EFFECTS OF A TWELVE-WEEK WEIGHT REDUCTION EXERCISE PROGRAMME ON SELECTED SPATIOTEMPORAL GAIT PARAMETERS IN OBESE INDIVIDUALS

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13TH OCTOBER, 2016

CERTIFICATION

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DEDICATION

This study is dedicated to almighty God

ABSTRACT

Obesity, a global clinical and public health challenge, has been documented to negatively affect spatiotemporal gait parameters. Although, weight reduction exercise programme is routinely used in the management of obesity, it has not been well documented if such intervention leads to improvement in spatiotemporal gait parameters. This study was carried out to investigate the effects of a twelve-week weight reduction exercise programme on selected spatiotemporal gait parameters of obese individuals and compare with those of their normal weight counterparts.

In this quasi-experimental study, 60 participants (30 obese and 30 age-matched normal weight individuals) were recruited and assigned into obese and normal weight groups respectively but only 58 participants (30 obese and 28 normal-weights) completed it. Obese participants had 12-weeks of weight reduction exercises while normal weight participants did not. Gait parameters: Walking Speed (WS), Cadence (CD), Step Length (SL), Step Width (SW) and Stride Length (SLT) were measured at baseline and at the end of weeks 4, 8 and 12 of the study. The data were summarized using descriptive statistics and further analysed using Repeated measures ANOVA and independent t-test at alpha level set at 0.05.

The ages of the Obese group (OBG) and normal weight group (NWG) (32.0± 8.26 years and 29.32± 6.06 years) were comparable but obese participants weighed significantly more and were significantly shorter than their normal weight counterparts. At baseline, the OBG had significantly lower WS (1.09± 0.17m/s; 1.29 ± 0.17 m/s), SL (58.68± 7.42cm; 66.42± 6.51cm) and SLT (117±14.86 cm; 133±13.02 cm) but higher CD (14.47± 0.97steps/min; 12.82± 0.39steps/min) and SW (13.67±4.15 cm; 9.79± 1.78 cm) than the NW group. At week 12, the group's WS (1.35±0.19 m/s; 1.35±0.32 m/s), SL (66.83±7.81cm; 67.91±6.53cm), SLT (134±16.68 cm; 136±13.10 cm), CD (12.77± 0.63step/min; 12.82±0.39 steps/min) and SW (8.81±1.81cm; 9.55±1.80cm) for OBG and NWG respectively were not significantly different. Within-group comparison however showed that the WS, SL and SLT in obese group were significantly increased while CD and SW decreased significantly across the four time points of the study.

The 12-week weight reduction exercise programme produced significant effects in the spatiotemporal gait parameters of the obese individuals to a level comparable to that in normal weight individuals. It is therefore recommended that weight reduction exercise programme should be adopted to improve spatiotemporal gait parameters of individuals presenting with obesity related problems.

Keywords: Obesity, Spatiotemporal gait, Weight reduction exercises.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction.

Obesity is a condition of excessive fat accumulation in adipose tissue which results from caloric intake that exceeds energy usage (Hill and Peter, 1998; Lai et al, 2008; Chugh and Sharma, 2012; Gutin, 2013). It is regarded as a global epidemic disease which was once believed to be an affliction of the Western society and has increased worldwide by more than 75% in the last three decades (Flegal et al, 1998; Chugh and Sharma, 2012). Although individuals affected by obesity often focus on its social stigma, the condition is far more than a cosmetic problem (Kopelman, 2000). Thus, it has been regarded as a known risk factor for several diseases such as increased incidence of cardiovascular disease, coronary heart diseases, pulmonary afflictions, type 2 diabetes mellitus (DM), hypertension, stroke, dyslipidemia, osteoarthritis, and some cancers (Fallon et al, 2005, Herring et al, 2010 and Ko et al, 2010). These conditions not only lead to reduced quality of life given their protracted nature, but also lead to premature death (Kopelman, 2000). Furthermore, obesity has also been reported to be a major hindrance to aerobic capacity and the ability to perform physical activities (Mattson et al, 1997; Friedman et al, 2002) which may have implications for physical therapists' interventions (Racette et al, 2003).

Body Mass Index (BMI) is the weight in kilograms divided by the square of the height in meters (kg/m^2) and its calculation is one of the recommended methods for evaluating obesity (WHO, 2000). Although BMI is often considered an indicator of body fatness, it is a surrogate measure of body fat because it measures excess weight rather than excess fat. However, studies have shown that BMI levels correlate with percentage body fat and also with future health risks hence a high BMI predicts future health problems (WHO, 2000). BMI is therefore considered as an appropriate measure in screening for obesity and its health risks (WHO, 2000). Using BMI, body weight has been classified as normal weight (18.5-24.9kg/m^2), overweight (25-29.9kg/m^2) and obese (>30kg/m^2) (WHO, 2000).

Obesity is further classified as class I (30-34.9kg/m^2), class II (35-39.9kg/m^2) and class III (> 40 kg/m^2) obesity. Gait is the manner or style of walking (Lipperts, 1993) and walking is the simplest act of falling forward and catching oneself (Magee, 1997).Obesity has been highly associated with impaired musculoskeletal function, which negatively affects physical functioning especially walking (Stenholm et al, 2007; Houston et al, 2009). Studies have identified gait alterations as one of the various negative consequences of obesity (Browning and Kram, 2007; Ko et al, 2012). Saibene and Minetti, (2003) and Xu et al, (2008) reported that higher metabolic expenditure and reduced gait efficiency due to the inertia of the abnormal weight in the lower limbs, are features of obesity and weight loss programmes have been found to improve gait efficacy by reducing metabolic expenditure. The effects of obesity on gait and mobility is such that it modifies the pattern of gait of such individuals and also imposes abnormal mechanics on body movements thereby increasing the risk of musculoskeletal injuries (Ling et al 2009; Herring et al 2010). Studies have shown that preferred walking speed, step length and step frequency are significantly lower in obese individuals compared to their non-obese counterparts (Spyropoulous et al, 1991; De Vita and Hortobagyi, 2003; Ling et al, 2012). Obese adults have also been documented to walk at a slower cadence (steps per minute) with wider step widths and shorter swing (Spyropoulous et al, 1991; Wearing et al, 2006; Ling et al, 2012).

Obesity causes gait modification in a manner that is directly related to the amount of extra weight carried by the body (Ling et al 2009; Herring et al 2010). This submission has also been supported by Ko et al (2010) who posited that older adults with obesity modify their gait patterns compared to their counterparts with normal weight while walking at preferred speed. Additionally, the obese was found to have a longer stance phase greater period of double support, reduced cadence as well as increased stance duration compared to their normal weight individuals (Spyropoulous et al, 1991; De Vita and Hortobagyi, 2003). Spyropoulous et al (1991) therefore suggested that obese individuals will have to walk slowly, take smaller strides and larger step width which provide a wider base of support for balance and longer double support. It has been established that in self-paced walking and at slower speeds; obese individuals exhibit shorter stride lengths, wider step widths, and an increased variation of hip abduction throughout the gait cycle (Miller, 2008; Sarkar et al, 2011; Ling et al, 2012). The wider step width observed in obese individuals is attributed to their larger thighs and shanks which help in implementing a balancing strategy and also induce an increased metabolic cost, with resultant premature fatigue and increased risk of injury during walking (Donelan et al, 2001; Sarkar et al, 2011).

Researchers have established that lifestyle interventions with various combinations of physical activities such as aerobic exercises, diet, and education programmes reduce obesity and its comorbidities (Dao et al, 2004; Savoye et al, 2007; Caranti et al, 2007). Physical activity has been documented as a vital part of a comprehensive weight reduction programme which results in decrease in abdominal fat, increase in cardiorespiratory fitness and loss of weight in obese adults (Aslan, 2011). Coker et al (2009) highlighted the need to incorporate physical activity into every strategy intended to prevent weight gain as well as to maintain weight loss over time. Walking at a constant intensity for a prolonged period of time has indeed been identified as a useful strategy for weight reduction in obese individuals because it is a convenient type of physical activity that can be used to expend a significant amount of metabolic energy (Hong et al, 2003; Browning et al, 2007) thereby helping the clients to attain a healthy weight (Babalola, 2005). McGlynn, (1999) and Babalola, (2005) have also established that weight loss through dietary modification alone without exercising can have a negative effect on body composition. They further opined that a balance between dietary modification and graded exercises in weight control is the vital tool in achieving desirable results in weight reduction programmes, hence, physical exercises especially weight reduction exercises combined with diet have been established to be more effective than diet alone (Shaw et al, 2006). Furthermore, research reports have shown that for the same magnitude of weight loss, exercises have the advantage of achieving weight loss faster than diet (Ross et al, 2000a; Ross et al, 2004a and Lee et al, 2005). Additionally, Akinpelu et al (2008) submitted that among other beneficial effects of exercises, regular physical activities are effective means of improving cardiorespiratory fitness and reducing waist circumference, visceral fat and subcutaneous fat. Physical activity is therefore recommended for reducing excess body weight, preventing body weight regain, and decreasing the subsequent risks of developing metabolic and orthopaedic conditions (Nantel et al, 2011).

The negative effects of obesity on gait have been widely reported in literature (Messier et al, 2005; De Souza et al, 2005; Nantel et al, 2006; Browning et al, 2009; Blaszczyk et al, 2011; Sarkar et al, 2011) but studies on the effects of weight reduction on gait parameters are rather scarce despite the documented differences between gait parameters of obese and normal weight individuals as well as role of exercises in weight loss. If obesity results in altered gait parameters, it is reasonable to expect that weight loss should restore and improve gait parameters. This study was hence designed to investigate the effects of a 12-week weight reduction exercise programme on selected spatiotemporal gait parameters of obese individuals.

1.2 Statement of the Problem.

The World Health Organization (WHO) proclaimed obesity as a global epidemic and estimated that it is the fifth leading risk factor for several diseases and deaths globally (WHO, 2011). Evidences from literature supported gait alterations as one of the major abnormalities demonstrated by obese individuals (Messier et al, 2005; De Souza et al, 2005; Browning et al, 2009; Ling et al, 2009) and that they develop as adaptations to excess weight loading on the lower limbs while walking and later result in musculoskeletal injuries (Ettinger et al, 1994; Xu et al, 2008; Ko et al, 2012).

Studies that compared the gait characteristics of obese and normal weight individuals have reported that the obese individuals take shorter steps (1.25m vs. 1.67m) and wider strides (0.16m vs 0.08m) than their normal weight counterparts (Spyropoulos et al, 1991; Browning and Kram, 2007). Other studies have also found that obese individuals have significantly lower preferred walking speed, reduced cadence, shorter step length, and wider step width than their normal weight counterparts (DeVita and Hortobagyi, 2003; Nantel et al, 2006; Browning and Kram, 2007; Blaszczyk et al, 2011). Ko et al (2010) evaluated the effects of obesity on some gait parameters using data from 164 older obese and non-obese adults and observed that spatiotemporal gait parameters were more affected by excess weight and therefore recommended that additional studies are needed to ascertain if losing weight will normalize gait pattern characteristics of obese individuals.

In spite of the availability of many studies on the effects of weight reduction exercise training on other variables of the obese such as cardio-respiratory metabolic parameters

(Peyrot et al, 2012), studies on the effects of weight reduction exercise programme on spatiotemporal gait parameters in obese individuals are rather scarce.

The work of Plewa et al, which is the only available closely related study to this present one, indicated that a 3-month weight reduction treatment produced significantly positive effects selected kinematic gait parameters of obese individuals. However, their participants only received unsupervised weight reduction activity in form of walking and professional education and there were no controls. This study was therefore aimed at investigating the effects of a 12-week supervised weight reduction aerobic exercise programme on selected spatiotemporal gait parameters (walking speed, stride length, cadence, step length and stride width) of obese individuals. Specifically, the following questions were answered by the study:

(i) Would a 12-week weight reduction exercise programme have any effects on selected spatiotemporal gait parameters (walking speed, cadence, step length, stride length and stride width) of obese individuals?

(ii) Would the selected spatiotemporal gait parameters of obese and age-matched normal weight counterparts at the beginning, during and at the end of a 12-week weight reduction exercise programme for the obese individuals be comparable?

1.3 Aims of Study.

1. To investigate the effects of a 12-week weight reduction exercise programme on walking speed, cadence, stride length, step length and stride width of obese individuals.

2. To compare the gait parameters of obese adults and that of age-matched normal weight controls at the beginning, during and at the end of a 12-week weight reduction exercise programme for the obese individuals.

1.4 Hypotheses

1.4.1 Main Hypotheses

1. There would be no significant difference between the walking speed, cadence, step length, step width and stride length of obese adults at the beginning, during and at the end of a 12-week weight reduction exercise programme.

2. There would be no significant difference between the walking speed, cadence, step length, step width and stride length of obese adults and their normal weight counterparts at the beginning, during and at the end of a 12 week weight reduction exercise programme.

1.4.2 Sub Hypotheses

1. There would be no significant difference in the walking speed (WS) of obese participants across baseline and weeks 4, 8 and 12 of the weight reduction exercise programme.

2. There would be no significant difference in the cadence (CD) of obese participants across baseline and weeks 4, 8 and 12 of the weight reduction exercise programme.

3. There would be no significant difference in the step length (SL) of obese participants across baseline and weeks 4, 8 and 12 of the weight reduction exercise programme.

4. There would be no significant difference in the stride length (SLT) of obese participants across baseline and weeks 4, 8 and 12 of the weight reduction exercise programme.

5. There would be no significant difference in the step width (SW) of obese participants across baseline and weeks 4, 8 and 12 of the weight reduction exercise programme.

6. There would be no significant difference between the WS of obese participants and their age matched normal weight controls at baseline, week 4, week 8 and week 12 of the study.
7. There would be no significant difference in the CD of obese participants and age-matched normal weight controls at baseline, week 4, week 8 and week 12 of the study.
8. There would be no significant difference in the SL of obese participants and age-matched normal weight controls at baseline, week 4, week 8 and week 12 of the study.
9. There would be no significant difference in the SLT of obese participants and age-matched normal weight controls at baseline, week 4, week 8 and week 12 of the study.
10. There would be no significant difference in the SW of obese participants and age-matched normal weight controls at baseline, week 4, week 8 and week 12 of the study.

1.5 Delimitation.

This study was delimited as follows:

1. Participants: Sixty participants 30 obese (BMI $\geq$30kg/m^2) and 30 normal weight (BMI 18-24.9kg/m^2) age-matched individuals who were resident in Owo, Ondo State.
2. Instruments:
   a. Stadiometer for weight and height measurements.
   b. Stethoscope and Sphygmomanometer for measuring blood pressure.
   c. Tape measure for waist circumference and hip measurements.
   d. Treadmill and Bicycle Ergometer for aerobic weight reduction training.
   e. Paper walkway footprint method for the assessment of gait parameters (Li et al, 2012).

1.6. Limitation of Study

The researcher could not ascertain the extent of participants' compliance with the diet menu provided to guide the eating habit of obese participants at home during the course of the study.

1.7 Significance of Study

i. The outcome of this study has provided evidence for the effectiveness of weight reduction programme in addressing gait problems of obese individuals which may find relevance in the management of gait problems in obese individuals and long-term reduction of risk of musculoskeletal injuries among obese individuals.

ii. The outcome of the study has further contributed to the existing body of knowledge on the overall benefits of weight reduction programme.

iii. The outcome of this study may also stimulate studies in other musculoskeletal problems associated with obesity.

1.8 Definition of terms

Obese individuals: Individuals with body weight of 30 kg/m^2 and above according to the body mass index classification (WHO, 2000).

Normal weight individuals: Individuals with body weight 18.5 kg/m^2 and 29.9 kg/m^2 according to the body mass index classification (WHO, 2000)

Spatiotemporal gait parameters: These are used to obtain information on time (temporal) and distance (spatial) gait variables. These are walking speed, cadence, stride length, step length and step width (Norkin, 1994).

CHAPTER TWO

LITERATURE REVIEW

2.0. Introduction

The World Health Organization recognizes obesity as a disease and defines it as the condition of excess body fat which impairs general health (WHO, 2000). Obesity is a chronic health problem which is recognised as a global epidemic that affects increasing number of people worldwide (Aucott et al, 2005) and the condition regarded as a disease with international classification of disease code E66 (WHO, 1997) which occurs as a result of positive energy balance over an extended period of time, where energy intake exceeds energy expenditure (WHO, 2000). Body weights of 20 -24.9kg/m^2, 25-29.9kg/m^2 and >30 kg/m^2 have been classified as normal, overweight and obese respectively using body mass index classification of body weight (WHO, 2000). Obesity is further classified as class I (BMI = 30-34.9kg/m^2), class II (BMI = 35-39.9kg/m^2) and class III (BMI > 40 kg/m^2) obesity.

Obesity has been identified as a risk factor for numerous disease conditions such as hypertension, type 2 diabetes mellitus, cardiovascular disease, stroke, cancers, osteoarthritis (OA), respiratory disease and premature death (Calle and Rodriguez, 2003; Hu et al, 2007; Herring et al, 2010; Ko et al, 2010). Obesity has also been reported to have a negative effect on spatiotemporal gait parameters due to overload on musculoskeletal structures of the lower limbs resulting into modification in walking pattern of such individuals (Nantel, 2006; Sarkar et al, 2011). Studies have revealed that this modification in spatiotemporal gait parameters resulted in lowered walking speed, reduced cadence, shorter step length, and wider step width in obese individuals compared to their normal weight counterparts (Spyropoulous et al, 1991; DeVita and Hortobagyi, 2003; Nantel et al, 2006; Browning and Kram, 2007; Ling et al, 2009; Ko et al, 2010).

2.1 Epidemiology of obesity

Obesity is a significant health problem and its incidence is increasing at an alarming rate worldwide (Hills et al, 2001). It has been estimated that obesity is the fifth leading risk factor for death globally with its high prevalence increasing continually and the problem becoming an important clinical and public health challenge throughout the world (WHO, 2000). In 2008, more than 1.4 billion adults (20 years and above) were overweight, and of these over 200 million men and nearly 300 million women were obese (WHO, 2012). The WHO (2000) through its global database reported that worldwide, over 400 million adults were obese in 2005, and estimated that by 2015, more than 700 million individuals are expected to have this condition. In the United States and the United Kingdom, nearly two-thirds of adults are considered overweight or obese (Flegal et al, 2002; Wannamethee et al, 2004). In the United States of America between 1980 and 2002, obesity's prevalence doubled among adults and overweight's prevalence tripled among children (Ogden et al, 2007). The prevalence of obesity among American adult men also increased from 27.5% in 1999 to 31.1% in 2004 (Ogden et al, 2007).

Studies have shown that the increasing trend of obesity in the world is even becoming more pronounced in developing countries of the world (WHO, 2000; Filozof et al, 2001). According to Popkin et al (1996), the prevalence of obesity in developing countries ranges from 7% to 10% of the adult population. In the West African countries of Ghana and Republic of Benin, obesity was found in 13.6% and 18% respectively of adults (Amoah, 2003; Sodjinou et al, 2008) while Abubakari et al (2008) reported a prevalence of 10% in the West African sub-region with a prevalence ratio of 3:2 among urban women and men. It was further stated in the study that in South Africa, one in every three men and more than half the female population was obese; while in Morocco 40% of the entire population was obese. In Nigeria, very scanty information on the prevalence of obesity in some geo-political areas of the country is readily available (Ogunjinmi et al, 2010). However, a cross-sectional study in southwestern Nigeria by Ojofeitimi et al (2007) indicated that 21.2% of the participants were obese while Kadiri and Salako (1997) found obesity in 21% and 28% of males and females respectively in a study of 146 middle-aged Nigerians. A systematic review by Chukwuonye et al (2013) showed that the prevalence of overweight and obesity in Nigeria were 20.3%–35.1%, and 8.1%–22.2% respectively.

2.2 Causes of Obesity

Obesity is a chronic condition that develops as a result of a complex interaction between genetic, behavioral, environmental, physiological, social and cultural factors and characterized by long-term energy imbalance due to excessive caloric intake and insufficient energy output (Racette et al, 2003; Gurevich-Panigrahi et al, 2009). The World Health Organisation Consultation on Obesity (WHO, 1998) extensively studied the relative contribution of each of these factors and concluded that behavioral and environmental factors such as sedentary lifestyles combined with excess energy intake are primarily responsible for the dramatic increase in obesity. Reduction in physical activity, metabolic rate and thermogenesis eventually decrease energy expenditure leading to increased energy storage and obesity. Availability of palatable food as well as hypothalamic injury and different drugs also stimulate food intake. A growing list of genetic factors including dysmorphic syndromes, leptin/receptor mutation, β-3 adrenergic receptors (β-3 AR) mutation and overexpression of neuropeptide Y (NPY) contribute to the development of obesity (Figure 2.1). The relative contributions of genetics and environment to the etiology of obesity have been evaluated in many studies though the result varies from study to study (Ravussin and Borgadus, 2000). Pi-sunyer (2002) reported that 30% to 40% of the variance in Body Mass Index (BMI) is attributed to genetics and 60% - 70% to environment. Bouchard and Tremblay (1990) demonstrated that the amount of body weight and fat gained, as well as the distribution of fat gained in response to overfeeding, had greater similarity within than between twin pairs, further supporting the heritability of the tendency to become overweight or obese. One of the mechanisms by which genotype affects body weight is in the regulation of energy expenditure. It is estimated that approximately 40% of the variance in daily energy expenditure (excluding vigorous physical activity) is attributable to genotype (Bouchard and Tremblay, 1990). Thus, there is substantial evidence implicating the role of genetics in body weight regulation. Despite the influence of genetics in the regulation of body weight, the trend at obesity has increased suggests that genetic factors cannot play the

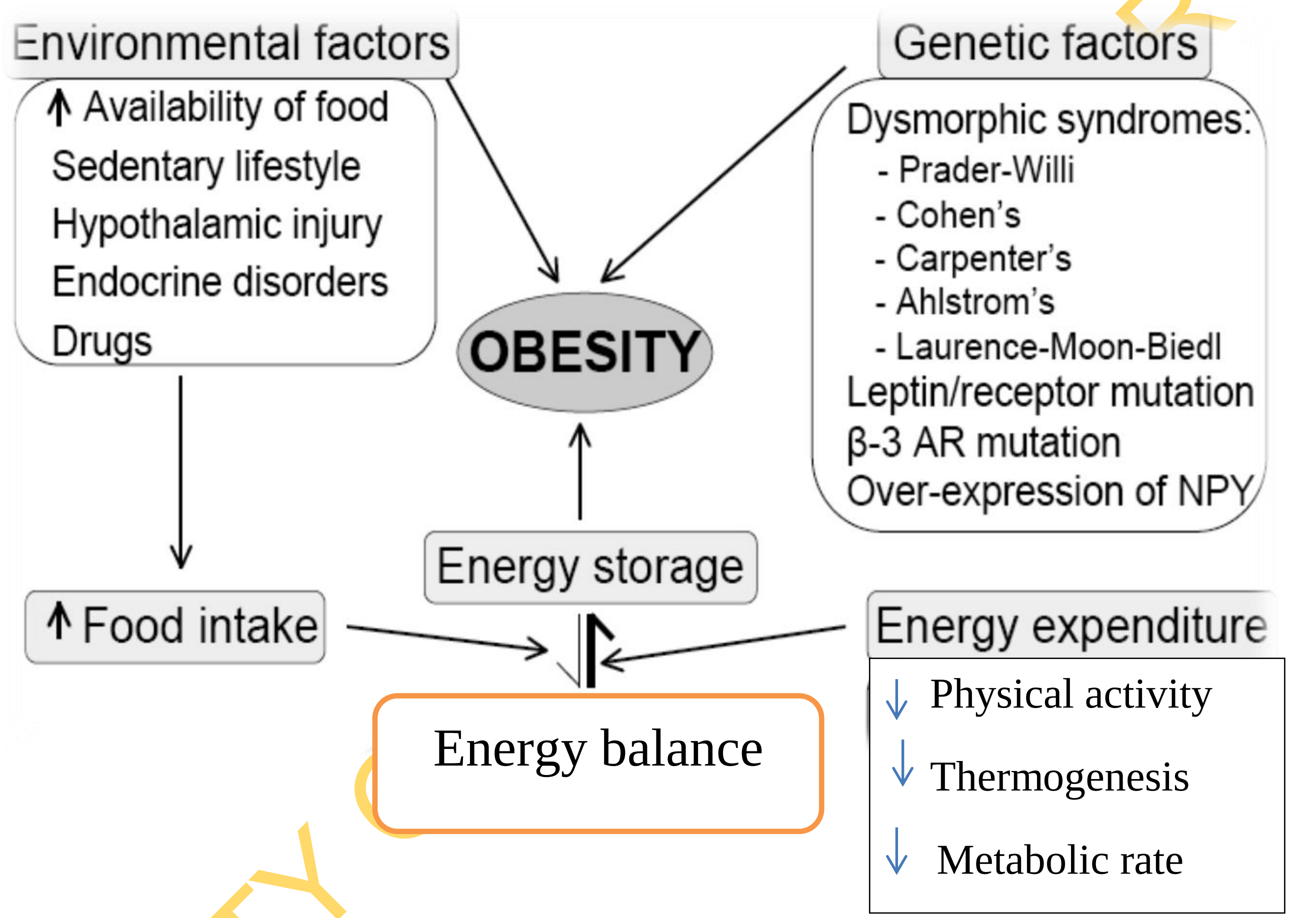

Figure 2.1: Energy balance and causes of obesity (Gurevich-Panigrahi et al, 2009).

predominant role in the current obesity epidemic but behavioral and environmental factors are largely responsible (Hill and Peter, 1998). In a given population, some people are genetically predisposed to develop obesity but that genotype may be expressed only under certain adverse environmental conditions, such as high-fat diets and sedentary lifestyles

(Stunkard, 1988). In the United States of America and some other Western countries, greater numbers of people are being exposed to these adverse environmental conditions, and consequently, the percentage of people expressing the obesity genotype has increased. Ravussin et al, (1994) investigated the impact of environment on obesity among Pima Indians residing in Arizona and also in a remote area in Mexico (Ravussin et al, 1994) and discovered higher obesity prevalence among those residing in Arizona despite their similar genetic predisposition. The Pima Indians in Mexico were found to live a traditional lifestyle and had significantly lower BMI than those living in the more affluent environment of Arizona (24.9kg/m^2 vs. 33.4 kg/m^2).This difference in obesity prevalence could be explained by the fact that Pima Indians living in Mexico eat a diet with less animal fat and caloric density and more complex carbohydrates than those in Arizona, and also have greater energy expenditure from physical labour (Ravussin et al, 1994). Environmental factors such as cultural habits, inadequate physical activity and improper diets (high fat, energy-dense diets) are also known to contribute to excessive weight gain (WHO, 1997; McGlynn, 1999). Yang et al (2007) hence submitted that the interactions of multiple genes, environmental factors, and behavior, and this complex etiology make management and prevention of obesity to be highly challenging.

2.3 Metabolic predictors of weight gain

Obesity develops only if energy intake, in the form of feeding or caloric intake, chronically exceeds total body expenditure. Energy expenditure includes physical activity, basal metabolism, and adaptive thermogenesis (Figure 2.2). Three metabolic factors have been reported to be predictive of weight gain namely: (1) a low adjusted sedentary energy expenditure, (2) a high respiratory quotient (RQ; carbohydrate-to-fat oxidation ratio), and (3) a low level of spontaneous physical activity. The resting metabolic rate (RMR) is strongly correlated to fat-free mass (FFM) in both men and women (Pi-sunyer, 2002).

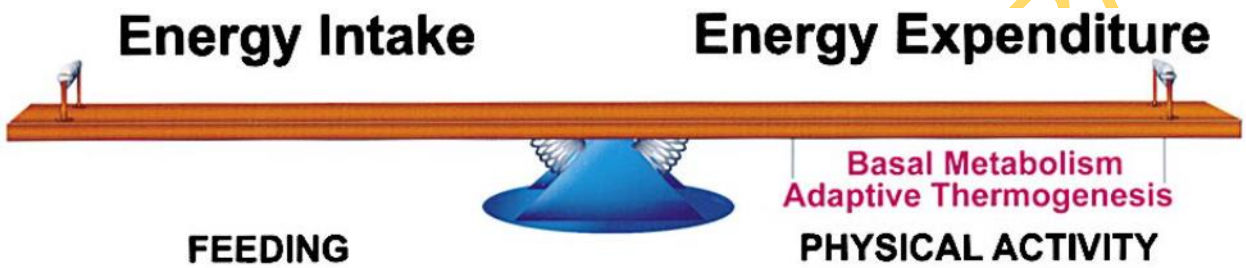

Figure 2.2. Key component of the energy balance system (Spiergelman and Flier, 2001)

However, RMR is only one component of the total daily energy expenditure, which also includes the thermic effect of food and physical activity (Swinburn and Ravussin, 1994). RQ is the second potential metabolic predictor of weight gain. A low RQ of 0.7 suggests that a person is oxidizing more fat than carbohydrate, whereas a ratio of 1.0 suggests that more carbohydrate than fat is being oxidized (Swinburn and Ravussin, 1994). The amount of the adipose tissue is tightly regulated through neural and humoral signals transmitted to the brain hence failure of fat cells to send adequate signals or failure of the brain to respond to appropriate signals causes obesity.

2.4 Complications of obesity

A substantial body of evidence demonstrates a harmful effect of obesity and excess adiposity on cardiovascular health (Cornier et al, 2011). Both abdominal obesity and general obesity are independently associated with cerebrovascular diseases (Hu et al, 2007and Strazzullo et al, 2010) and coronary heart disease (Wilsgaard and Arnesen, 2007). Furthermore, obesity is associated with increased overall mortality (Whitlock et al, 2009) and mortality after cardiovascular events (Zhou et al, 2008; Towfighi and Ovbiagele, 2009) Although some studies have shown a J-shaped curve between BMI and mortality, with higher mortality rates in individuals in both the highest and lowest BMI categories, often referred to as the obesity paradox (Oki et al, 2006), comorbidities associated with excess fat appear to increase across the continuum of overweight and obesity. Furthermore, abdominal obesity, an important component of the metabolic or cardio metabolic syndrome, has been shown to be associated with stroke (Chen et al, 2006), coronary heart disease (Cabrera et al, 2007) and overall mortality (Jacobs et al, 2010). Overweight and obesity are also associated with increased risk of a number of other comorbid conditions, such as type II diabetes mellitus, systemic hypertension, dyslipidemia, obstructive sleep apnea, osteoarthritis, depression, gout, nonalcoholic liver disease, reproductive-endocrine disorders, and several cancers. (Cornier et al, 2011). Studies have also identified gait alterations as one of the various negative consequences and complications of obesity (Browning and Kram, 2007; Ko et al, 2012).

2.5. Classifications of body weight

2.5.1 Body Mass Index

The most commonly used measurement for assessing body weight status is the Body Mass Index (BMI). It is defined as weight (kg)/height^2 (m) (McArdle, 2000). The World Health Organization (WHO) recommends the following body mass index cut-points to classify weight status in adults and children:

(a) Adults:

Underweight: BMI <18.5 kg/m^2

Normal or acceptable weight: BMI 18.5–24.9 kg/m^2

Overweight: BMI 25–29.9 kg/m^2

Obese: BMI $\geq$ 30 kg/m^2

The degree of obesity is further sub-classified as follows:

- Class 1 or Mild Obesity: BMI 30–34.9 kg/m^2.
- Class 2 or Moderate Obesity: BMI 35.0 –39.9 kg/m^2.
- Class 3 or Severe, Extreme, Morbid Obesity: BMI $\geq$ 40 kg/m^2

(b) Children (youths between 2 and 19 years of age):

The absolute value of BMI (as used for adults) is not used to classify weight status in children because change in BMI is normal and expected as children grow and develop (WHO, 2000). Instead, BMI percentiles adjusted for age and sex are used. In children of ages 2 to 19 years, the following BMI categories are used:

Underweight: BMI < 5th percentiles are used to define underweight status (CDC, 2006).

Normal: BMI between the 5th and 85th percentile is healthy.

Overweight: BMI of 85th to 94th percentile

Obese: BMI >95th percentile or BMI of 30 kg/m^2, whichever is lower

Severe obesity: 99th percentile BMI (30 to 32 kg/m^2 for youth 10–12 years of age, 34 kg/m^2 for youth 14–16 years of age).

Although BMI is by far the most commonly used index for classifying general obesity in adults (WHO, 2000), its major limitation is that it does not differentiate between weight that is fat (fat mass) and weight that is muscle (fat-free mass), and therefore may lead to mis-classification of very muscular individuals as overweight (Racette et al, 2003). Anthropometric measurements such as skinfolds, body fat mass and percentage body fat have hence been recommended as more accurate estimates of obesity status (Lei et al, 2006).

2.6 Obesity and the musculoskeletal system.

Obesity has been reported to be highly associated with impaired musculoskeletal function, particularly in the lower limbs (James, 2008). It is thought that excess weight increases the stress within the bones, joints, and soft tissues, resulting in impaired musculoskeletal function such as abnormal mechanics (Wearing et al, 2006). Fjeldstad et al (2008) reported obese individuals to have a higher prevalence of falls (27% vs 15%) and ambulatory stumbling (32% vs 14%), or a loss of balance that was restored without falling, than their normal-weight counterparts. They also identified fall as the most common cause of injuries in the obese (approximately 36% of all injuries) and the cause of a higher proportion of injury-related hospitalization in the obese compared to the non-obese. Approximately 6% of falls result in a major injury such as fracture or dislocation and as such, fractures have been reported as the most common injury among the obese (Fjeldstad et al, 2008).

DeVita and Hortobagyi (2003) found that obese adults tend to have a more erect posture while walking at a standard speed, compared to non-obese adults, as a result of reduced knee and hip flexion. It is possible that this posture provides stability in the obese by counteracting an anterior displacement of the center of mass (COM) from the longitudinal axis of the body associated with obesity and thereby reducing the amount of corrective torque needed to maintain balance. The obese have also been shown to have impaired muscle strength; a strongly rated risk factor for falls (Close et al, 2005). More specifically, knee and ankle weakness have been identified as factors in poor balance and indicate a greater risk of falls (Takazawa et al, 2003). Although obese adults can generate higher absolute strength and power with the lower extremity, strength and power are significantly lower in obese adults when normalized to body weight (Close et al, 2005). For example, Lafortuna et al (2005) investigated the effects of obesity on strength and power of the lower limb muscles involved with anti-gravitational movements (quadriceps, gluteus, gastrocnemius, and soleus) and found that the absolute lower limb strength was significantly higher in the obese individuals. Studies have also shown absolute knee strength to be higher and knee strength per body weight to be lower in the obese compared to the non-obese (Hulen et al, 2001 and Maffiuletti et al, 2007). These findings indicated that although a greater absolute force is used by the obese to perform daily activities, their musculoskeletal system is impaired because they cannot produce equivalent force per weight compared to the non-obese.

2.7. Gait

2.7.1 The basic concept of gait

Gait is the manner or style of walking (Smith et al, 1996) and walking is the simplest act of falling forward and catching oneself (Magee, 1997). In the normal gait pattern, as the body moves forward one limb typically provides support while the other limb is advanced in preparation for its role as the support limb (Bogey, 2001). Walking is one of the most common human movements and it means to transport the body safely and efficiently across ground level, uphill or downhill (Paroczai et al, 2006). Walking is learnt during the first year of life and reaches maturity around the age of seven, remaining at the same level until age of sixty (Paroczai et al, 2006). Human walk is a biomechanical process involving a complex interplay between muscular and inertial forces that results in the smooth progression of the body through space while minimizing the expenditure of energy (Wearing et al, 2006). Walking is a key component in daily functioning and activity, a treatment for chronic diseases such as diabetes and obesity and a means of health promotion and disease prevention (National Institutes of Health, 2000; Haskell et al, 2007; American Diabetes Association, 2008). Walking is the most popular form of physical activity used for weight management, presumably because it is easier to do and required considerable metabolic energy (Browning, 2012).

2.7.2 The gait cycle

Gait is a cyclic event, which simultaneously propels the body forward and maintains stance stability (Mezghani et al, 2011). The gait cycle is the period from heel contact of one foot (for example, the left foot) to the next heel contact of the same left foot (Delisa, 1998 and Ling et al, 2009) (Figure 2.3). It is common to start the cycle (0% of the period) with the first contact so that the end of the cycle (100% of the period) will be the initial contact of the next cycle. According to Bogey (2001), the gait cycle in its simplest form comprises the stance and swing phases. The stance phase is the period of time during which one or two feet are in contact with the ground, and lasts approximately 60% of the gait cycle (Magee, 1997, Ling et al, 2009 and Mezghani et al, 2011). The stance phase can however be divided into three sub-phases, namely the ipsilateral double limb support, the ipsilateral single limb support and the final contralateral double limb support periods (Ling et al, 2009 and Mezghani et al, 2011). The swing phase is the period when one foot is not in contact with the ground and lasts approximately 40% of the gait cycle (Ling et al, 2009). It consists of three sub-phases namely: initial swing or acceleration, mid-swing and terminal swing or deceleration (Magee, 1997).

According to Ling et al (2009), gait can further be broken down into a repetitive series of patterns, each representing distinct functional tasks. There are eight of these sub-phases of gait: 1) Initial contact, 2) Loading response, 3) Mid stance, 4) Terminal stance, 5) Pre-swing, 6) Initial swing, 7) Mid-swing, and 8) Terminal swing. Initial contact and loading response sub-phases are involved in weight acceptance, which involves shock absorption, initial limb stability, and the preservation of progression. Mid stance and Terminal stance sub-phases make up the single limb support section of gait. During single-limb support, one limb entirely supports the weight of the body in both the sagittal (side) and coronal (frontal) planes. Limb advancement continues through the three phases of the swing: initial swing, mid-swing, and terminal swing. During the initial swing the swing leg is

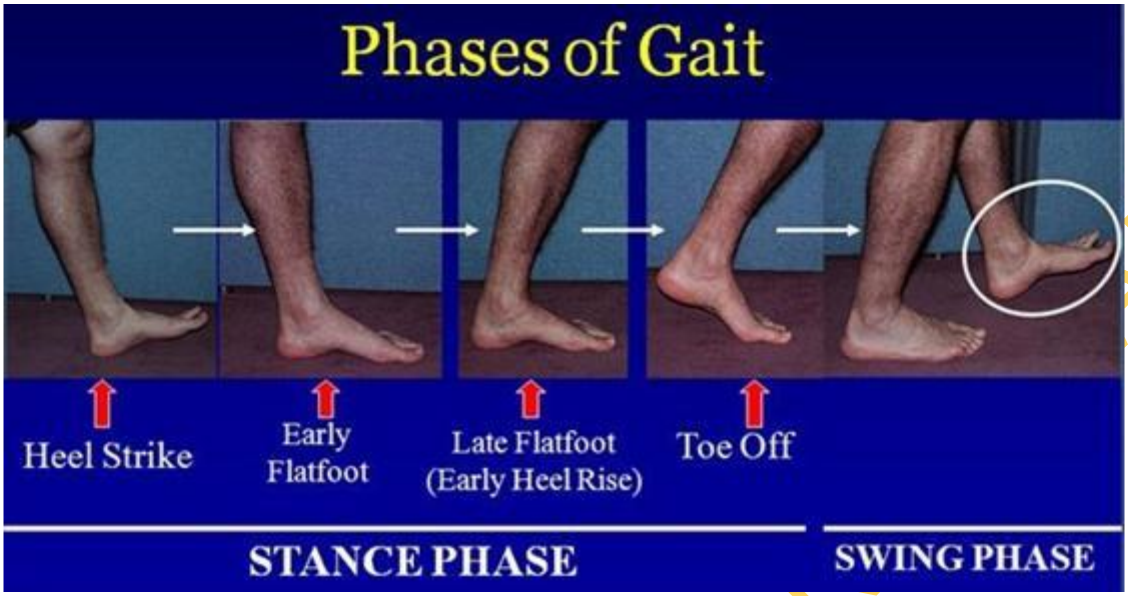

Figure 2.3: Phases of gait cycle (www.footeducation.com)

accelerated forward by hip and knee flexion together with ankle dorsiflexion. The mid-swing occurs when the accelerating limb is aligned with the stance limb. In the terminal swing the decelerating leg prepares for contact with the ground and is controlled by the hamstring muscles (Ling et al, 2009).

Gait is comprised of three interacting components: the physiologic objectives, the functional tasks and the phases of the gait cycle (Ling et al, 2009). There are four physiologic objectives governing gait (Ling et al, 2009). They are propulsion (movement), balance, minimization of shock to the body structure and minimization of energy expenditure for all of these activities (WHO, 2000). These objectives translate into the force, speed and degree of movement during gait. Gait must also accommodate environmental challenges to stability and protect body structures while propelling the individual at the lowest energy cost possible and at the consciously or subconsciously chosen speed. Along with these physiologic objectives, gait must fulfill three specific functional tasks. These are weight acceptance, weight bearing on a single limb (single limb support - SLS) and moving a limb forward (swing limb advancement – SLA). Weight acceptance involves the distribution of body mass over the lower limbs for stability. SLS involves centering the total body mass on one leg, while SLA refers to moving the leg that is not supporting weight. From the perspective of mobility and the gait cycle, the body is divided into two sections – the active component (hips and legs) and the passenger component (pelvis and trunk) (WHO, 2000; Ling et al, 2009). While the pelvis and trunk are not as active as the knee in taking a step, as passengers they contribute to work load and physiologic cost of gait. The passenger unit constitutes the majority of the load that must be moved; and it must absorb impact, contribute to stability and help determine energy expenditure (WHO, 2000).

2.7.3 Gait analysis.

2.7.3.1 Types of gait analysis.

Gait can be analyzed directly and indirectly in two main ways namely; kinematics and kinetics (Norkin, 1994). Kinematic gait analysis is the description of the relative joint position and orientation of one body segment to the adjoining one (Delisa, 1998). Kinetic gait analysis is used to determine the forces that are involved in gait, that is ground reaction forces, joint torques, centre of pressure and intrinsic foot pressure (Norkin, 1994).

Kinematic gait analysis can either be qualitative or quantitative. Qualitative analysis assesses displacement (linear and rotational) with description of patterns of movement deviations from normal and joint angles at specific joints in the gait cycle (Norkin, 1994). Quantitative analysis assesses the spatiotemporal variables of gait. They are used to obtain information on time-temporal variables which include velocity, step time, stride time, and distance- spatial gait variables which are stride length, step length and step width (Norkin, 1994). These measures quantify the force, speed and degree of movement and capture the physiologic objectives of gait. Changes occur in the balance between the phases when impairments such as diminished proprioception or muscle weakness are present (Ling et al, 2009).

2.7.3.2 Methods of gait analysis

There are different techniques for measuring time and distance gait variables (Norkin, 1994). These can be broadly divided into observational gait analysis and instrumental gait analysis systems (Norkin, 1994). Observational Gait Analysis (OGA) is defined as the visual inspection of walking (Norkin, 1994). This approach is sufficient to note gross abnormalities in walking but is inappropriate to characterize most gait pathologies (Bogey, 2001). The disadvantage of OGA is the tendency to focus the eye on the gross gait deviations while overlooking the more subtle ones (Norkin, 1994). It is therefore subjective and dependent on the experience of the clinician. Instrumental gait analysis systems are more often used in academic or research settings because they are less user-friendly for the clinician. They include:

1. **Dynamic Electromyography**: Voltage potentials detected by surface or wire electrodes provide information about the timing and intensity of muscle contraction. The timing of muscle activity is the most frequently used parameter obtained from electromyography (Norkin, 1994). It gives the clinician an accurate representation of what the muscles are doing to contribute to the gait deviations observed.

2. **Electrogoniometers**: These are electromechanical devices that span a joint to be measured with attachments to the proximal and distal limb segments (Bontrager, 1998). They provide an output voltage proportional to the angular change between the two attachment surfaces. Their operation is based on the assumption that the attachment surface moves with the midline of the limb segment onto which they are attached and thereby measure the actual angular change at the joint (Bontrager, 1998).

3. **Video Motion:** Video systems utilize one or more video cameras to track bright markers placed at various locations on the person being tested (Bontrager, 1998).

4. **Footswitches:** These are convenient and inexpensive ways of obtaining temporal gait measurements. They are usually configured as thin insoles which can be placed between the foot and shoe (Bontrager, 1998). When pressure is applied, the insoles compress and the conductive rubber cylinders contact the pieces of brass on each side of the insole, closing an electrical circuit (Bontrager, 1998).

5. **Gait mats:** These are relatively new systems that provide both temporal and spatial gait parameters. These mats consist of a long strip of walking surface into which is embedded an array of switches running across and along the length of the mat. As the subject walks down the mat, the switches under the feet enable the timing of each switch closure to be calculated by the computer. Since the geometry of the mat is known, the spatial parameters of gait can also be calculated (Bontrager, 1998).

6. **The footprint analysis**: Variables such as foot angle, step width, step length and stride length can be assessed simply and inexpensively in the clinic by recording the patient's footprint during gait. This is done by creating walkways using various materials such as paper taped to the floor or by using an uncarpeted floor or hallway (Norkin 1994). The subject is then asked to walk barefooted on the walkway after smearing the soles of the foot with dye. Footprint analysis can be performed quickly; it is quantitative and objective and allows visualization of uneven weight-bearing distribution or pressure areas, of toe drag and of asymmetry of anatomical structures. It also serves as a permanent record for later comparison and for motivating the patient to walk more effectively.

2.7.4 Spatial and temporal characteristics of gait

Spatiotemporal gait parameters which are providing timing and position information about an individual's gait pattern comprise walking speed, stride length, cadence, stance phase, swing phase, single leg support duration and double leg support duration (Ling et al, 2009). Two steps make up each gait cycle, or each stride, and each side is roughly symmetrical in healthy, able-bodied individuals. The general spatiotemporal gait parameters most often used are walking speed, cadence, step length, stride length, step or stride width (Figure 2.3).

1. The cadence refers to the number of steps taken per minute and it is measured by counting the number of individual steps taken during some known interval of time (Ling et al, 2009).

2. Walking speed refers to distance traveled over the time taken and it is measured by timing the subject during some known walking distance (Ling et al, 2009).

3 The stride length refers to the length between the first and second placement of the same foot (Ling et al, 2009).

4 Step length is the distance between corresponding successive points of heel contact of the contralateral feet.

5 Step or stride width is the side-to-side distance between the line of the two feet.

6 Swing phase refers to the percentage of the gait cycle when a specific limb is in motion and stance phase refers to the percentage of the gait cycle when the limb is in contact with the ground (Ling et al, 2009).

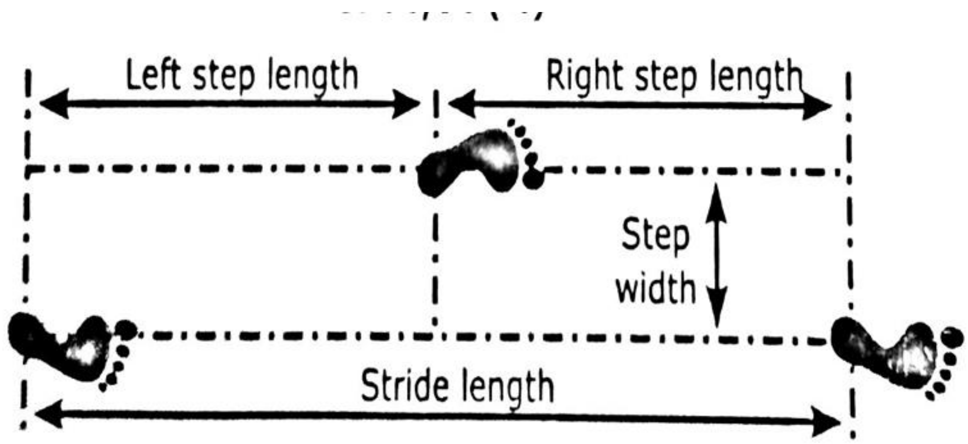

Figure 2.3: Stride length, step length and step width (Lyytinen, 2015)

2.7.5 Obesity and gait

Obesity is a known risk factor for several diseases (WHO, 2000), and it also negatively affects physical functioning especially walking ability and performance (Houston et al, 2009; Stenholm et al, 2007). Studies have shown that walking ability is an important prerequisite for autonomy in activities of daily living. Ling et al (2012) opined that gait changes increase as BMI increases and individuals with Class III obesity (BMI of > 40) are more likely to face mobility problems associated with gait when compared with people who have lower BMIs. These gait deviations may affect the ability to participate in physical activity especially walking (Ling et al, 2009). Walking and obesity describes how the locomotion of walking differs between an obese individual and a non-obese individual (Flegal et al, 2002). Evidence exists that obesity affects standing up (Galliet et al, 2000), walking (Messier et al, 1994; Saibene and Minetti, 2003; Vismara et al, 2007) and running (De Souza et al, 2005). Excess of mass has been found to impose abnormal mechanics on body movements (Xu et al, 2008) thereby influencing the body shape (Rodacki et al, 2005; Liuke et al, 2005; Menegoni et al, 2008), which can therefore hinder the joints' physiological range of motion and enhance the risk of musculoskeletal overload (Xu et al, 2008). Gait in obese individuals has been quantitatively studied and generally show a normal pattern with some differences in the temporal and angular components, for which the excessive adipose tissue in the thighs might mainly account (Spyropoulous et al, 1991; De Souza et al, 2005; Lai et al, 2008). Researchers have found that obese individuals have a larger step width during walking which provides a wider base of support for balance and also some gait parameters like speed, cadence, stride and foot angle were found to be significantly lower in obese individuals compared to their lean counterparts (Spyropoulous et al, 1991; Larsson and Mattsson, 2003; Devita and Hortobagyi, 2003; De Souza et al, 2005; Browning et al, 2006).

2.8. Obesity and weight Control.

2.8.1 Weight management goals

The general goals for weight management are to reduce body weight (BW), maintain a lower weight over long term and prevent further weight gain. The general principle of weight loss is to create an energy deficit (Chugh and Sharma, 2012). Obesity is an extremely difficult problem to solve. However, its solution takes realistic goal setting, patience, counseling and positive reinforcement. Realistic goal setting involves evaluation of the body composition, setting a target body weight, short-term and long term goals. Target body weight means the amount of weight to be lost in a week or in a year (Babalola, 2005). Factors such as enthusiasm, maturation, mental state, eating habits/patterns and socialization must be considered when treating obesity (McGlynn, 1999). According to Mc Ardle et al (1996) the balance between food intake and energy expenditure is very important in weight control and if the total caloric intake ingested as food exceeds the daily energy expenditure, the excess calories will be stored as lipid in the adipose tissue.

2.8.2 Energy balance and weight control

A person is said to be in a state of energy balance when he or she is able to maintain a constant weight (Gurevich-Panigrahi et al, 2009). That is, the number of calories consumed in food equals the number expended in the three energy requiring processes which are basal metabolism, physical activity, and thermic effect of food (Babalola, 2005). Under this condition, the body weight should remain constant and should neither increase nor decrease by any appreciable amount (Babalola, 2005). A positive energy balance exists when the caloric intake is greater than caloric expenditure. The extra calories will be stored and the person gains weight (Babalola, 2005). There are three ways to unbalance the energy balance in the direction of weight loss and achieve negative energy balance:

1. Reduction of caloric intake in such a way that it will be below the daily energy requirements.
2. Maintenance of normal caloric intake and increase energy expenditure through additional physical activity above the daily routine of activities.
3. Combination of both methods by decreasing daily caloric intake and increasing daily energy expenditure.

While many treatments for obesity are presented to the public, exercise in the form of walking is an easy, relatively safe activity that has the potential to move a person towards a negative energy balance and if done for a long enough time may reduce weight (Jakicic et al, 1999).

2.8.3 Obesity and weight reduction exercise.

Exercise is an integral part of any weight loss programme but losing weight through exercise takes time just as it takes many years to put on a lot of extra weight (McGlynn, 1999). Studies were conducted to establish the beneficial effects of exercise and weight reduction on obese individuals, alleviating some of the health disorders (Villareal et al, 2006; Vantasev and Cakmakci, 2010; Geiger et al, 2010). The effectiveness of regular exercise in achieving weight loss is linked to one's degree of obesity (Babalola, 2005). Generally, persons who are obese lose weight and fat more readily with exercise than their counterparts of normal weight. When exercise is used for weight loss, factors such as frequency, intensity, duration and the specific form of exercise must be considered (Babalola, 2005). Continuous, big muscle, aerobic activities having moderate to high caloric cost such as walking, running, rope skipping, stair stepping, cycling and swimming are ideal. Many recreational sports and games are also effective in reducing body fat (McArdle et al, 1996; Wilmore and Costill, 2005). The more vigorous or exhausting the physical activity, the greater the number of calories burned per minute. Activities like running and cross country skiing probably burn up the highest number of calories – up to 20 calories per minute. Swimming is also rated very high in caloric expenditure (McGlynn, 1999). Babalola (2005) made the following conclusions concerning exercises and body weight:

1. Aerobic exercise decreases percent body fat.
2. Cycling, running, and walking are equally effective in altering body composition
3. Exercising three to four times a week produces significant changes in body composition.
4. Low-intensity aerobic exercise is better than high-intensity exercise in weight loss.
5. High intensity (heavy weights with low repetitions) resistance training is effective in decreasing percentage boy fat and increasing lean body mass.

2.8.4 Dieting and exercise for weight control.

According to Babalola (2005), exercise in combination with mild dietary restriction can be used to effectively unbalance the energy balance equation in the direction of weight loss. This combined approach is less likely to induce the feelings of intense hunger and psychological stress that occur when weight loss is attempted using caloric restriction exclusively. It also provides unique and significant health related benefits, and contributes to the long-term success of weight loss effort (Babalola, 2005). Weight loss without exercising can have a negative effect on body composition (Babalola, 2005). Frequent intermittent dieting, alternating with weight gain, in the absence of exercise will result in a loss of lean body tissue and an increase in body fat content (McGlynn, 1999).

2.9 Summary of Studies on the effects of weight reduction exercise programme on gait parameters of obese individuals.

Studies on the effects of weight reduction exercises on the spatiotemporal gait parameters in obese individuals were sought using pubmed, medline search, google-scholar, google search and Mendeley as search engines. Keywords like obesity, weight reduction exercises, biomechanics, gait, locomotion and spatiotemporal were adopted as search terms. There is dearth of literature on the main purpose of this study, however, the study by Plewa et al, (2007) was found to be closely related to this present study. There were eight other studies found on the characteristic gait pattern in obese individuals due to the excess body weight as compared with their normal weight counterparts. The summary of all the available studies is presented in the Table 2.1.

A study by Plewa et al, (2007) investigated the effects of weight reduction treatment on selected kinematic gait parameters (velocity of gait, cadence, stride length, stride time, stance time, swing time and double support time) of obese individuals at baseline and after a 12-week weight loss treatment and weight reduction that resulted in significant improvements in all the selected kinematic gait parameters were observed.

In the studies available, selected gait parameters in obese individuals were investigated and compared with those of their normal weight counterparts and there was no weight reduction programme. Variables like preferred walking speed, step length, and stride length were found to be significantly lowered with wider step width in obese individuals (Spyropoulous et al, 1991; De Souza et al, 2005; Lai et al, 2008; Ko et al, 2010; Blaszczyk et al, 2011; Sarkar et al, 2011; Ling et al, 2012; DaSilva-Hamu, 2013).

Ko et al, 2010 investigated the specific characteristics of gait associated with body weight in normal weight, overweight and obese individuals respectively. The results showed that as the body weight increases, the gait speed became slower and generally, obese had slower walking speed, wider stride width and higher stance duration than their overweight and normal weight individuals.

In conclusion, in the only study in which the effects of weight reduction exercise programme on selected gait parameters of obese individuals were investigated, the duration of intervention was 12 weeks, the age range of the obese participants was 18-57 years while the sample size was 52. For the other 8 studies, the age range of the participants was 18-65 years while their sample sizes were ranged between 12 to 180 for the obese and normal weight participants.

Table 2.1: Summary of studies on the effects of weight reduction exercise programme on gait parameters of obese individuals.

Author/Year of publication (country)	Purpose of study	Sample size/participants	Methods/intervention	Parameters	Outcomes/results/conclusion
DaSilva-Hamu et al, (2013) (USA)	To identify changes in kinematic gait parameters in obese young women	24 obese women and 24 normal weight women	The gait of the women was evaluated by the system Vicon Motus 9.2	Walking speed, cadence, right and left step length and stride lengths	There was a decrease in walking speed, cadence, right and left step and stride lengths than their normal weight counterparts.
Ling et al (2012) (USA)	To examine the gait and function associated with class III obesity and compare gait components with those of their non-obese counterparts.	180 potential participants were approached, 61 were screened, 50 were enrolled, 21 declined, 8 were found ineligible, and 32 completed the study.	Gait observation during a 6-week timed walk.	Walking speed, step width	Obese participants accommodate their greater body weight by walking slower with wider steps. obese individuals make relatively minor kinematic adjustments compared to non-obese individuals during level walking,
Blaszczyk et al, (2011) (Poland)	To determine the impact of excess body weight on basic spatiotemporal gait measures and to test the hypothesis that leg swing phase may account for a load-related adaptation of stride characteristics.	136 participants (100 obese and 36 normal weight women).	Participants were allowed to walk with their self-selected pace on a 10-meter long and 1 m wide instrument. Stance, swing times and stride lengths were recorded by means of contact copper-film electrodes	Walking speed, cadence, stance time and double limb support	Obese participants walked with reduced speed and cadence than their lean weight counterparts. Stance and double limb supports were longer in obese groups

			attached to their sole.		
Hergenroeder et al, (2011) (USA)	To assess physical function in adult women across BMI categories using self-reported and performance based measures and to determine the influence of BMI on the relationship between measures	50 sedentary females (10 in each of BMI categories of normal, overweight, classes I,II and III obesity)	Demographic, past medical history, physical activity level, BMI, late life function and disability instruments and 6-minutes' walk test were used for assessment.	Walking speed	Obese individuals scored lower on self report measures of physical function and slower gait speed was observed. They also demonstrated poorer performance in the 6-minute walk test compare to their normal counterparts
Sarkar et al,(2011) (India)	To investigate the effects of obesity on some gait parameters.	60 participants in two groups (30 obese and 30 non-obese individuals in each group).	Footprint method was used for gait parameters measurements	Step width, walking speed	Step width in obese was more than in non-obese males. Obese individuals had slower walking speed than their normal weight counterparts.

Ko et al, (2010) (Finland)	To identify specific characteristics of gait associated with body mass index (BMI).	164 participants. [participants were classified into three groups, namely normal weight (19 ≤ BMI < 25 kg/m^2;N=56), overweight(25 ≤ BMI < 30 kg/m^2; N=74), and obese (30 ≤ BMI < 40 kg/m^2; N=34)]	During the gait test, participants were asked to walk across a 10-m long gait laboratory walkway at preferred speed and maximum speed.	Walking speed, step width, stance duration.	Preferred walking speed was slower with increasing BMI and obese had slower speed than normal weight participants. Step width was wider and the stance duration was higher in obese participants compared to normal weight participants for the preferred speed walking. Gait speed was progressively lower with increasing BMI.
Lai et al (2008) (Hong Kong)	To investigate the three dimensional gait characteristics of Chinese obese adults and compare the results with that of their normal weight counterparts	14 obese participants (8 females and 6 males).	The kinematic and kinetic data of all the participants were recorded during their self-selected walking speed with a three-dimensional motion analysis system.	Walking speed, stride length, stance time, double support time.	Obese group walked more slowly and with shorter stride length. They spent more time on stance phase and double support in walking.

Plewa et al (2007) (Poland)	The objective of this study was to investigate whether a 3-month weight reduction treatment influences some gait parameters in obese women.	The study group included 52 obese Women.	Gait parameters were measured on a 10-m long instrumented walkway consisted of very soft wire netting fixed to the floor.	Walking speed, cadence, stride time, stance time, swing time and double support time.	A significant weight reduction which resulted in characteristic changes of gait parameters among obese women: they walked faster, made more steps per minute, stride length and swing duration increased, whereas reduced cycle time, stance and double support phases were observed. Reduction of body mass in obese individuals has positive effects on gait kinematics.

CHAPTER THREE.

MATERIALS AND METHODS.

3.1 Materials.

3.1.1 Participants.

Sixty participants (30 obese and 30 normal- weight) who were residents of Owo, Ondo State and aged 20-57 years commenced this study but only 58 participants (obese=30; normal-weight= 28) completed the 12- week study.

3.1.1.1 Inclusion Criteria

The following categories of individuals were considered eligible for this study:

1. Obese individuals (BMI $\geq$30kg/m^2)

2. Normal weight individuals (BMI 18-24.9kg/m^2)

3.1.1.2 Exclusion Criteria

The following category of individuals was excluded from the study:

Individuals with musculoskeletal disorders like low back pain, osteoarthritis and ankle injuries.

3.1.2 Venue

This study was carried out at the gymnasium of the Physiotherapy Department, Federal Medical Centre, Owo. Ondo state.

3.1.3 Instruments

The following instruments were used in this study:

1). A motorized Treadmill- A treadmill (GC-5906TV – China**)** was used for aerobic exercises.

1). A motorized Treadmill- A treadmill (GC-5906TV – China**)** was used for aerobic exercises.

2**). Bicycle Ergometer-** A bicycle ergometer (Cycle PEC-3220 –Taiwan) was used for aerobic exercise in sitting.

3). Stadiometer- A stadiometer (Gulfex Medicals and Scientific- England) was used to measure participants' height and weight. The weighing scale component was calibrated from 0 - 160 kg while the height meter component was calibrated from 0 – 190 cm.

4). White paper walkway-This was used to determine the gait parameters such as step length, stride length, stance width. The white paper (length: 10m, width: 1m) was spread and taped to the platform in a section of the department's gymnasium.

5). Stop watch- A Quartz stop watch (Quartz, USA) was used to time activities like walking speed, cadence and heart rate of the participants.

6). Tape Measure-Inelastic measuring tape (Butterfly, China) was used to measure the 10- meter distance in the gymnasium. It has a range of 0 to 150 cm.

7). Ruler-A plastic long ruler (Sativ-2) was used to measure step length, step width and stride length of the participants from their footprints. It was calibrated from 0 to 75 cm.

8). Sit-up bench (Proteus, China)- The participants were made to lie on this sit-up bench to perform sit-up exercises.

9). Stethoscope (Litman, England) and Sphygmomanometer Accoson. England)- These were used to monitor participants' systolic and diastolic blood pressure before and after each aerobic exercise programme. The mercury-in-glass sphygmomanometer has a scale within range of 20 to 300 mmHg. The cuff was 22.0cm long and 12.0 cm wide.

10). Physical Activity Readiness Questionnaire (Appendix II) - This questionnaire was used to screen the potential participants for their eligibility to take part in this study.

3.2 Methods

3.2.1 Sampling and assignment techniques.

Purposive sampling technique was used to recruit participants for this study while participants were assigned into obese (BMI $\geq 30kg/m^2$) and normal weight (BMI 18.5-24.9kg/m^2) groups respectively.

3.2.2. Sample size determination.

The sample size was determined using Cohen's table (Cohen, 1988) with power of 80% at $\alpha = 0.05$

n= (sample size of comparison groups) = 26

Therefore, the total sample size for the two groups, N= 26x2 =52

Allowing for 10% attrition, the total number of participants recruited for this study was estimated to be 60 (for the two groups).

3.2.3 Research design.

This study employed a quasi-experimental design.

3.2.4. Procedure for the data collection

3.2.4.1 Ethical Approval.

Ethical approval of the Health Research Ethics Committee of the University of Ibadan/ University College Hospital, Ibadan was sought and obtained before the commencement of the study. A letter to seek the permission to use the gymnasium was written to the management of Federal Medical Centre, Owo and approval was obtained. The procedures involved in the study were explained to each participant and informed consent was sought and obtained prior to the commencement of this study. The following bio-data were obtained directly from the participants: age, sex, occupation and marital status.

3.2.4.2 Procedure for participants' recruitment.

Prior to the commencement of the research procedure, the researcher printed and distributed information hand-bills and flyers to inform interested members of the public about the nature, purpose and benefits of the research. Participants were also recruited through referrals from Dietetics Department of the Federal Medical Centre, Owo. The initial screening procedure involved administering the Physical Activity Readiness Questionnaire on all participants (Appendix II) and only those who satisfied the inclusion criteria were assigned into either the intervention (obese) or control groups respectively according to their BMI.

3.3 Tests and Measurements.

3.3.1.1 Height and Body Weight measurements

The participants were asked to put on a light apparel of top vest and a pair of shorts or leggings. They were made to stand barefooted on the stadiometer with their knees straight and hands by their sides. Height measurement was measured by the researcher as the distance between the vertex of the head and the heels and was recorded to the nearest centimeter with each participant looking straight and the hands by his/her side (plate 3.1). The weight of the participant was also measured on the scale and recorded to the nearest 1.0kg by the researcher (plate 3.2). The body mass index (BMI) which was used to classify each participant into obese and normal weight groups was thereafter calculated using the following formula:

$BMI = wt\,(kg)/ht^2(m)$

3.3.1.2 Heart Rate.

The resting heart rate (Resting HR) of the participants was taken by palpating for the radial pulse and counting for 60 seconds in sitting position 30 minutes after arriving the venue of the exercise programme (Plate 3.3). The amount of time from peak activity back to resting heart rate is known as the recovery time and the faster the recovery time, the fitter the participant. The target heart rate (Target HR) is the recommended level of working to challenge the cardiorespiratory system and to ensure working in the training or aerobics zone which was determined by considering the safe level of moderate intensity as 60-70% of age- predicted maximum heart rate (MaxHR) (Holtgrefe and Glenn, 2007). The most commonly used method of determining target heart is the Karvonen formula (Karvonen and Vuorimaa, 1988) which calculates the percentage of the heart rate reserve (HRreserve) (difference between the resting rate and the maximum heart rate).

HRreserve = MaxHR- Resting HR.

The maximum heart rate (MaxHR) which is the highest heart rate a person can attain during exercise was determined using the following formula:

Maximum Heart Rate (MaxHR) = 220-Age (in years)

Using this formula, the generally accepted heart rate range is 60-80% of maxHR Reserve.

Target HR = %intensity x HRreserve + Resting HR.

It is recommended that the formula be applied to both ends of the range 60% and 70% to determine the target heart rate training zone.

Plate 3.1: Participant’s height measurement

Plate 3.2: Participant's weight measurement

Plate 3.3: Participant's heart rate was taken in sitting position

3.4 Measurement of spatiotemporal gait parameters.

Spatiotemporal gait parameters were obtained by the footprint method whereby the soles of the feet was smeared with delible ink and the participants walked at their comfortable walking speeds along a 10-meter walkway covered with white paper (Plate 3.4). This method is an adaptation of the protocol by Jingguang et al (2006) as documented by Li et al (2012). Participants' step length, stride length and step width were subsequently obtained from the footprints and recorded. Stride length which is the longitudinal distance between the initial contact of one foot (heel strike) and the next initial contact of the same foot was recorded in centimetres. Step length which is the longitudinal distance between the two feet was measured from the first point of contact of the left foot (heel strike) to the initial contact of the right foot (heel strike) and recorded in centimetres. The step width (i.e. the width of walking base which is the linear distance between one foot and the other foot) was measured as the linear distance between the midpoint of the heel of one foot and a similar point on the other foot. The walking speed is the 10 meter distance covered by participants' and the time taken to cover the distance. It is recorded as meter per second. The cadence is considered as the number of steps taken by participants to cover a 10 meter distance. It is recorded as steps per minute.

All the aforementioned spatiotemporal gait parameters were assessed in obese and normal weight groups at baseline and at the end of week 4, week 8 and week 12 of the study. The starting point of walking was selected to allow at least three steps before reaching the white paper platform to ensure steady-state gait (Nantel et al, 2006). Trials were considered satisfactory when both feet were in full contact with each of the white paper platforms. Enough rest periods were also given between trials to avoid fatigue (Nantel et al, 2006).

Plate 3.4: Participant walking along a 10-meter walkway (footprint method) to assess spatiotemporal gait parameters.

3.5 Intervention

(a) Obese group.

Each participant was instructed to continue on their normal balanced diet and not to take any junk meal in between their daily meals. The researcher demonstrated all the activities to be performed before the commencement of the training sessions. The research assistants helped in monitoring and supervising activities carried out by participants to ensure that they were properly carried out. Obese participants performed the weight reduction exercise sessions on three alternate days each week after all the required baseline measurements have been taken. The exercise programme focused on aerobic exercises, stationary cycling on ergometer as well as walking on the treadmill. The warm-up comprised flexibility and stretching exercises to the arms, legs and trunk while cool down comprised of strolling around the research area. All the exercises were carried out at a safe level of moderate intensity between 60% - 70% of age predicted maximum heart rate. The obese participants' spatiotemporal gait parameters were assessed at baseline and at the end of weeks 4, 8 and 12 of the study. The exercise protocol (Holtgrefe and Glenn, 2007) was in 3 phases which comprised the following:

A. Warm-up exercises

The warm-up exercises which lasted for 5 minutes included the following: flexibility exercises (Plate 3.5), head rotations to the right and left, neck flexion and extension, shoulder shrugs/arms stretching (Plate 3.6), alternate leg bends, alternate leg stretch, trunk side bends, waist circles, strolling and light jogging (Pollock et al, 1998).

B. Aerobic exercises (Main menu)

Exercise 1

Type: Sit up exercise

Starting Position: Supine lying on the sit-up bench with knees bent and hands clasped behind the neck (Plate 3.7)

Instruction: Participant was instructed to lift up the head and trunk from the lying to upright position (Plate 3.8), hold the position for about 10 seconds and slowly lower the body to the initial lying position. The exercise was carried out for duration of 5

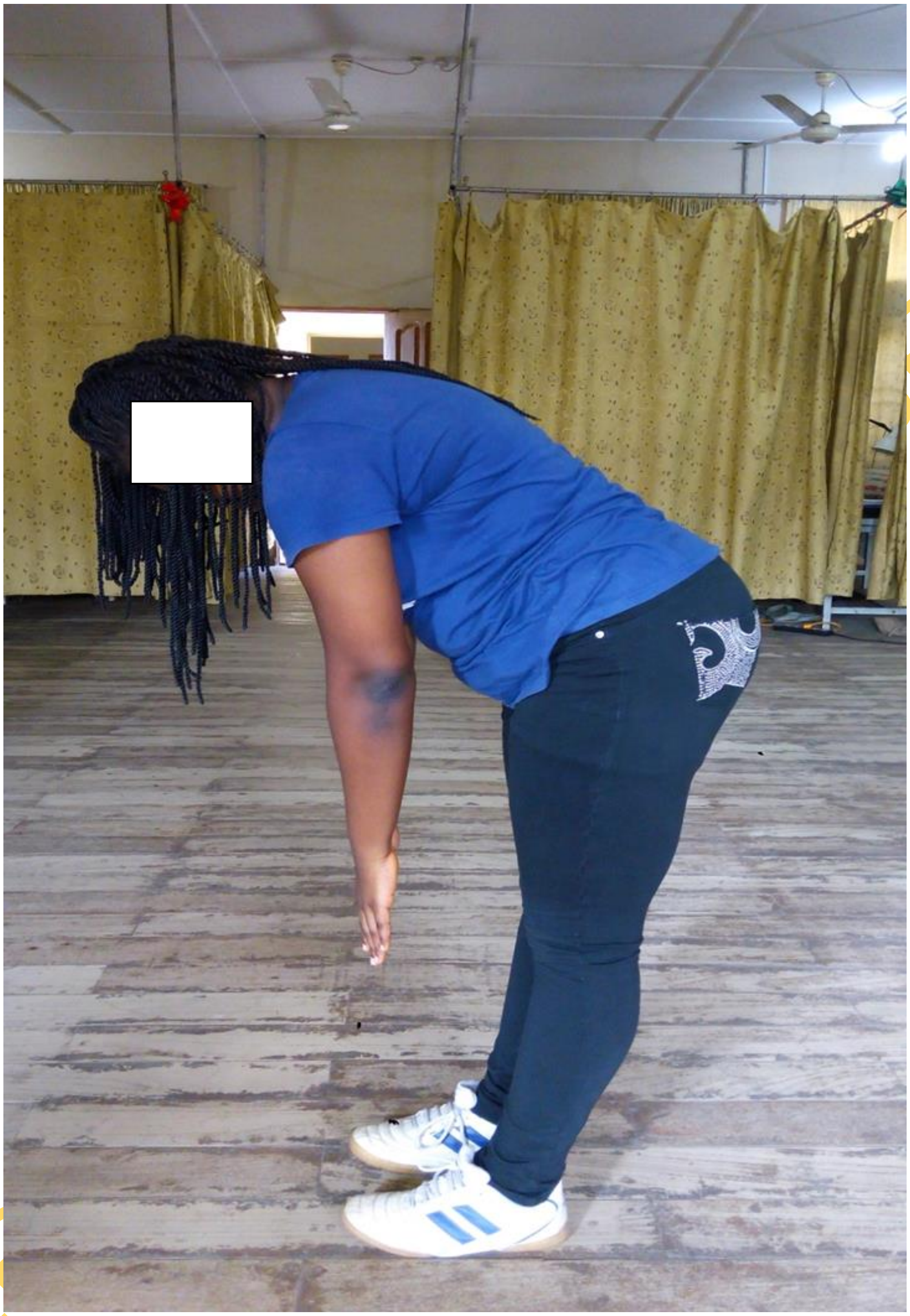

Plate 3.5: Participant performing flexibility exercise

Plate 3.6: Participant performing arm stretching flexibility exercises

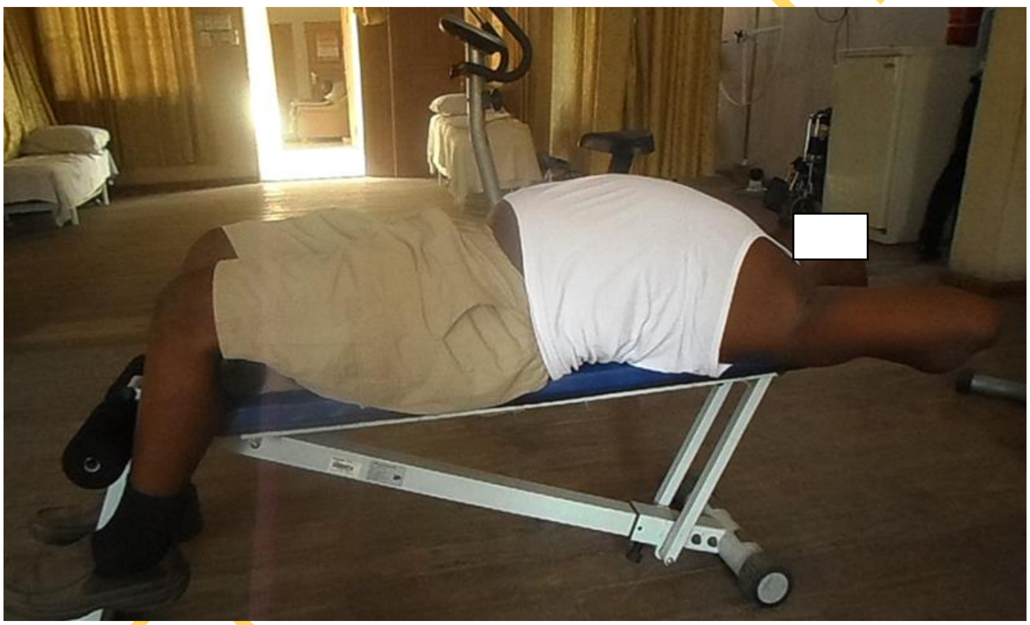

Plate 3.7: Starting position for sit-up exercise on sit-up bench

Plate 3.8: Participant performing sit-up exercise on sit-up bench

minutes (between baseline and week 4), 7 minutes (between week 4 and week 8) and 10 minutes (week 8 and week 12) with a rest period of 3 minutes before the next exercise.

Exercise 2

Type: Cycling

Starting Position: Sitting on the bicycle ergometer with feet well placed on the pedals.

Instruction: Participants rode on the bicycle ergometer against zero resistance for about 5 minutes, 8 minutes and 10 minutes duration between baseline- week 4, week 4- week 8 and week 8- week 12 respectively with a rest period of 3 minutes (Plate 3.9).

Exercise 3.

Type: Treadmill Exercises

Position: Standing on the Treadmill

Instruction: Participant walked at a comfortable pace on the treadmill zero inclination and resistance for a period of 5 minutes (baseline- week 4), 10 minutes (week 4- week 8) and 18 minutes (week 8- week 12) with a rest period of 2 minutes (Plate 3.10).

C.Cool down

The participant was asked to take a stroll around the research area for 5 minutes to achieve cool down.

Exercise Intensity: Prescribed intensity was 60-70% of the maximum heart rate (MHR). Each obese participant commenced the exercise training programme at 60% of heart rate reserve. Progression was made after every four weeks, ensuring 5% increment in the obese participants' exercise heart rate. This exercise intensity progressed continually until the upper limit of 70% of heart rate reserve was reached.

Exercise frequency: Three (3) sessions a week (alternate days) was ensured throughout the 12-week of the study.

Plate 3.9: Participant riding on bicycle ergometer during exercise

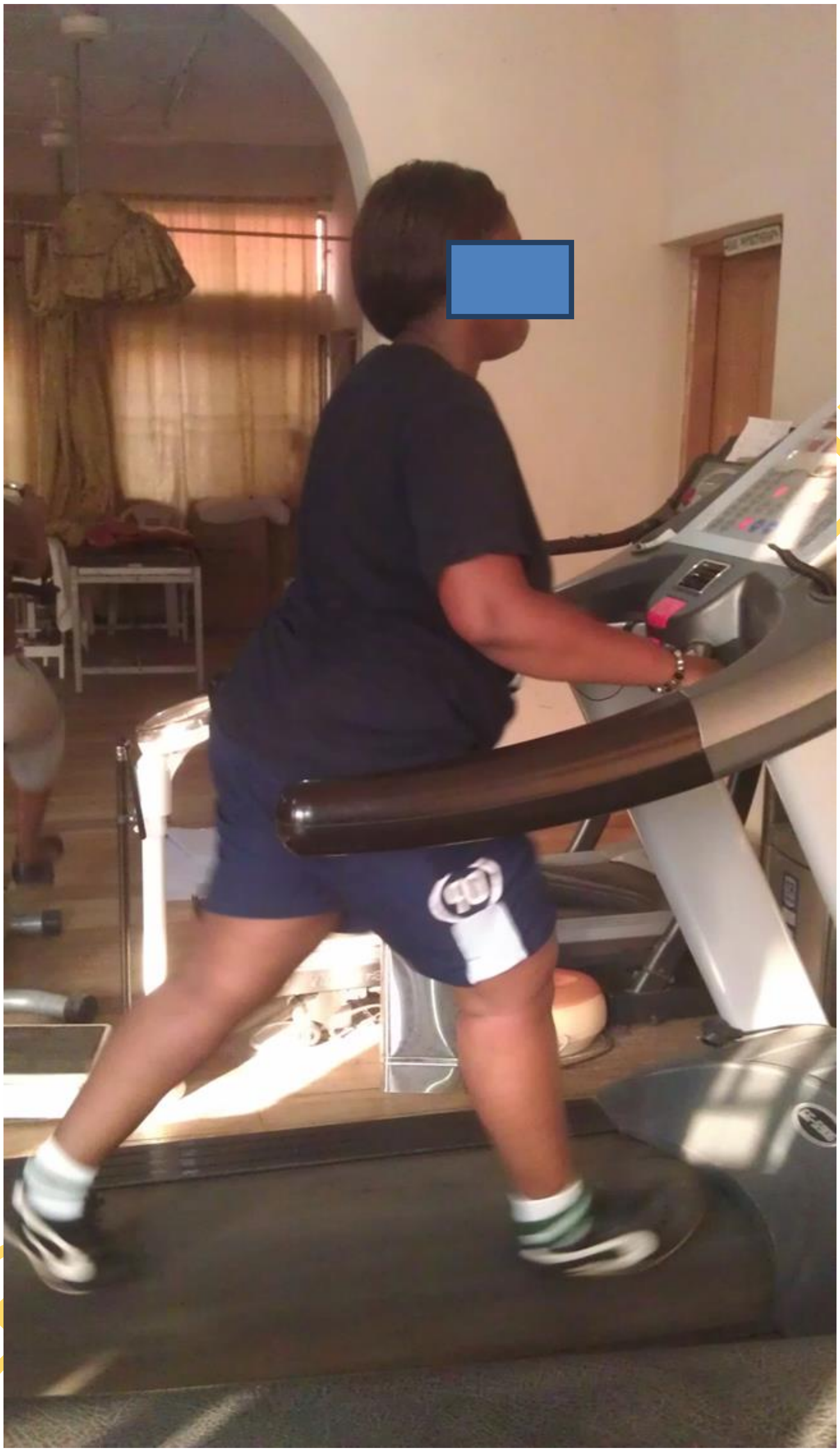

Plate 3.10: Participant performing walking on the treadmill.

(b) Normal weight group.

Participants in this group were instructed to maintain their usual diet and activities during the study period (Nantel et al, 2006). The participants were not allowed to partake in any form of weight reduction exercise but had their walking speed, cadence, step length, step width and stride length assessed at baseline, end of weeks 4, 8 and 12 of the study.

3.6 Data Analysis.

The data analyses were carried out using SPSS 16.0 version software (SPSS Inc., Chicago, Illinois, USA).

1. Descriptive statistics of mean, standard deviation, percentages, graphs and tables were used to summarise the data.

2. Repeated Measures ANOVA was used for within-group comparison of obese group participants' walking speed, cadence, step length, step width and stride length across baseline, week 4, week 8 and week 12 of weight reduction exercise programme.

3. Paired t-test with Bonferroni adjustment was used for Post-hoc analysis to locate pairs that significantly differed in (2) above.

4. Independent t-test was used to compare the walking speed, cadence, step length, stride length and stride width of obese and control groups at baseline and at end of week 12 of the study.

Level of significance was set at 0.05 and 0.0125 for between and within group comparisons respectively.

CHAPTER FOUR

RESULTS AND DISCUSSION

Results

4.1.1 Participant's Profile

Sixty participants (30 obese, 30 normal weight) commenced the study but only 58 participants (30 obese, 28 normal weight) completed the study thus indicating an attrition rate of 3.4%. The 2 normal weight individuals relocated out of town after three weeks of commencement of this study and as such, could not continue the study. The flowchart of participants during the study is presented in Figure 4.1. The mean age, weight, height and BMI for obese participants were 32.0± 8.26 years, 96.42± 15.02 kg, 1.66± 0.06 m and 35.03± 4.91 kg/m^2 respectively while the mean age, weight, height and BMI for normal weight participants were 29.32± 6.06 years, 69.29± 4.77 kg, 1.71± 0.07 m and 23.55± 1.17 kg/m^2 respectively. The groups were not significantly different in their ages ($p<0.125$) but obese participants were significantly shorter ($p<0.003$) and weight was significantly more ($p<0.001$) as shown in Table 4.1.

4.1.2 Comparison of obese and normal weight groups' walking speed and cadence at baseline, week 4, week 8 and week 12 of the study.

Walking speed: The mean values of the walking speed of the obese group were 1.09± 0.17m/s, 1.21±0.26 m/s, 1.28± 0.31 m/s and 1.35± 0.19 m/s at weeks 0, 4, 8 and 12 of the study respectively, while that of the normal weight group were 1.29 ± 0.17 m/s, 1.29± 0.17 m/s, 1.35± 0.19 m/s and 1.35± 0.19 m/s for weeks 0, 4, 8 and 12. Independent t-test at $\alpha = 0.05$ showed that normal weight participants had a significantly faster walking speed ($p< 0.05$) than the obese group participants at baseline only (Table 4.2). The trends of the walking speed of obese and normal weight groups are presented in Figure 4.2.

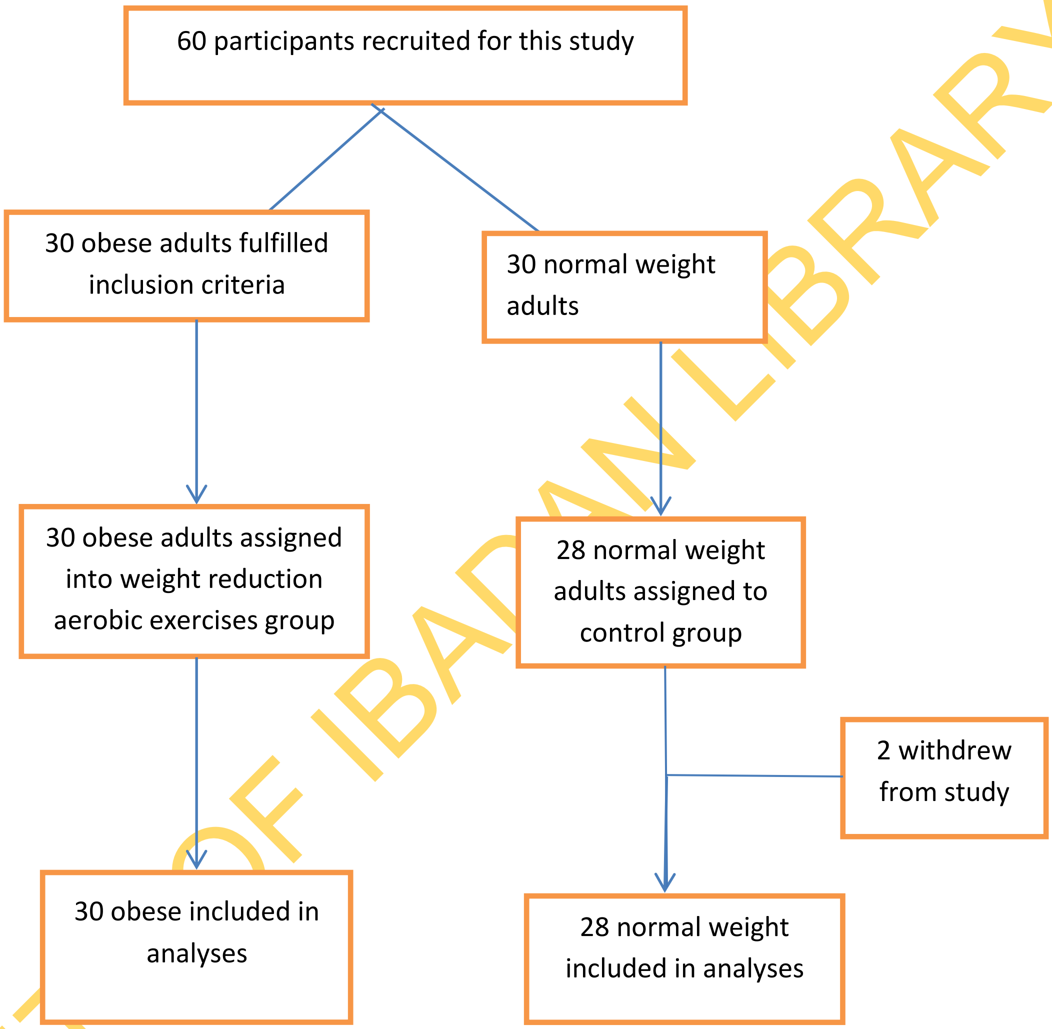

Figure 4.1: Flowchart of participants during the study.

Table 4.1. Physical characteristics of obese and normal weight participants

	Obese group (n = 30)	Normal weight group (n = 28)		
Variable	**Mean±SD**	**Mean±SD**	**t**	**p-value**
Age (years)	32.0± 8.26	29.32± 6.06	1.557	0.125
Weight (kg)	96.42±15.02	69.29±4.77	9.135	< 0.001*
Height (m)	1.66 ± 0.06	1.71± 0.07	3.145	0.003*
BMI (kg/m^2)	35.03±4.91	23.55±1.17	12.06	< 0.001*

***** indicates significance level at alpha = 0.05

Table 4.2: Independent t- test comparison of obese and normal weight groups' walking speed and cadence at baseline week 4, week 8 and week 12 of the study

parameters	Time frame	Obese group (OAG) (n = 30) Mean ± SD	Normal weight(NWAG) (n = 28) Mean ± SD	p-value
WS (m/s)	Week 0	1.09 ± 0.17	1.29 ± 0.17	<0.001*
	Week 4	1.21 ± 0.26	1.29 ± 0.17	0.163
	Week 8	1.28 ± 0.31	1.35 ± 0.19	0.229
	Week 12	1.35 ± 0.32	1.35 ± 0.19	0.989
CD (steps/sec)	Week 0	14.47 ± 0.97	12.82 ±0.39	<0.001*
	Week 4	13.93 ±0.83	12.82 ±0.39	<0.001*
	Week 8	13.13 ±0.86	12.82 ±0.39	<0.001*
	Week 12	12.77 ±0.63	12.82 ±0.39	0.084

*Indicates significant between group difference at alpha = 0.05

WS = Walking Speed
CD = Cadence
SD = Standard deviation

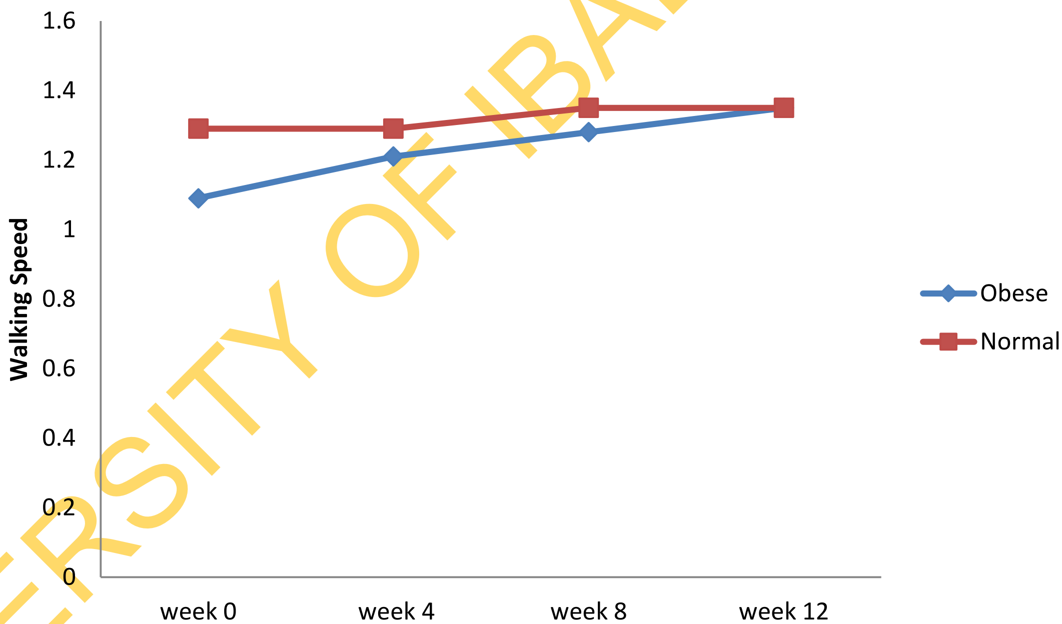

Figure 4.2: Obese and normal weight participants walking speed across the four time frames of the study

There was a slight increase in the walking speed of obese participants between week 0 and week 4 which was virtually constant between week 4 and week 12 while there was a plateau in the walking speed of normal weight group between week 0 and week 4 followed by a slight increase between week 4 and week 8 which remained unchanged between week 8 and week 12 of the study.

Cadence: The mean values of the cadence of the obese group were 14.47± 0.97 steps/min, 13.93± 0.83 step/min, 13.13± 0.86 step/min and 12.77± 0.63 step/min at weeks 0, 4, 8 and 12 of the study respectively while that of the normal weight participants were 12.82± 0.39 steps/min, 12.82± 0.39 steps/min, 12.82± 0.39 steps/ min and 12.82± 0.39 steps/min for weeks 0, 4, 8 and 12 of the study (Table 4.2). Independent t-test at $\alpha = 0.05$ showed that the obese participants had a significantly higher cadence ($p<0.05$) than the normal weight counterparts at weeks 0, 4, 8 and 12 of the study. The trends of the cadence for obese and normal weight groups are presented in Figure 4.3. There was a marked decrease in obese participants' cadence between week 0 and week 8 of the study which became reduced between week 8 and week 12 while a constant trend was observed in normal weight group throughout the study the four time frames of the study.

Step length: The mean step lengths of the obese group were 58.68± 7.42 cm, 62.67± 8.23 cm, 65.34± 8.38 cm and 66.83± 7.81cm at week 0, week 4, week 8 and week 12 of the study respectively while that of the normal weight group were 66.42± 6.51cm, 66.42± 6.51 cm, 67.91± 6.53 and 67.91± 6.53 at weeks 0, 4, 8 and 12 of the study. Independent t-test at $\alpha = 0.05$ showed that the normal weight participants' step length was significantly longer ($p<0.05$) than the obese group participants at all the study's time frame points (Table 4.3). The trends of the step length for both the obese and normal weight groups are presented in Figure 4.4. The step length of the obese group increased sharply between week 0 and week 8 but lesser between week 8 and week 12 while the normal weight group's strength length appeared virtually unchanged.

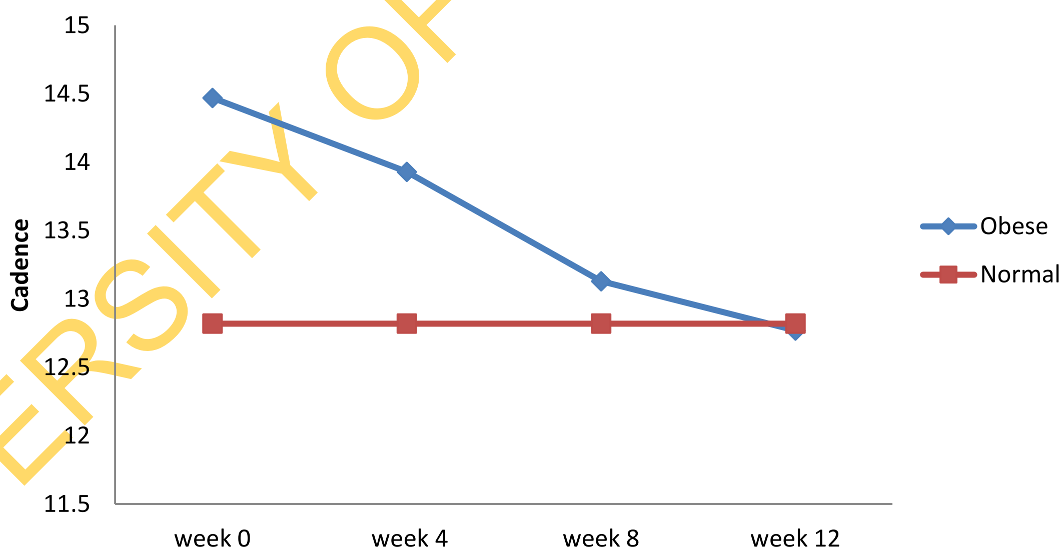

Figure 4.3: Obese and normal weight participants' cadence across the four time frames of the study

Table 4.3: Independent t-test comparison of obese and normal weight groups' step length, step width and stride length at baseline, week 4, week 8 and week 12 of the study.

parameters	Time frame	Obese group (OAG (n = 30) Mean ± SD	Normal weight(NWAG) (n = 28) Mean ± SD	p-value
StpL	Week 0	58.68± 7.42	66.42± 6.51	<0.001*
	Week 4	62.67± 8.23	66.42± 6.51	0.061
	Week 8	65.34± 8.38	67.91± 6.53	0.200
	Week 12	66.83± 7.81	67.91± 6.53	0.573
StpW	Week 0	13.67±4.15	9.79± 1.78	<0.001*
	Week 4	11.79± 3.19	9.79± 1.78	0.005
	Week 8	10.27±2.53	9.55±1.80	0.218
	Week 12	8.81±1.81	9.55±1.80	0.125
StrdL	Week 0	117±14.86	133±13.02	<0.001*
	Week 4	126±16.67	133±13.02	0.073
	Week 8	130±16.93	136±13.09	0.073

	Week 12	134±16.68	136±13.10	0.716

*Indicates significant between group difference at alpha = 0.05

StpL = Step length

StpW = Step width

StrdL = Stride length

SD = Standard deviation

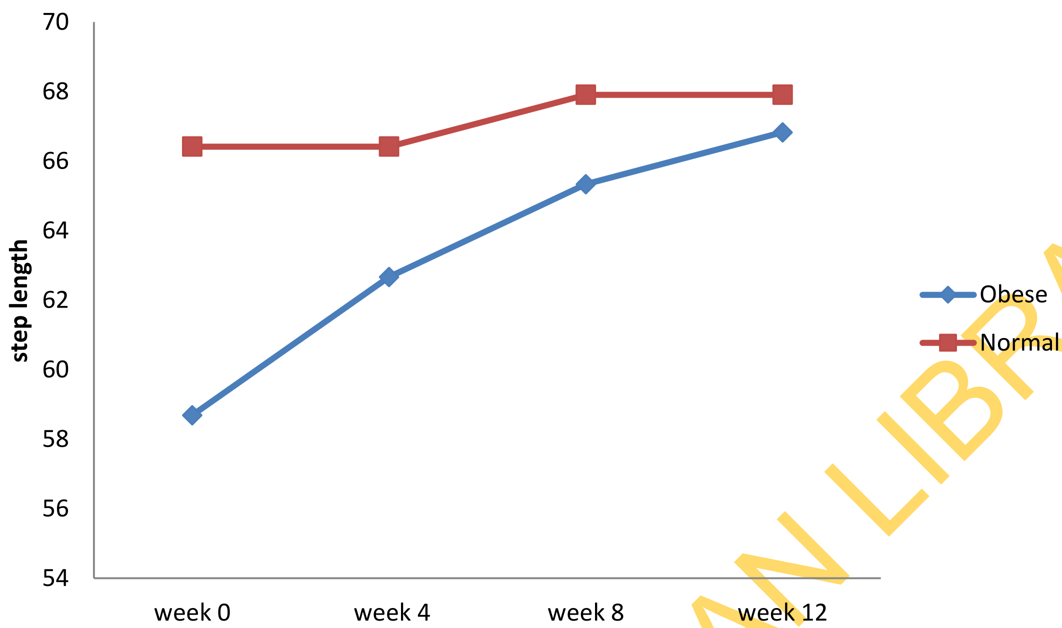

Figure 4.4: Obese and normal weight groups' step length across the four time frames of the study

Step width: The mean step widths of the obese group were 13.67±4.15 cm, 11.79± 3.19 cm, 10.27±2.53 cm and 8.81±1.81cm at weeks 0, 4, 8 and 12 of the study respectively while that of the normal weight group were 9.79± 1.78 cm, 9.79± 1.78 cm, 9.55±1.80 cm and 9.55±1.80 at week 0, week 4, week 8 and week 12 of the study respectively.

Independent t-test at $\alpha = 0.05$ showed the obese group participants had significantly wider step width ($p<0.005$) than the normal weight group at week 0, week 4, week 8 and week 12 of the study (Table 4.3). The trends of the step width for both the obese and normal weight groups are presented in figure 4.5. There was a steady decrease in obese group's step width all through the four time points of the study while it was virtually constant in normal weight group.

Stride length: The mean stride lengths of the obese group were 117±14.86 cm, 126±16.67 cm, 130±16.93 cm and 134±16.68 cm at weeks 0, 4, 8 and 12 respectively while that of the normal weight group were 133±13.02 cm, 133±13.02 cm, 136±13.09 cm and 136±13.10 cm at weeks 0, 4, 8 and 12 of the study respectively. Independent t-test at $\alpha = 0.05$ showed that the normal group had significantly longer ($p<0.05$) stride length than the obese group at week 0 of the study only while the groups were not significantly different at other time points of the study (Table 4.3). The trends of the step lengths for both groups of the participants are presented in figure 4.6. The stride length of the obese group increased sharply between week 0 and week 4 while the increase was steady for the rest of the study. The stride length for the normal weight group however remained virtually constant throughout the study.

4.1.3 Within-group comparison of obese groups' walking speed across week 0, week 4, week 8 and week 12 of the study.

The walking speed of participants in obese group were compared across baseline, week 4, week 8 and week 12 using the Repeated measures ANOVA at $\alpha = 0.05$ (Table 4). Results indicated that participants' walking speeds were significantly different across the 4 time points of the study. Post-hoc analysis using paired t-test with the alpha level set at 0.0125 using Bonferroni adjustment showed significant differences in participants' walking speed at week 0/week 4, week 0/week 8, week 0/week 12, week 4/week 8, week 4/12 and week 8/week 12 time frames of the study.

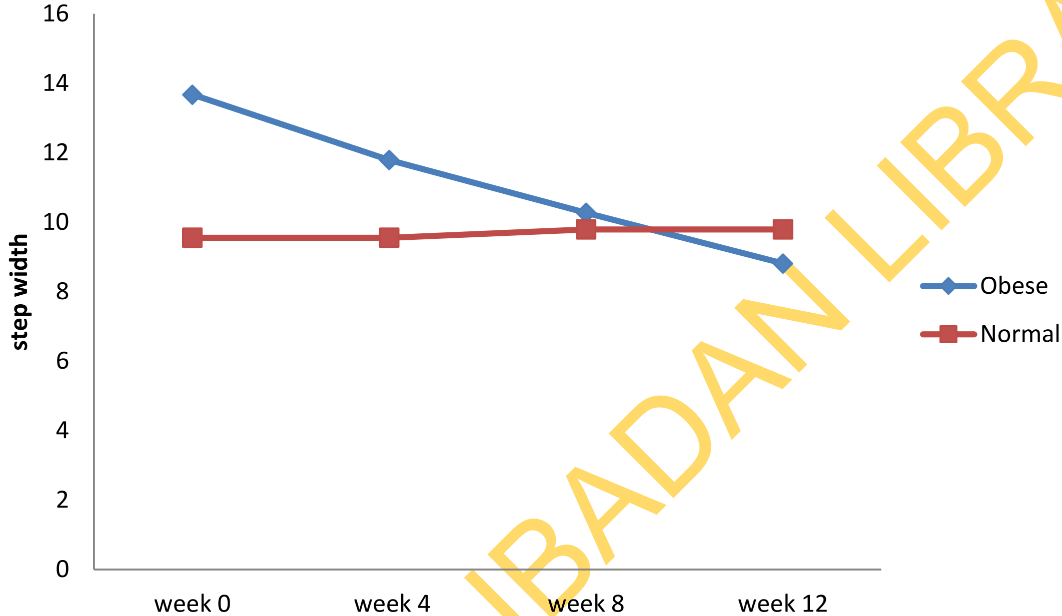

Figure 4.5: Obese and normal weight groups' step width across the four time frames of the study

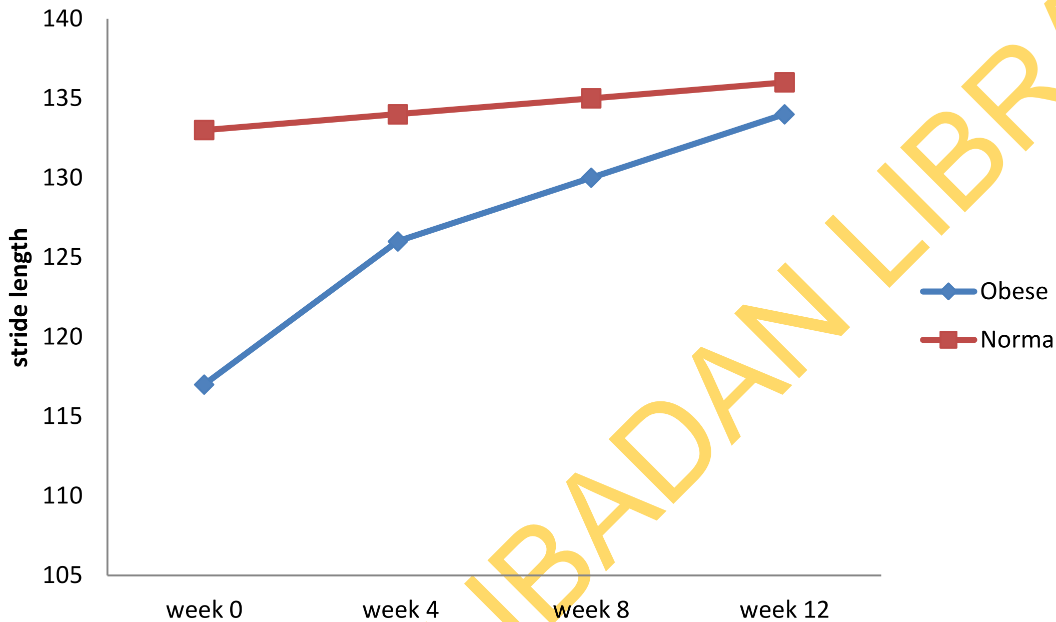

Figure 4.6: Obese and normal weight groups' stride length across the four time frames of the study

4.1.4 Within-group comparison of obese groups' cadence across week 0, week 4, week 8 and week 12 of the study.

Repeated measures ANOVA at $\alpha = 0.05$ was used to compare the cadence of participants in the obese group across week 0, week 4, week 8 and week 12 of the study (Table 4.4). Results indicated that participants' cadence was significantly different across the four time points of the study. Post-hoc analysis using paired t-test with the alpha level set at 0.0125 using Bonferroni adjustment showed significant differences in participants' cadence at week 0/week 4, week 0/week 8, week 0/week 12, week 4/week 8, week 4/12 and week 8/week 12 time frames of the study.

4.1.5 Within-group comparison of obese groups' step length across week 0, week 4, week 8 and week 12 of the study.

The step length of obese participants were compared across the four point times of the study using the Repeated measures ANOVA at $\alpha = 0.05$ (Table 4.4). Results showed that participants' step length was significantly different across the 4 time points of the study. Post-hoc analysis using paired t-test with the alpha level set at 0.0125 using Bonferroni adjustment showed significant differences in participants' step length at week 0/week 4, week 0/week 8, week 0/week 12, week 4/week 8, week 4/12 and week 8/week 12 time frames of the study.

4.1.6 Within-group comparison of obese groups' step width across week 0, week 4, week 8 and week 12 of the study.

The step width of participants in obese group were compared across week 0, week 4, week 8 and week 12) using the Repeated measures ANOVA at $\alpha = 0.05$ (Table 4.4). Results indicated that obese participants' step width was significantly different across the four time points of the study. Post-hoc analysis using paired t-test with the alpha level set at 0.0125 using Bonferroni adjustment showed significant differences in obese participants' step width at week 0/week 4, week 0/week 8, week 0/week 12, week 4/week 8, week 4/12 and week 8/week 12 time frames of the study.

4.1.7 Within-group comparison of obese groups' stride length across week 0, week 4, week 8 and week 12 of the study.

Repeated measures ANOVA at $\alpha = 0.05$ was used to compare the stride length of participants in obese group across the four point times of the study (week 0, week 4, week 8 and week 12) as presented in Table 4.4. Results showed that participants' stride length was significantly different across the study periods. Post-hoc analysis using paired t-test with the alpha level set at 0.0125 using Bonferroni adjustment showed significant differences in participants' stride length at week 0/week 4, week 0/week 8, week 0/week 12, week 4/week 8, week 4/12 and week 8/week 12 time frames of the study.

4.1.8 Within-group comparison of obese groups' Body Mass Index (BMI) across week 0, week 4, week 8 and week 12 of the study.

Repeated measures ANOVA at $\alpha = 0.05$ was used to compare the obese group's BMI across the four point times of the study (week 0, week 4, week 8 and week 12) (table 4.4). Results showed that obese participants' BMI was significantly different across the study periods. Post-hoc analysis using paired t-test with the alpha level set at 0.0125 using Bonferroni adjustment showed significant differences in participants' stride length at week 0/week 4, week 0/week 8, week 0/week 12, week 4/week 8, week 4/12 and week 8/week 12 time frames of the study.

Table 4.4. Repeated Measures ANOVA and paired t-test post- hoc multiple comparison of obese group participants across the 4 time points of the study

	Baseline	Week 4	Week 8	Week 12		
Parameter	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	F	P-value
WS (m/s)	1.09± 0.17[a]	1.21± 0.26[b]	1.28± 0.31[c]	1.35± 0.32[d]	44.84	< 0.001*
CD (stp/s)	14.47± 0.97[a]	13.93± 0.83[b]	13.13± 0.86[c]	12.77± 0.63[d]	138.99	< 0.001*
StpL (cm)	58.69± 7.42[a]	62.67± 8.23[b]	65.34± 8.38[c]	66.83± 7.82[d]	87.19	< 0.001*
StpW(cm)	13.67± 4.15[a]	11.79± 3.19[b]	10.27± 2.53[c]	8.81± 1.81[d]	54.26	< 0.001*
StrdL(cm)	117.35± 14.86[a]	125.63±16.6[b]	129.55± 16.95[bc]	134.33±16.68[c]	42.83	< 0.001*
BMI kg/m²	35.03 ± 4.91[a]	34.17± 4.73[b]	32.85± 4.52[c]	31.43± 4.48[d]	93.19	<0.001*

*Indicates significant within-group difference across the four time points with $\alpha = 0.0125$ by Bonferroni adjustment.

Superscripts (a,b,c,d).

For a particular variable, mean values with different superscripts are significantly ($p<0.05$) different. Mean values with same superscript are not significantly ($p>0.05$) different. The pair of cell means that is significant has different superscripts.

WS = Walking speed

CD = Cadence

StpL = Step length

StpW = Step width

StrdL = Stride length

BMI = Body mass index

4.2 HYPOTHESES TESTING

1. Hypothesis 1: The hypothesis stated that there would be no significant difference in the walking speed of obese adults across baseline, week 4, week 8 and week 12 of the study.

Alpha level: $\alpha = 0.05$

Test statistic: Repeated measures ANOVA

p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED.

2. Hypothesis 2: The hypothesis stated that there would be no significant difference in the cadence of obese adults across baseline, week 4, week 8 and week 12 of the study.

Alpha level: $\alpha = 0.05$

Test statistic: Repeated measures ANOVA.

p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED.

3. Hypothesis 3: The hypothesis stated that there would be no significant difference in the step length of obese adults across baseline, week 4, week 8 and week 12 of the study.

Alpha level: $\alpha = 0.05$

Test statistic: Repeated measures ANOVA.

p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED.

4. Hypothesis 4: The hypothesis stated that there would be no significant difference in the step width of obese adults across baseline, week 4, week 8 and week 12 of the study.

Alpha level: α = 0.05

Test statistic: Repeated measures ANOVA.

p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED.

5. Hypothesis 5: The hypothesis stated there would be no significant difference in the Stride length of obese adults across baseline, week 4, week 8 and week 12 of the study.

Alpha level: α = 0.05

Test statistic: Repeated measures ANOVA.

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED

6. Hypothesis 6: The hypothesis stated that there would be no significant difference in the walking speed of obese adults and their age-matched controls at baseline, week 4, week 8 and week 12 of the study.

Alpha level: α = 0.05

Test statistic: Independent t-test

Baseline

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for the baseline of the study.

Week 4

Observed p-value =0.163

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 4 of the study.

Week 8

Observed p-value = 0.229

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 8 of the study

Week 12

Observed p-value = 0.989

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 12 of the study

7. Hypothesis 7: The hypothesis stated that there would be no significant difference between the cadence of obese adults and their age-matched controls at baseline, week 4, week 8 and week 12 of the study.

Alpha level: $\alpha = 0.05$

Test statistic: Independent t- test.

Baseline

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for baseline of the study.

Week 4

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for week 4 of the study.

Week 8

Observed p-value = 0.001

Since the observed p-value was lower than 0.05, the hypothesis was therefore REJECTED for week 8 of the study

Week 12

Observed p- value = 0.693

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 12 of the study.

8. Hypothesis 8: The hypothesis stated that there would be no significant difference between the step length of obese adults and their age-matched controls at baseline, week 4, week 8 and week 12 of the study.

Alpha level: α = 0.05

Test statistic: Independent t-test

Baseline

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for baseline of the study.

Week 4

Observed p-value = 0.061

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 4 of the study.

Week 8

Observed p-value = 0.200

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 8 of the study

Week 12

Observed p-value = 0.573

Since the observed p–value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 12 of the study.

9. Hypothesis 9: The hypothesis stated that there would be no significant difference in the step width of obese adults and their age-matched controls at baseline, week 4, week 8 and week 12 of the study.

Alpha level: $\alpha = 0.05$

Test statistic: Independent t- test

Baseline

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for baseline of the study.

Week 4

Observed p-value = 0.005

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for week 4 of the study

Week 8

Observed p-value = 0.218

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 8 of the study

Week 12

Observed p-value = 0.125

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 12 of the study.

10. Hypothesis 10: The hypothesis stated that there would be no significant difference between the stride length of obese adults and their age-matched controls at baseline, week 4, week 8 and week 12 of the study.

Alpha level: $\alpha = 0.05$

Test statistic: Independent t-test.

Baseline

Observed p-value = 0.001

Since the observed p-value was lesser than 0.05, the hypothesis was therefore REJECTED for baseline of the study

Week 4

Observed p-value = 0.073

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 4 of the study

Week 8

Observed p-value = 0.073

Since the observed p-value was higher than 0.05, the hypothesis was therefore NOT REJECTED for week 8 of the study

Week 12

Observed p-value = 0.716

Since the observed p-value was higher than 0.05. The hypothesis was therefore NOT REJECTED for week 12 of the study.

4.3 DISCUSSION

4.3.1 Physical characteristics of the groups

The obese and normal weight groups were not significantly different in their mean ages (32.0 ± 8.26years and 29.32± 6.06 years respectively) which implied that the groups were comparable in their ages. The obese group participants had significantly more in weight and were significantly shorter than their normal weight groups. The mean BMI of the obese participants in this study was 35.03± 4.91 kg/m^2 which classifies them as having class II obesity according to the WHO classification of obesity (WHO, 2000). Twenty-three (76.7%) of the obese participants were females while 7 (23.3%) were males. Although, this is not a prevalence study, the male to female distribution of obese participants in this study may be a reflection of the higher incidence of obesity among females (Abubakari et al, 2008).

4.3.3 Comparison of spatiotemporal gait parameters of obese and normal weight participants at the beginning, during and at the end of the 12-week study.

The aim of this study was to investigate the effects of a twelve week weight reduction exercise programme on selected spatiotemporal gait parameters (walking speed, cadence, step length, step width and stride length) of obese individuals and compare with that of their age-matched normal weight counterparts at the beginning, during and at the end of a twelve-week weight reduction exercise programme for the obese participants.

At baseline, the obese participants demonstrated reduced walking speed, shorter step length and stride length, wider step width and higher cadence when compared to their normal weight counterparts. The results were not unexpected because previous studies have shown that obese individuals had strong association with altered spatiotemporal gait parameters such as lower gait speed, shorter strides, and increased step width, and a significantly higher metabolic cost of walking compared to their normal weight counterparts (Spyropoulous et al, 1991; DeSouza et al, 2005; Browning and Kram, 2007; Lai et al, 2008; Xu et al, 2009). The findings of this study may hence be explained in the light of such previous research findings. Spyropoulous et al (1991) reported a slower walking speed and shorter stride and step lengths for all classes of obese adults compared to those of their normal weight counterparts. De Souza et al (2005) examined the gait parameters of class II and III obese individuals and compared them with that of their normal-weight counterparts and observed that the obese participants exhibited a slower walking speed, reduced cadence, and reduced stride length. The mean baseline walking speed, step length and stride length observed among obese participants in this study were in agreement with the findings of most previous studies. The result of this study showed a significantly higher cadence in obese individuals which is at variance with previous studies (Spyropoulous et al, 1991; DeSouza et al, 2005; Wearing et al, 2006; Ling et al, 2009) which showed that obese adults walk at a slower cadence compared to their normal weight counterparts. De Souza (2005) specifically attributed the decrease in the cadence among obese individuals relative to their normal weight counterparts to the increased effort by the obese to move his/her heavier leg. This contradiction may be attributed to racial differences among the obese participants involved in this study and that of the previous studies.

At the fourth week of the study, there were significant differences in walking speed, step length, step width and stride length of the obese and normal weight groups but there was no significant difference between their cadences. The result implied that there were some improvements in the spatiotemporal gait parameters which could be attributed to the effects of the weight reduction exercise intervention. Despite these results, the walking speed, step length and stride length of the obese participants were still found to be lower than those of their normal weight counterparts.

At week 8 of the study, the result showed that there were no significant differences in obese groups' walking speed, step length, step width, stride length but a significantly higher cadence than their normal weight group. This finding indicated that the effects of weight reduction exercise training on the obese participants have produced significant improvements in most of the selected spatiotemporal gait parameters. There was paucity of studies on the effects of weight reduction programme on spatiotemporal gait parameters of obese individuals after eight weeks of intervention hence findings from this study cannot be compared with that from previous studies.

At week 12, the groups were not significantly different in their walking speed, cadence, step length, step width and stride length. It can hence be deduced from the findings of this study that the twelve-week weight reduction exercise programme produced desirable and positive effects on all the five tested spatiotemporal gait parameters of the obese individuals which became comparable to those of their normal weight counterparts who did not undergo any exercise training at the end of the study.

The result of a recent randomized controlled trial by Song et al (2015) indicated that the obese group had significantly reduction in step width than the normal group while the two groups remained comparable in terms of other tested spatiotemporal gait parameters following a twelve-week weight reduction programme. The difference between the work of Song et al (2015) and the findings of this study may be attributed to mode of exercise used for weight reduction; their older participants only had unsupervised self-paced walking without any time limit while the obese participants in this study had supervised progressive graded exercises such as treadmill walking, bicycle ergometry, sit-up exercise and self-paced walking.

Studies conducted by Saibene and Minetti (2003) and Foster et al. (1995) indicated that excessive amount of adipose tissue also increases energy output due to increased body inertia making the locomotion of obese less efficient. Increased energy expenditure is required in obese to overcome friction between thighs, arms and torso and to perform clearance maneuvers (legs and arms swinging wide to move around thighs and torso, respectively). The observed positive effects of the weight reduction exercise programme from the fourth week of this study may hence be assumed as evidence in support of the aforementioned viewpoints.

4.3.4 Effects of weight reduction exercise programme on selected gait parameters of the obese group across the four time points of the study.

There were significant differences in the walking speed, cadence, step length and step width of the obese participants across the four time points of the study (week 0, week 4, week 8 and week 12 of the study). Also, a significant decrease in BMI of obese participants was observed across the four time points of the study. This therefore shows that the 12- week weight reduction exercise programme was sufficient and capable of significantly improving selected spatiotemporal gait parameters of obese individuals to a level comparable to their normal weight counterparts at the end of the study. Studies (Messier et al, 2005; Coker et al, 2009; Arslan, 2011) have shown that high intensity physical activities such as weight reduction exercises result in decrease in body fat and consequent reduction in body weight. Studies on the effects of weight reduction exercise programme on spatiotemporal gait parameters of obese are rather scarce but the findings of this study regarding the effects of weight reduction programme on spatiotemporal gait parameters are in agreement with the work of Plewa et al, (2007) who investigated the effects of a 3-month weight reduction programme on some selected kinematic gait parameters (walking speed, cadence, stride length, stride time, stance time, swing time and double support time) among 52 obese women. They reported significant increases in walking speed, cadence, stride length but significant reductions in cycle time, stance and double support phases. Other available previous studies only evaluated some beneficial effects of weight reduction on some measures of adiposity such as body mass index and percentage body fat (Messier et al, 2005), improvement in cardiovascular risk factors such as decrease in blood pressure (Neter et al, 2003), improvement in lipid profile and glucose tolerance (Flechtner-Mors et al, 2000; Dattilo and Kris-Etherton, 1992), reduction inflammation (Tchernof et al, 2002), and improvement in physical function and health related quality of life (Kaukua et al, 2003; Fontaine et al, 2004; Jensen et al, 2004; Messier et al, 2004; Villareal et al, 2006). Gait modifications in the obese are caused by the excess body weight induced by their larger thighs and shanks (Donelan et al, 2001; Ling et al, 2009; Herring et al, 2010); hence the obese individuals modify their gait patterns by walking at their preferred speed as a way of implementing a balancing strategy (Sarkar et al, 2011). For instance, obese individuals compensate for their reduced waking speed with faster cadence.

4.3.5 Clinical implication of the findings from this study

The outcome of this study indicated that a twelve-week weight reduction exercise programme had significant effects on walking speed, cadence, step length, step width and stride length of obese individuals to a level comparable to that of the normal weight individuals at the end of the twelve week weight reduction exercise training on the obese participants. It is therefore suggested that Clinicians, Physiotherapists, exercise physiologists and other health care providers could adopt this exercise programme as a means of improving the spatiotemporal gait parameters among individuals with obesity.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.1 SUMMARY

Obesity is a chronic health problem which is becoming an important clinical and public health challenge, assuming an epidemic dimension globally. Although, obesity has been documented to affect gait, the effects of weight reduction exercises on gait parameters of obese individuals has not been documented. This study was therefore carried out to investigate the effects of a twelve – week weight reduction exercise programme on selected spatiotemporal gait parameters (walking speed, stride length, step length, cadence and stride width) of obese individuals and compare with those of their normal weight controls at baseline, and at the end of weeks 4, 8 and 12 of the study.

Extensive literature review was done on the epidemiology, pathophysiology, etiology, complications and classifications of obesity, gait cycle and gait analysis, obesity and gait, weight control and obesity, and weight reduction exercises.

This was a two- group pre-test post-test quasi experimental study. Ethical approval was sought and obtained from the Joint University of Ibadan/University College Hospital Health Research Ethics Committee prior to the commencement of this study. Participant's informed consent and the permission of the management of Federal Medical Centre, Owo were sought and obtained. Potential obese participants were initially screened with the Physical Activity Readiness Questionnaire (PARQ) to ensure that participants met the inclusion criteria for the study. Sixty (30 obese and 30 age-matched normal weights) individuals were recruited for the study. The participants were assigned into obese and normal weight groups according to body mass index (BMI) classification (WHO, 2000). Fifty-eight participants (30 obese, 28 normal weight) completed the twelve- week study.

Obese participants performed weight reduction exercises on three alternate days per week while their normal weight counterparts were not involved in any form of exercise but both groups had their spatiotemporal gait parameters (walking speed, cadence, step length, step width and stride length) assessed at baseline and end of the weeks 4, 8 and 12 of the study.

Spatiotemporal gait parameters of all the participants in both groups were obtained by the footprint method. The data were summarized by using descriptive statistics of mean, standard deviation, percentages and graphs. Repeated Measures ANOVA was used for within-group comparison of obese participants' selected gait parameters' while independent t-test was used for between-group comparison participants' gait parameters at baseline, week 4, week 8 and week 12 of the study. Level of significance was set at 0.05.

Comparison between the two groups showed that they were not significantly different in ages ($p< 0.125$) but obese participants were significantly shorter ($p=0.003$) and weighed more ($p<0.001$) and had significantly greater BMI ($p<0.001$) than their normal weight counterparts. At baseline, the obese group had significantly lower walking speed (1.09± 0.17m/s; 1.29 ± 0.17 m/s), step length (58.68± 7.42cm; 66.42± 6.51cm) and stride length (117±14.86 cm; 133±13.02 cm) but higher cadence (14.47± 0.97steps/min; 12.82± 0.39steps/min) and step width (13.67±4.15 cm; 9.79± 1.78 cm) than the normal weight group. Between-group comparison at week 12 did not reveal any significant difference between the groups' walking speed (1.35±0.19 m/s; 1.35±0.32 m/s), step length (66.83±7.81cm; 67.91±6.53cm), stride length (134±16.68 cm; 136±13.10 cm), cadence (12.77± 0.63step/min; 12.82±0.39 steps/min) and step width (8.81±1.81cm; 9.55±1.80cm). Within-group comparison however showed that the walking speed, step length and stride length in obese group were significantly increased while cadence and step width decreased significantly across the four time points of the study.

The results obtained were discussed by comparing and contrasting the findings of the study with those of related past studies. Literatures were appropriately cited to corroborate the results obtained in this study. Reasons were adduced for the result obtained in the light of literature and clinical reasoning.

5.2 CONCLUSIONS

1. Twelve-week weight reduction exercise programme produced significant effects on selected spatiotemporal gait parameters (walking speed, cadence, step length, step width and stride length) assessed in obese individuals specifically observed from week 4 through the end of the study.
2. The selected spatiotemporal gait parameters assessed in obese participants were found to be comparable with their normal weight counterparts at the end of a twelve-week weight reduction exercise intervention on the obese group.

5.3 RECOMMENDATIONS

1. Weight reduction exercise programme is recommended to improve spatiotemporal gait parameters of obese individuals and to reduce the risk of other health related problems associated with obesity .
2. Further studies could employ longer duration of weight reduction programme for more positive effects on measures of adiposity.

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APPENDIX I

INFORMED CONSENT FORM

My names are Jegede, Joseph Adeiza. I am a postgraduate student of the Department of Physiotherapy, College of Medicine, University of Ibadan. I am conducting a study to investigate the effects of a 12-weeks weight reduction programme on selected spatiotemporal gait parameters of obese individuals. This study is being carried out in partial fulfillment of the requirement for the award of Master of Philosophy (Physiotherapy) degree of the College of Medicine, University of Ibadan. You are invited to participate in this study, based on the assumption that the exercise programme that will be prescribed to you will help in reducing your body weight and improve your health status.

Information given by you will be kept confidential and used for the purpose of the research only.

Please not that your participation in this study is voluntarily and you have right to withdraw from this study at any time. I will be grateful if you will participate in this study.

Consent: Now that this study has been explained to me in details and I understand the nature, purpose and benefits of the study, I will be willing to participate.

____________________________ __________________________

Signature/Date of the Participant Signature of Researcher/Date

APPENDIX II

Sample Physical Activity Readiness Questionnaire

Activity Readiness Questionnaire (r-PARQ)1

Please answer honestly yes or no for each of the following questions, by placing a tick in the appropriate box.

Questions: Yes ☐ No ☐

1. Has a doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

   Yes ☐ No ☐

2 Do you ever feel pain or tightness in your chest when you do physical activity?

Yes ☐ No ☐

3 In the past month have you had pain or tightness in your chest when you were not doing physical activity?

Yes ☐ No ☐

4 Have you ever fallen over or lost consciousness as a result of dizziness?

Yes ☐ No ☐

5 Do you have a bone or joint problem that could be made worse by a change in your physical activity (such as riding a bicycle)?

Yes ☐ No ☐

6 Has a doctor ever recommended medication for your blood pressure or a heart condition?

Yes ☐ No ☐

7 Are you aware, through your own experience or a doctor's advice, of any other reason why you should not do physical activity without medical supervision?

Yes ☐ No ☐

8. Are you on any medication that may prevent you from undertaking this activity safely?

Yes ☐ No ☐

If you answered YES to any of these questions, you will need to visit a doctor and you will need a medical certificate indicating your suitability for riding short to medium length trips for work.

If you answered NO to all questions, you can be reasonably sure that you can start becoming more physically active.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever-wait until you feel better: or
- You are or may be pregnant – talk to your doctor before you start becoming more active.

Note: If your health changes so that you then answer YES to any of the above questions, ask for advice from your fitness or health professional.

I certify that the information provided above is true and correct to the best of my knowledge.

Name: ……………………………………………………………………………………

Signature: …………………………………………………………………………………..

Date: ………………………………………………………………………………………

AHA/ACSM Joint Position Statement: Recommendations for Cardiovascular screening, staffing, emergency policies at health/fitness facilities. Medicine and Science in Sport and Exercise 1998: 30(6); 1009-1018.

APPENDIX III

Research Number:______ Age: ________ Gender: _______No of Pregnancy: _______
Height:_______Occupation: ___________ Marital Status:_______LMP: __________

Section B:

S/N	Variables	Baseline week0	2nd week	4th week	6th week	8th week	10th week	12th week

1	Weight							
2	BMI							
3	Pulse Rate $_{(rest)}$							
4	Pulse Rate $_{(ex)}$							
5	$SBP_{(rest)}$							
6	$DBP_{(rest)}$							
7	$SBP_{(ex)}$							
8	$DBP_{(ex)}$							
9	WS							
10	CD							
11	SL							
12	SLT							
13	SW							
14	WC							

KEY:

BS: Baseline Measurement
WS: Walking speed
CD: Cadence
SL: Step length
SLT: Stride length
SW: Stance width
BMI: Body Mass Index
Weight: Body Weight (Kg)
Pulse Rate $_{(rest)}$: Resting Heart rate
Pulse Rate $_{(ex)}$: Exercise Heart Rate

$SBP_{(rest)}$: Resting Systolic Blood Pressure
$DBP_{(rest)}$: Resting Diastolic Blood Pressure
$SBP_{(ex)}$: Exercise Systolic Blood Pressure
$DBP_{(ex)}$: Exercise Diastolic Blood Pressure

APPENDIX IV

MEAL TABLE FOR OBESE INDIVIDUALS AS PRESCRIBED BY DIETETICS DEPARTMENT, FEDERAL MEDICAL CENTRE, OWO.

DAYS	BREAKFAST	LUNCH	DINNER

Monday	Yam and fish stew with vegetable and fish	Moimoi	Eko with vegetable and fish
Tuesday	Rice and beans with vegetable and fish	Fruits	Amala with vegetable and fish
Wednesday	Pap with moimoi	Beans with maize	Semo with okro or ewedu and fish or ponmo
Thursday	Bread and tea	Plantain with vegetable and fish	Rice with vegetable and fish
Friday	Yam with garden egg or fish stew	Fruits	Pap with vegetable
Saturday	Amala with vegetable and ponmo	Rice and beans with vegetable and fish	Boiled plantain with vegetable and ponmo
Sunday	Beans with maize and fish	Pounded yam with vegetable and ponmo	Eko with vegetable and fish