This could result in the accumulation of body fat. Conversely, individuals in low socio-economic groups would tend to walk long distances, and do chores still using old-fashioned and more laborious methods. This practice could result in smaller or negative energy balances. If this condition persists it could reduce the body fat or even lead to Chronic Energy Deficiencies (CED). This could further lead to diminished LTM.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Using correlation and regression analysis, age was found to be the single most independent predictor of variations in body composition. The correlations between socio-economic status, energy expenditure, energy intake and energy balance were not as strong, but still significant.

From crude regression analysis, age and socio-economic status wer found to be significant predictors of the indicators of body composition used in the current study, namely Upper-arm Fat Estimate (UFE), Total Skinfold Thickness (TSKF), Fatmass (FM), Percent Body Fat (BF$\%_{(DER)}$ and BF$\%_{(LEAN)}$), Lean Tissue Mass (LTM), and Bone Mineral Content (BMC). Energy expenditure and intake were significant predictors for Upper-arm Fat Estimate and Total Skinfold Thickness, while energy balance only significantly predicted Upper-arm Fat Estimate.

Bone mineral content was highly dependent on age and this could be due to the study participants having adequate calcium nutrition status as a result of improved intakes during early adulthood (since calcium is the predominant mineral in the body)

Socio-economic status affected body fat content in a variety of ways, mainly through energy expenditure and intake (and hence energy balance). It could reduce energy expenditure while increasing energy intake, and this could lead to large energy balances. A prolonged existence in a positive energy balance coupled with an increased metabolic susceptibility to accumulate body fat in preference to glycogen could then result in an increase in body fat content.

One possible reason for this lack of a stronger relation between indicators of body composition and energy expenditure, energy intake and energy balance could have been due to the reliance on the memory of the respondents which could have possibly led to under/over estimation of the energy indices. Some of the equations used to obtain indicators of body composition, were generated using relatively young populations, or were developed for use in specific sites hence their practicability on an adult population in a developing country could be less reliable.

6.2 Recommendations

Based on results and observations made from the current study, the following recommendations are made:

More studies on body composition need to be carried out using more sophisticated, direct and indirect methodologies such as Dual X-ray / Photon Absorptiometry (DXA /DPA), Bioelectric Impedance Analysis (BIA), Computer Tomography (CT), Magnetic Resonance Imaging (MRI) etc. together with anthropometry. This could help develop site-specific prediction models for various indicators of body composition for use in a developing country like Ghana.

Body composition studies should also be carried out among individuals with different metabolic and physiologic conditions to identify how these individuals vary in body composition compared with others.

Furthermore, long-term studies on the relationship between nutrition, lifestyle, and body composition and the incidence of chronic diseases and mortality should also be of priority in this field of research.

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APPENDIX I

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

UNIVERSITY OF GHANA- LEGON

Dear Sir,

I am a student from the University of Ghana, and I am carrying out a study on the Body Composition of Adult Males with different Lifestyles and Occupations.

The findings of this study will be helpful in identifying lifestyles compatible with ideal body compositions. It could also be useful in nutrition education

I will therefore be grateful if you could furnish me with information about your socio-economic status, physical activity and food intake pattern. Total confidentiality is guaranteed on any information given. Thank you.

Subject No...........

SOCIO-ECONOMIC STATUS

1 Background Information

a) How old are you?.................years

b) What is your level of education? (Please tick where applicable)

No school [ ] Primary school [ ] Secondary school [ ]

Post secondary/ polytechnic/ vocational school [ ]

University (first degree) [ ] Post graduate degree [ ]

Other (specify)

c) How many individuals are in your household?......................

2. Housing

a) Are you the sole occupant of your house? Yes [ ] No [ ]

b) How many rooms do you have in your house........................

c) What type of furniture do you have in your living room? E. g. stuffed chairs or 'dining room' chair type... ....

3. Toilet and Bathroom Facilities

a) What type of bathroom facility do you have? (please tick where applicable).

Ordinary bucket [ ] Shower [ ] Bathtub [ ]

Other [ ] (specify)……………………………………………..

b) What toilet facility do you have? (please tick where applicable)

Water closet [ ] Pan latrine [ ] Public toilet [ ]

Other [ ] (specify)…………………………………………………….

4. Transportation

What means of transportation is available to members of your household‘

(please tick where applicable)

Private transport [ ] Public transport [ ] No means [ ]

Other [ ] (specify)………………………………………………..

5. Indicators of Wealth

Please do you have any of the following items? (please tick where applicable).

None [ ] Radio [ ] Radio + television [ ]

Radio + television + refrigerator [ ]

Radio + television + refrigerator + others e.g. VCR, air conditioner, personal computer [ ].

ACTIVITY PATTERN QUESTIONNAIRE

ACTIVITY NO.	Description of activity	Duration (rs)

FOOD INTAKE QUESTIONNAIRE

Day	Meal	Description of food	Quantity
1	Breakfast		
	Lunch		
	Supper		
	Snacks		
2	Breakfast		
	Lunch		
	Supper		
	Snacks		
3	Breakfast		
	Lunch		
	Supper		
	Snacks		

FOOD FREQUENCY QUESTIONNAIRE

FOODS	FREQUENCY								PORTION SIZE ESTIMATE		
	Never or less Than once/month	1-3/ month	1 / week	2-4/ week	5-6/ week	1/ day	2-3/ day	4/day	small	Med.	large
STRACHY ROOTS/TUBERS											
Cassva (boiled)											
Plantain (boiled)											
Plantain (fried)											
(roasted)											
Yam (fried)											
(boiled)											
Cocoyam (boiled)											
Potatoes											
Fufu											
Gari											
Kokonte											
CEREALS											
Kenkey											
Banku											
Maize porridge											
Oats											
Bread											
Rice											
Doughnut/biscuit											

FOODS	FREQUENCY								PORTION SIZE ESTIMATE		
	Never or Less than Once/mo	1-3/ month	1/ week	2-4/ week	5-6/ week	1/day	2-3/ day	4/ day	small	medium	large
FRUITS											
Pineapple											
Orange											
Banana											
Water melon											
Mango/ Pawpaw											
FAT/OILS											
Butter											
Magarine											
Red palm Oil											
Veg. oils											
MEAT/EGG PRODUCTS											
Beef											
Corned beef											
Mutton											
Poultry											
Organ meat											
pork											
FISH											
Smoked fish											
Fried fish											
Canned fish											

FOODS	FREQUENCY								PORTION SIZE ESTIMATE		
	Never or Less than/ Month	1-3/ month	1/ week	2-4/ week	5-6 /week	1/ day	2-3/ day	4/ day	small	medium	large
LEGUMES/ PULSES											
Groundnuts(roasted)											
Cowpea											
Bambara groundnut											
MILK/ MILK PRODUCTS											
Evaporated milk											
Condensed milk											
Cheese											
Chocolate drinks											
Yoghurt etc.											
DRINKS /BEVERAGES											
Soft drinks											
Malt drinks											
Beers											
spirits											

APPENDIX II

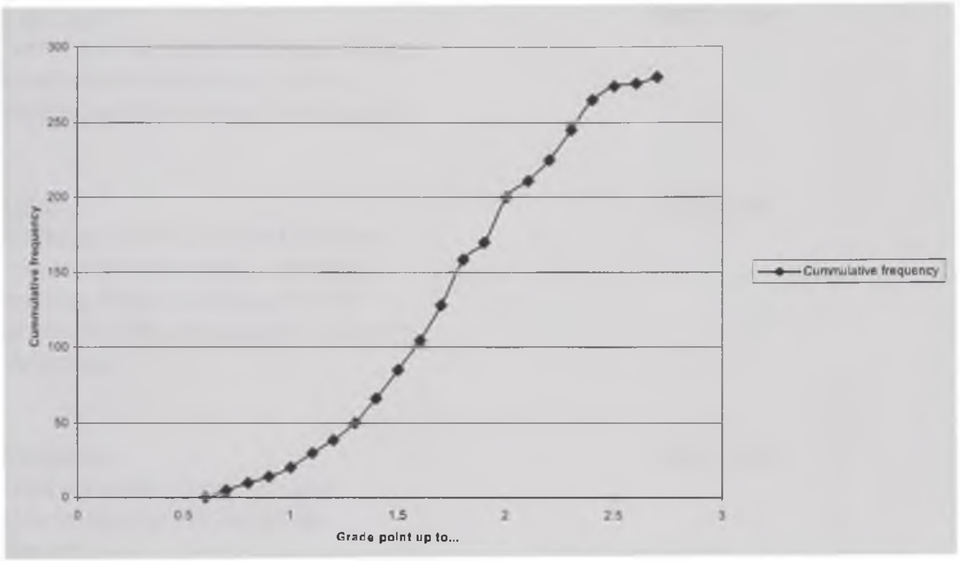
Grade points used for socio-economic indicators

INDICATOR	GRADE POINT	INDICATOR	GRADE POINT
a) LEVEL OF EDUCATION		b)FAMILY SIZE (no of individuals)	
No school	0.0	1 – 3	2.5
Primary level	0.5	4 – 6	1.5
Middle level	1.0	7 10	1.0
Secondary level	1.5	>10	0.5
Post secondary level	2.0	c) TENANCY/ HOUSE OWNERSHIP	
University level	3.0	Sole occupant	2.0
Post graduate level	3.5	Other(s)	1.0
d) NO. OF ROOMS		e) TYPE OF FURNITURE	
1	0.5	Dining room type	0.5
2	1.0	Arm chair	1.0
3	2.0	Stuffed chairs	2.0
more than 3	3.0		
f) BATHROOM FACILITIES		g) TOILET FACILITIES	
Ordinary bucket	0.5	water closet	1.0
Shower	1.0	pan /pit latrine	0.5
Bath tub	2.0	Public toilet	0.0
h) OTHER INDICATORS OF WEALTH		i) MEANS OF TRANSPORTATION	
None	0.0	No personal means	0.5
Radio	1.0	Bicycle	1.0
Radio and TV	2.5	Motor bike	2.0
Radio, TV, refrigerator	3.5	Own car	3.0
Radio, TV, refrigerator and more	4.0		

Sample Calculation

$$\text{Mean Grade Point} = \frac{a + b + c + d + e + f + g + h + i}{9}$$

Cummulative frequency distribution for socio-economic status of study participants



Individuals with grade points:

below 1.39 - low socio-economic status

between 1.40 and 2.09 - medium socio-economic status

above 2.09 - high socio-economic status.

APPENDIX III

Approximate energy expenditure for various activity categories in relation to resting needs

Activity categories	Representative values for activity factors per unit time of activity
Resting Sleeping, reclining	**REE x 1.0**
Very light Seated and standing activities, driving laboratory work, typing, ironing, cooking, playing musical instrument	**REE x 1.5**
Light Walking, on level surface, cooking with coalpot /firewood, carpentry, teaching, house cleaning, driving larger vehicles, playing golf, restaurant/ shop trades	**REE x 2.5**
Moderate Walking uphill, carrying a load, Construction works, weeding, Hoeing	**REE x 5.0**
Heavy Heavy manual digging, tree felling Soccer, basketball, hockey	**REE x 7.0**

(NRC., 1989)

Sample Calculation

Activity as multiples of REE		Duration (hr)	Weighted REE factor
Resting	1.00	9.50	9.50
Very light	1.50	12.50	18.75
Light	2.50	1.00	2.50
Moderate	5.00	0.50	2.50
Heavy	7.00	0.50	3.50
Total		24	36.75
MEAN			1.53

For expended in kcal/ day;

For a 31- year old, 60 kg man

Equation for predicting REE = (11.6 x weight) + 879

REE = (11.6 x 60) + 879

REE = 1575 kcal

Energy expended per day = 1575 x 1.53

=2409.8 kcal /day

APPENDIX IV

Average weight of portion size estimates of foods eaten by study participants.

FOODS	WEIGHT IN GRAMS		
	Small	Medium	Large
Roots and tubers			
Cassava (boiled)	150	280	350
Plantain (boiled)	120	240	350
Plantain (roasted)	83	185	275
Plantain (fried)	65	130	250
Potatoes (boiled)	120	240	420
Fufu	220	320	450
Gari	45	110	180
Kokonte	120	200	300
Yam (boiled)	150	320	450
Yam (fried)	76.5	225	350
Cereals			
Tou zaafi	150	230	350
Kenkey	140	240	320
Banku	150	230	350
Maize	100	200	250
Bread	60	120	230
Rice	120	250	320
Doughnuts	46	77	120
Legumes			
Groundnuts (roasted)	20	42.5	60.5
Groundnut (soup)	35	85	150
Cowpea	130	210	370
Bambara groundnut	126	210	370

FOODS	**WEIGHT IN GRAMS**		
	Small	**Medium**	**Large**
Meat and fish products			
Smoked fish	60	150	250
Canned fish	26	52	77.7
Beef	35	58.5	120
Corned beef	30	55	100
Fats and oils			
Butter	15	30	50
Magarine	15	30	50
Palm oil	15	30	50
Vegetable oils	15	30	50
Milk and milk products			
Evaporated milk	10	30	50
Condensed milk	6	25.2	30.2
Cheese	25	38	50.5
Chocolate drinks	16.5	25	35
Others e.g. yoghurt	150	250	300
Fruits			
Pineapple	66	165	350
Orange	60	150	220
Banana	35	77	115
Pawpaw/mango	25	50.5	75.5
Soft drinks and alcoholic beverage (ml)			
Soft drinks	150	300	600
Malt drinks	170	330	660
Beers	330	670	1300
Gin	30	50	80

APPENDIX V

Clothing worn by men during weighing and their weights

Description	Weight (g)
1) Cotton short sleeved shirt	250
2) Cotton long sleeved shirt	280
3) Light textured T-shirt	150
4) Lacoste T-shirt	250
5) Cotton 'singlet'	90
6) Polyester cotton trousers	350
7) Khaki trousers	500
8) Jeans trousers	725
9) Dacron trousers	515
10) Woolen trousers	450
11) Flying tie	35
12) Vest	225
13) Sock	38
14) Leather-jeans belt	250
15) Light leather belt	130
16) Briefs	60
17) Leather sandals	990
18) Dressing shoes	890
19) Khaki overalls	780

APPENDIX VI

Summary of equations and models used to generate derived variables and indicators of body composition.

Body Mass Index (BMI) = weight (kg)/ height^2 (m^2)

Waist - hip Ratio (WHR) = waist circumference/ hip circumference

Upper-arm Fat Estimate (UFE) (mm) = MUAC x Triceps skinfold thickness/2

(Rolland-Cachera et al.,1997)

Total Skinfold Thickness (TSKF) (mm) = sum of skinfolds at 4 sites; (biceps, triceps, subscapula and suprailliac)

Percent Body Fat ($BF\%_{DER}$) = (1.20 x BMI)+(0.23 x AGE)-(10.80 x SEX)-5.4

(Deurenberg et al.,1991)

Percent Body Fat (BF%LEAN) = (0.35 x WAIST)+(0.76 x TRICEPS)+ (0.24 x AGE)-26.4

(Lean et al.,1996)

Fatmass (FM) (kg) = (0.59 x WEIGHT)-(0.38 x HEIGHT)+ 36.0

Lean Tissue Mass (LTM) (kg) = (0.36 x HEIGHT)+(0.39 x WEIGHT) -34.2

Bone Mineral Content (BMC) (g) = (21.3 x WEIGHT)+(106.3 x AGE)-525.3

(Ellis 1997)