**SCHOOL OF BIOLOGICAL SCIENCES**

**COLLEGE OF BASIC AND APPLIED SCIENCES**

**UNIVERSITY OF GHANA**

# PREVALENCE, PERCEIVED BARRIERS, PREDICTORS AND ASSOCIATED BIOMARKERS OF WEIGHT LOSS MAINTENANCE SUCCESS AMONG PREVIOUS PARTICIPANTS OF A COMMERCIAL WEIGHT LOSS PROGRAMME IN ACCRA, GHANA.

**BY**

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**DEPARTMENT OF NUTRITION AND FOOD SCIENCE**

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# DECLARATION

I Sandra Ayisi Addo, hereby declare that, aside the references made to authored works of others which have been duly acknowledged, this work being presented is exclusively the results of my personal original research under the supervision of Professor Matilda Steiner Asiedu (Lead Supervisor) and assisted by other supervisors: Professor Christina Nti, Dr. Frederick Vuvor and Dr. Jonathan Adjimani and has not been presented for another degree elsewhere.

------------------------------------------ 01-04-2021 ------------------------------

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# ABSTRACT

**Background:** Weight Loss Maintenance (WLM) although necessary for the preservation of the health benefits derived from weight loss, is difficult to attain. Research investigating the perceived barriers and predictors of WLM success as well as the impact of WLM success on cardiovascular related biomarkers are usually limited to short-term post weight loss periods not exceeding two years. Studies on commercial weight loss programmes are mostly limited to short-term efficacy studies with little known about the long-term outcomes. Additionally, investigations on WLM so far, are mostly carried out in developed countries with no data on WLM outcomes of commercial weight loss programmes in developing countries such as Ghana, and the associated factors of WLM success. Given the global importance of commercial programmes for weight loss, there is the need to gain insight into their long-term outcomes in developing countries including Ghana, and determine the perceived barriers, predictors, and the associated biomarkers of WLM success.

**Methods:** A retrospective cohort study involving 230 participants who formerly enrolled in a commercial weight loss programme between 2008 and 2016 was undertaken in Accra, Ghana. The prevalence of WLM success was determined using a definition of successful WLM as achieving ≥ 5.0% weight loss below starting weight for a period of at least six months post weight loss intervention and unsuccessful WLM as otherwise. An interviewer-administered questionnaire was used to obtain information on the demographic, behavioural, psychosocial and programme based characteristics of participants as well as the perceived barriers to WLM success. A sub-sample of 112 individuals were selected for biochemical analysis on fasting blood lipids and glucose parameters. Categorical Principal Component Analysis (CATPCA) was employed to determine the various components of perceived healthy eating and physical activity related barriers to WLM success. Multivariate binary logistic regression analysis was conducted to identify the predictors of WLM success.

Multiple linear regression was used to determine the association between WLM and the concentrations of lipids/glucose biomarkers.

**Results:** The prevalence of WLM success was 23.9%. The healthy eating related barriers to WLM success were locational, cost of healthy eating, food craving, emotional factors and lack of social support and accounted for 66.9% of the variance in data. The physical activity related barriers to WLM success were the cost of physical activity, environmental factors and personal factors and accounted for 65.6% of the variance in data. Achieving ≥ 10% weight loss at the end of the weight reduction programme increased the odds of WLM success compared to not achieving ≥10.0% weight loss (AOR = 6.72, 95.0% C.I = 3.15-14.31). Similarly, logging physical activity compared to not logging (AOR = 3.52, 95.0% C.I = 1.49-8.32), limiting food portions at meal times compared to not limiting (AOR = 3.51, 95.0% C.I = 1.07-11.57), and a good/excellent perceived competence in carrying out behaviours for weight maintenance compared to a poor/disappointing perceived competence (AOR = 5.93, 95.0% C.I = 1.74-20.19), increased the odds of successful WLM. Being out of the weight loss treatment for three years or more as at the time of this study reduced the odds of WLM success compared to being out of treatment for less than three years (AOR = 0.46, 95.0% C.I = 0.22-0.97). Successful Weight Loss Maintainers (SWLM) compared to Unsuccessful Weight Loss Maintainers (UWLM) had significantly lower concentrations of adjusted serum total cholesterol (TC) (5.69±0.24mmol/L versus 6.26±0.18mmol/L, respectively, P<0.013) and triglycerides (TG) (1.11±0.10mmol/L versus 1.34±0.07mmol/L, respectively, P<0.021). SWLM with 10.0% or more weight loss had significantly lower concentrations of adjusted LDL compared to UWLM (3.86±0.31mmol/L versus 4.46±0.18mmol/L, respectively, P = 0.046). The adjusted serum High Density Lipoprotein (HDL), Fasting Blood Glucose (FBG) and glycosylated haemoglobin (HbA1c) concentrations did not differ between SWLM and UWLM.

**Conclusions:** About a quarter (23.9%) of study participants were successful at WLM. Perceived priority barriers to WLM success were costs of healthy eating and physical activity, locational factors and food craving. Participants with varying baseline demographic backgrounds, previous weight loss attempt history and physical activity may be targeted for WLM. A high magnitude of weight loss (≥10.0%) achieved at the weight loss phase predicted WLM success. After the weight loss period, logging of physical activity, limiting food portions at meal times, and a good/excellent perceived competence in carrying out weight management behaviours increased the odds of WLM success. A longer time out of the weight loss programme (three years or more) decreased the odds of successful WLM. SWLM compared to UWLM had significantly lower levels of serum TC and TG but similar HDL, FBG, HbA1C levels. Additionally, SWLM with 10.0% or more weight loss had significantly lower LDL levels compared to UWLM.

# DEDICATION

*To God Almighty who makes everything beautiful in its time.*

*To my husband Stephen, my siblings, and to the memory of my departed parents.*

*To Professor Matilda Steiner-Asiedu*

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Finally this would have never been made possible without the overwhelming and unwavering support of my family, especially my husband Dr. Stephen Ayisi Addo, who has been a strong pillar of support, guidance, encouragement and inspiration through thick and thin for the successful realisation of my PhD dream.

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AORs: | Adjusted Odd Ratios |
| AUC: | Area Under the Curve |
| BMI: | Body Mass Index |
| CARDIA: | Coronary Artery Risk Development in Young Adults |
| CATPCA: | Categorical Principal Component Analysis |
| CI: | Confidence Interval |
| CIA: | Central Intelligence Agency |
| CHD: | Coronary Heart Diseases |
| CVD: | Cardiovascular Diseases |
| EDTA: | Ethylene di-amine tetra acetic acid |
| FAO: | Food and Agriculture Organisation |
| FBG: | Fasting Blood Glucose |
| GSS: | Ghana Statistical Service |
| GHS: | Ghana Health Service |
| HbA1c: | Glycosylated Haemoglobin |
| HDL: | High Density Lipoprotein |
| HIV: | Human Immunodeficiency Virus |
| HR: | Hazard Ratio |
| IQR: | Interquartile Range |
| IBM: | International Business Machines Corporation |
| KMO: | Kaiser-Meyer-Olkin |
| LDL: | Low Density Lipoprotein |
| Look AHEAD: | Action for Health in Diabetes Study |
| MI: | Macro International Incorporated |
| NHANES: | National Health and Nutrition Examination Survey |

| | |
|---|---|
| NMIMR: | Noguchi Memorial Institute for Medical Research |
| NWCR: | National Weight Control Registry |
| NWLP: | Nutriline Weight Loss Programme |
| OECD: | Organisation for Economic Co-operation and Development |
| PCA: | Principal Component Analysis |
| PTT: | Post weight loss Treatment Time |
| ROC: | Receiver Operating Characteristics |
| RODAM: | Research on Obesity and Diabetes among African Migrants |
| RR: | Relative Risk |
| SBP: | Systolic Blood Pressure |
| SD: | Standard Deviation |
| SKN: | Saint Kitts Nevis |
| SWLM: | Successful Weight Loss Maintainers |
| TC: | Total Cholesterol |
| TG: | Triglycerides |
| USA: | United States of America |
| UWLM: | Unsuccessful Weight Loss Maintainers |
| VLDL: | Very Low Density Lipoprotein |
| WHO: | World Health Organisation |
| WLM: | Weight Loss Maintenance |

# OPERATIONAL DEFINITIONS

**Baseline weight**: This is the starting weight of participants at the time of enrolment into the weight reduction programme.

**WLM success:** WLM success was defined as achieving ≥ 5% weight loss below baseline weight for at least six months post weight loss intervention. WLM success in this study was with reference to the first bout of weight loss.

**Number of bouts of weight loss:** This is the number of weight reduction enrolments embarked on in the weight loss programme. Each programme enrolment has a start and an end date. Initial enrolment into the weight loss programme until its expiry is termed the first bout of weight loss. Subsequent renewals of enrolment were considered as second bout, third bout and so on.

**Baseline Body Mass Index (BMI)**: This is the BMI at the time of enrolment into the weight loss programme. It was calculated by dividing weight (kg) by the square of height (m) at the time of enrolment into the weight reduction programme.

**BMI at the end of the weight loss programme:** This was calculated by dividing weight (kg) at the end of the weight loss programme by the square of height (m) at the time of enrolment into the weight reduction programme.

**BMI at study time:** This was calculated by dividing weight (kg) by the square of height (m) at the study time.

**Post Treatment Time (PTT):** This was the time that elapsed after completing the weight loss programme/intervention till the time of the study. It was calculated as the length of time (in months) starting from the date of ending the weight loss programme until the date that the participant was interviewed for this study.

**Weight change at the end of the weight reduction programme:** This is the weight change that occurred from the time of enrolment into the weight reduction programme till the end of the weight reduction programme. It was determined using the formula: End of programme weight minus weight at the time of enrolment into the weight reduction programme (baseline weight). A negative value indicated that weight loss was achieved at the end of the weight reduction programme, while a positive value meant weight was gained. A zero value meant there was no change in weight.

**Percent weight loss at the end of the programme:** This is the percentage weight loss achieved from the time of enrolment into the weight reduction programme till the end of the weight reduction programme. It was determined by the formula $\frac{Weight\ loss\ achieved\ at\ the\ end\ of\ weight\ reduction\ programme}{Baseline\ weight} \times 100$.

**Weight change at the time of the study:** This is the weight change from the time of enrolment into the weight reduction programme till the study time. This was determined using the formula: weight at time of study minus baseline weight. A negative value indicated weight loss was achieved at the time of the study while a positive value meant weight gain. A zero value meant no change in weight or a return to baseline weight.

**Percent weight loss at time of the study:** This is the percentage weight loss achieved from time of enrolment into the weight reduction programme till the study time. It was determined using the formula: $\frac{Weight\ loss\ achieved\ at\ the\ time\ of\ the\ study}{Baseline\ weight} \times 100$.

**Percent of weight loss retained**: This is the proportion of the total weight loss achieved at the end of the weight reduction programme that was retained at the time of the study. This was determined using the formula: $\frac{Weight\ loss\ achieved\ at\ the\ time\ of\ the\ study}{Weight\ loss\ achieved\ at\ the\ end\ of\ the\ programme} \times 100$ .

**Length of stay in the weight loss programme:** This is the duration in weeks from the date of enrolment into NWLP until the date of last weight loss review visit.

**Percent attendance to treatment review sessions:** Each duration of the Nutriline Weight Loss Programme enrolled into has a fixed number of required review visits. The percent attendance to treatment review sessions was derived from the formula: $\frac{Actual\ number\ of\ review\ visits\ made}{The\ required\ number\ of\ review\ visits} \times 100$ .

**Priority healthy eating and physical activity related barriers:** Barrier components or items with Likert scores equal to or greater than the median score of 2.5 were defined as priority barriers.

**Blood parameter concentrations:** These were TC, LDL, HDL, TG, and FBG concentrations measured in mmol/L, and HbA1c concentration measured in percentage (%).

**Commercial weight loss programme**: This is a commercially operated weight loss programme offered outside the healthcare environment.

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background

On a global scale, almost two billion adults were overweight (BMI greater than or equal to 25.0 kg/m$^2$ and less than 30.0 kg/m$^2$) or obese (BMI of 30.0 kg/m$^2$ or higher) in the year 2016 (World Health Organisation, 2018a). Although overweight/obesity continues to be a challenge for developed as well as developing countries, the rate of increase has slowed down for most developed countries and continues to rise for developing countries (Seidell & Halberstadt, 2015; Ng *et al.*, 2014). Overweight/obesity are major risk factors for disease conditions such as type 2 diabetes, hypertension, cardiovascular diseases (CVD), various types of cancers and other disease conditions (Hruby & Hu, 2016). The causes of overweight/obesity include behavioural factors (dietary factors and patterns, physical activity level, sleep duration, use of certain medications), genetic risk, environmental factors (exposure to obesogens, built environment) (Hruby *et al.*, 2016), and hormonal factors (hypogonadism, hypothyroidism, Cushing's disease, leptin resistance) (Sidhu, Parikh & Burman, 2017).

In Ghana, the Demographic and Health Surveys conducted from the years 1993 to 2014 have shown consistent growth (13.0% to 40.0%) in the prevalence of overweight and obesity in women aged 15-49 years (GSS, GHS & ICF International, 2015; GSS, GHS & ICF Macro, 2009; GSS, NMMR, & ORC Macro, 2004; GSS & MI., 1994). Additionally, a recent systematic review of literature on overweight and obesity in Ghanaian adults reported a prevalence of 43% (Ofori-Asenso, Agyeman, Laar, & Boateng, 2016). The increasing overweight/obesity prevalence in Ghana is also linked to a rising trend in obesity related co-morbidities. Hypertension, for instance, is a growing public health challenge in both urban and rural parts of Ghana (Dosoo *et al*., 2019; Bosu, 2010), with adult prevalence estimated at 13.0% (Sanuade, Boatemaa, & Kushitor, 2018). Diabetes prevalence is likewise on the ascendancy. The number of adult diabetes cases in Ghana increased from 450,000 in 2014 (Ofori-Asenso & Garcia, 2016) to over 518, 000 cases in 2017 representing an adult prevalence of 3.6% (International Diabetes Federation, 2017). In Accra, infectious and parasitic conditions, which were the leading cause of death in 1966, were replaced by CVD in 1991 and 2001 (Agyei-Mensah & de-Graft Aikins, 2010). In 2008, CVDs were considered the dominant cause of national deaths that were derived from institutions (Ghana Health Service, 2010). Stroke and Coronary Heart Disease (CHD) are currently rated as the first and second cause of death, respectively, in Ghana (World Life Expectancy, 2018). The World Health Organisation determined the likelihood of death from key non-communicable conditions (cancer, diabetes, CVD, chronic respiratory disease) in Ghana for persons within the ages of 30-70 years to be 20.0% (World Health Organisation, 2014a).

The benefits of healthy deliberate weight loss (5.0%-10.0% of baseline weight) in overweight or obese subjects have been widely documented (Centers for Disease Control and Prevention, 2018; Elffers *et al*., 2017; Brown, Buscemi, Milsom, Malcolm, & O'Neil, 2016; Weiss, Albert, Reeds, Kress, Mcdaniel, Klein, & Villareal, 2016; Wing *et al*., 2011). Magkos *et al*. (2016) reported significant improvements in glucose metabolism after weight reduction in participants who at baseline were insulin resistant. In another study, weight loss significantly predicted a reduction in type 2 diabetes incidence (Kim *et al*., 2018). Weight reduction has been documented to improve other cardiovascular risk factors such as dyslipidaemia, besides type 2 diabetes (Elffers *et al*., 2017; Brown *et al*., 2016; Cefalu *et al*., 2015). Modest weight reduction is also associated with a reduction in risk for some cancers as a result of reduction in inflammation inducing cytokines (Luo *et al*., 2017; Tajik *et al*., 2013) and significant improvements in sleep apnoea and other health conditions

(Pietrzykowska, 2018). The majority of the studies exploring the health benefits of weight reduction often do so during the weight loss phase or up to two years post weight loss (Brown *et al.*, 2016; Weiss *et al*., 2016; Tapsell, Batterham, Thorne, O'Shea, Grafenauer, & Probst, 2014; Wing *et al*., 2011), creating a dearth in knowledge about the health benefits of WLM success achieved over a longer time span (> 2 years).

The widespread education on the health benefits of weight loss has contributed to a rise in the numbers of people attempting weight reduction at some point in their lives. This was evident in a recent report by Santos, Sniehotta, Marques, Carraça, and Teixeira, (2017), which showed that forty percent of the global adult population attempted to lose weight between the years 2010 and 2015, most of whom were overweight/obese. In Ghana, the majority of women participating in the Women's Health Survey in Accra were aware of the health implications of being obese and a number of them were willing to shed some weight in order to be healthier (Benkeser, Biritwum, & Hill, 2012).

The most common procedures for weight reduction and its maintenance across the world are those related to increased energy expenditure and decreased energy intake (Santos *et al.*, 2017), which are consistent with internationally accepted guidelines for obesity management (Garvey *et al.*, 2016). Increased energy expenditure and/or reduced dietary intake for weight reduction and weight maintenance are commonly attained through self-help measures or via other avenues such as consultations with health professionals and structured weight loss programmes (commercial or clinical based programmes) (Santos *et al.*, 2017).

Although structured weight loss programmes are efficacious in yielding temporary weight loss, maintenance of the weight loss attained has been challenging (Hall & Kahan, 2018). WLM success is generally defined as achieving and sustaining a minimum magnitude of weight reduction over a specified length of time. Almost two decades ago, Anderson, Konz, Frederich and Wood, (2001) demonstrated that the majority of people who lose weight recover a greater part of the lost weight within three to five years post weight loss. In later years however, research has revealed that a substantial proportion of people are still successful at keeping their weight loss for a long period despite the difficulty associated with the preservation of weight loss (Evans *et al.*, 2019; Kraschnewski, Boan, Esposito, Sherwood, Lehman, Kephart, & Sciamanna, 2010; Phelan, Wing, Loria, Kim, & Lewis, 2010; De Zwaan, Hilbert, Herpertz, Zipfel, Beutel, Gefeller, & Muehlhans, 2008; Weiss, Galuska, Khan, Gillespie, & Serdula, 2007). Maintenance of lost weight is important if the health gains derived from weight reduction are to be sustained. Additionally, weight regain impacts negatively on cardiovascular related health benefits derived from weight loss (Kroeger, Hoddy, & Varady, 2014; Beavers, Beavers, K. M., Lyles, & Nicklas, 2013).

Considering the challenges associated with WLM success, studies on the predictors and perceived barriers to WLM success are needed to enhance the development of interventions that will improve the odds of WLM success. Research exploring the association between baseline demographic factors such as age, gender, status in marriage and WLM success so far, have shown inconsistent results. Some studies (Varkevisser, Stralen,Van, Kroeze, Ket, & Steenhuis, 2019; Abildso, Schmid, Byrd, Zizzi, Quartiroli, & Fitzpatrick, 2014; Phelan *et al.*, 2010) found no relationship with WLM while others have shown some association (Rancourt, Jensen, Duraccio, Evans, Wing, & Jelalian, 2018; Svetkey *et al.*, 2014; Kraschnewski *et al.*, 2010). Knowledge about baseline demographic predictors of WLM will help in establishing the baseline demographic pre-requisites for WLM success and help in the selection of candidates with demographic profiles that increase the odds of WLM success.

Programme based factors existing during the weight reduction programme have been shown to impact on WLM outcomes. These include the magnitude of weight loss obtained in a weight reduction programme and the length of stay in treatment. Higher magnitudes of weight reduction (Varkevisser *et al*., 2019; Sawamoto, Nozaki, Nishihara, Furukawa, Hata, Komaki, & Sudo, 2017; Pekkarinen, Kaukua, & Mustajoki, 2015) and a longer stay in treatment (Jiandani, Wharton, Rotondi, Ardern, & Kuk, 2016; Montesi, Ghoch, Brodosi, Calugi, Marchesini, & Dalle Grave, 2016; Abildso *et al*., 2014) were revealed to predict successful WLM. Post programme factors such as PTT are known to significantly predict WLM success. The shorter the PTT, the higher the odds of being successful at WLM (Abildso *et al*., 2014; Befort, Stewart, Smith, Gibson, Sullivan, & Donnelly, 2008).

Being physically active expends energy, which helps to adjust energy balance in favour of weight loss or its maintenance (Manore, Larson-meyer, Lindsay, Hongu, & Houtkooper, 2017; Swift, Johannsen, Lavie, Earnest, & Church, 2014). Some studies have reported a positive relationship between increased physical activity and WLM success (Varkevisser *et al*., 2019; Gilis-Januszewska *et al*., 2018; Abildso *et al*., 2014; Swift *et al*., 2014). A number of other behavioural factors practised after the weight loss programmes have been documented to predict WLM success. Dietary behaviours such as limiting snacking, regular consumption of breakfast, and self-monitoring behaviours (limiting food portion size, logging of food intake and physical activity) that are practised after the weight loss intervention have been shown to be associated with WLM success (Varkevisser *et al*., 2019; Kruseman, Schmutz, & Carrard, 2017; Montesi *et al*., 2016; Abildso *et al*., 2014; Burke, 2011). Successful WLM largely requires the maintenance of diet and physical activity behaviours used during the weight loss programme even when the weight loss intervention ends (Evans *et al*., 2019; Sawamoto *et al*., 2017; Metzgar, Preston, Miller, & Nickols-Richardson, 2015).

Psychosocial factors, perceived healthy eating and physical activity related barriers to WLM success, have implications for WLM. High levels of self-efficacy and satisfaction with weight reduction, realistic weight loss expectation, a low frequency of previous weight loss attempts and low levels of stress and depression are some important psychosocial factors that are strongly correlated with better WLM (Pétré *et al*., 2018; Calugi, Marchesini, El Ghoch, Gavasso, & Dalle Grave, 2017; Montesi *et al*., 2016; Burke *et al*., 2015; Dalle Grave *et al*., 2015; Richardson, Arsenault, Cates, & Muth, 2015; Abildso *et al*., 2014; Wingo, Desmond, Brantley, Appel, Svetkey, Stevens, & Ard, 2013). Perceived barriers to WLM success such as inadequate time for physical activity, lack of social support, being at a party, being on a trip, and the costs related to healthy eating have been documented as important negative correlates of WLM success (Al-mohaimeed, Abuzeid, & Elmannan, 2017; Calugi *et al*., 2017; Karfopoulou, Anastasiou, Avgeraki, Kosmidis, & Yannakoulia, 2016; Metzgar *et al*., 2015; Abildso *et al*., 2014; Musaiger *et al*., 2014).

Although commercial weight loss programmes are increasingly gaining popularity across the globe, little is known about their long-term outcomes. Moreover, there is scarcity of data on the factors (perceived barriers, demographic, behavioural, psychosocial, programme based characteristics, and cardiovascular related biomarkers) associated with WLM success among participants who have been out of weight loss treatment for periods longer than two years.

This study therefore sought to determine the extent of WLM success and the perceived barriers and predictors of WLM success among adults who had been out of a commercial weight loss programme in Accra, Ghana, for a period ranging from six months to nine years. The study also determined the association between WLM success and selected cardiovascular related biomarkers.

### 1.2 Problem Statement

Overweight/Obesity are important public health conditions for both developed and developing countries (Seidell & Halberstadt, 2015; Ng *et al*., 2014). Overweight/Obesity are associated with serious health conditions such as hypertension, type 2 diabetes, CVD and many others (Hruby & Hu, 2016). On a global scale, many overweight and obese individuals are attempting weight loss due to the awareness of the health benefits of losing weight (Santos *et al*., 2017). WLM success however, continues to be a challenging task for most people who lose weight, whether through self- help measures or formal weight loss programmes (Hall & Kahan, 2018). Successful WLM is of great necessity if the health benefits of weight loss are to be sustained. Moreover, there is scarcity of information on the long-term outcomes of commercial weight reduction programmes (services rendered in a non-clinical setting), which are increasingly being patronised by people all over the world. There is, therefore, the need to investigate the long-term outcomes of commercial programmes and the associated predictors, perceived barriers and cardiovascular related biomarkers of WLM success. These will contribute to the development of strategies that promote successful WLM.

### 1.3 Study Rationale

Public patronage of commercial weight loss programmes is globally common. There is however, scarcity of literature on the prevalence of WLM success for commercial programmes, particularly that of the developing world (Gudzone *et al.*, 2015) and for that matter, Ghana. This has created a dearth in knowledge about how participants of commercial weight reduction programmes fare in the long-term, after their weight loss intervention ends. Literature available on the predictors, perceived barriers, and the cardiovascular related health benefits of WLM success are mostly limited to short-term post weight loss studies not exceeding two years, and to the developed world with no information on developing countries such as Ghana. Additionally, the studies on the predictors and barriers of WLM success are mostly carried out among participants in the general population or in clinical trials. Overweight/obese individuals in the general population however, differ in several ways from those who seek weight loss treatment. Treatment seeking overweight/obese individuals tend to be heavier, have more binge eating episodes and psychopathology (anxiety, depression, other mood disorders), and are generally more difficult to treat compared to obese individuals in the general population (Mccuen-Wurst, Ruggieri, & Allison, 2018; Fitzgibbon, Stolley, & Kirschenbaum, 1993). Further, those seeking weight loss treatment in clinical settings tend to have more binge eating episodes and psychopathology compared to those who seek treatment in non-clinical settings like the commercial weight loss programmes (Burton *et al*., 2018; Lowe, Kral, & Miller-Kovach, 2008). Given the global importance of commercial programmes for weight loss, there is the need to determine the long-term outcomes of these programmes in Ghana and the factors associated with WLM success.

### 1.4 Conceptual Framework on Weight Loss Maintenance Success

The conceptual framework below presents the factors prevalent at the various phases (pre, during and post) of the weight loss programme that are known to impact on WLM success as participants move through the phases of the programme. It further shows the known impact of WLM success on selected cardiovascular related biomarkers. The factors prevalent at the various phases (pre, during and post) of the weight loss programme serve as the explanatory variables for the outcome variable (WLM success). With respect to the biomarkers studied, WLM success serves as the explanatory variable and the biomarkers are the outcome variables.

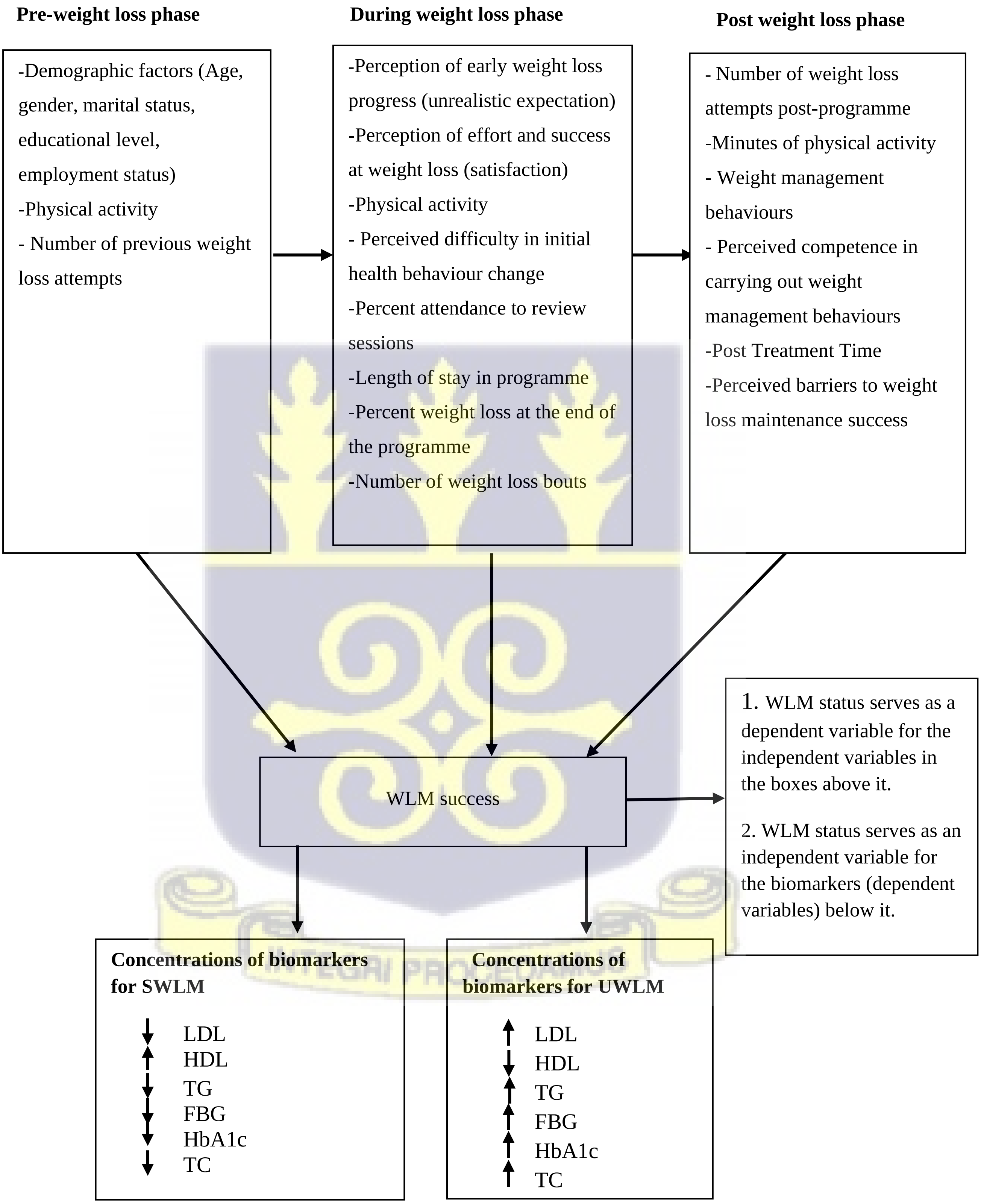


**Figure 1.1: Conceptual framework showing the association between the pre, during and post weight loss factors, selected biomarkers, and WLM success.**

## 1.5 Research Questions

1. What is the prevalence of weight loss maintenance success in the study population?
2. What are the perceived healthy eating related barriers to weight loss maintenance success?
3. What are the perceived physical activity related barriers to weight loss maintenance success?
4. What are the pre, during and post weight loss characteristics (baseline demographic, behavioural, programme based and psychosocial factors) associated with WLM success?
5. What is the association between weight loss maintenance success and the fasting blood concentrations of lipids [Total Cholesterol (TC), Low Density Lipoprotein (LDL), High Density Lipoprotein (HDL), Triglycerides (TG)], Glycosylated Haemoglobin (HbA1c) and Fasting Blood Glucose (FBG)?

## 1.6 Aims and Objectives

### 1.6.1 Aims

The aims of this study were to:

1. Determine the extent of WLM success, investigate the perceived barriers and predictors of weight loss maintenance success among adults who formerly participated in a commercial weight loss programme in Accra, Ghana.
2. Determine the association between WLM success and selected biomarkers.

### 1.6.2 Specific objectives

1. To determine the prevalence of WLM success among previous participants of a commercial weight loss programme.
2. To determine the perceived healthy eating related barriers to WLM success.
3. To determine the perceived physical activity related barriers to WLM success.

4. To determine the pre, during and post weight loss characteristics (baseline demographic, behavioural, programme based and psychosocial factors) associated with WLM success.
5. To determine the association between WLM success and fasting blood lipids, glucose and glycosylated haemoglobin concentrations.

## 1.7 Study Outcome Measures

### 1.7.1 Primary outcome measure

The primary outcome measure for the study was the prevalence of WLM success.

### 1.7.2 Secondary outcome measures

Secondary outcome measures were categorised into those for the pre, during and post weight loss phases as follows:

**Pre-weight loss phase:** Pre-programme physical activity and number of previous weight loss attempts.

**During the weight loss phase:** Perception of initial weight loss progress, perception of effort and success at weight loss, perceived difficulty in initial health behaviour change, physical activity during the weight loss programme, completer of programme, percent attendance to review sessions, length of stay in programme, percent weight loss at the end of the programme, and number of weight loss bouts.

**Post weight loss phase:** Number of weight loss attempts post programme, physical activity minutes per week, weight management behaviours (frequency of self-weighing, weight control method, frequency of breakfast consumption, logging of physical activity, exercising at the gymnasium at the time of the study, keeping a food log, maintaining consistent eating patterns across weekdays and weekends, using a shake to replace a meal sometimes, eating restaurant meals less than once per week, eating out of home meals less than once per week, eating five or more servings of fruits and vegetables per day, limiting the amount of oils/fats consumed, limiting food portion size at meals, limiting or avoiding snacking throughout the day, limiting or avoiding snacking in the evenings, limiting or avoiding juices, limiting or avoiding fizzy and sweetened drinks, limiting or avoiding alcohol), perceived competence in carrying out weight management behaviours, PTT, perceived barriers to WLM success and blood parameter (TC, LDL, HDL, TG, HbA1c and FBG) concentrations.

### 1.7.3 Other outcome measures

Other outcomes of interest that were measured were: baseline BMI, BMI at the end of the weight loss programme, BMI at study time, percent of weight loss retained.

## 1.8 Significance of the Study

The prevalence of WLM success in this study will reveal the long-term outcome of this commercial weight loss programme (NWLP). Additionally, an in-depth knowledge about the predictors and perceived barriers to WLM is necessary if WLM is to be achieved to promote health, enhance quality of life, and decrease health care and social costs. Awareness of these factors will help reveal the baseline demographic requirements for successful WLM and the behavioural, programme based, and psychosocial strategies that should be developed during the different phases (pre, during, post) of the weight loss programme. It will further facilitate the development of appropriate messages for counselling overweight/obese patients at the different stages of the weight loss journey. This study will guide the adoption of alternative therapies for those whose baseline characteristics make them less likely to be successful at WLM. In addition, the findings of this study will serve as a guide for future studies on WLM within commercial weight loss programmes in Ghana.

# CHAPTER TWO

# 2.0 LITERATURE REVIEW

**Preamble**

This chapter reviews the literature on the challenge and the importance of WLM success as well as the associated factors of WLM success. It begins by reviewing available information on the global burden and trends of overweight/obesity, the health risks associated with these conditions, the health benefits of weight loss, the potential modifiers of the health benefits derived from weight loss, and the commonly used weight loss methods with emphasis on the growing use of commercial programmes for weight loss. It further reviews available information on the prevalence of WLM success across several countries, revealing the difficulty associated with WLM and the varying definition of WLM success as presented by different studies. The review ends by presenting information on the associations of physical activity, demographic, behavioural, psychosocial, and programme based factors, perceived healthy eating and physical activity related barriers as well as PTT with WLM success.

## 2.1 Overview of Global Overweight/Obesity Prevalence and Trends

Overweight and obesity are conditions that result from the excessive deposition of body fat, resulting in negative health consequences, and are characterised in adults by a BMI greater than or equal to 25.0 kg/m$^2$ and less than 30.0 kg/m$^2$ for overweight and a BMI greater than or equal to 30.0 kg/m$^2$ for obesity (World Health Organisation, 2018a). Globally, nearly two billion adults, 18 years and above, were overweight or obese in the year 2016 (World Health Organisation, 2018a), and this represented more than 30.0% of the world's population (Ng *et al*., 2014). While the rate of increase in overall obesity prevalence in developed countries seems to have relatively slowed down, that of developing countries continues to rise (Seidell & Halberstadt, 2015; Ng *et al*., 2014). Globalisation, improved income, unhealthy diets and a sedentary lifestyle may be responsible for the rising prevalence of obesity in the developing world (Ford, Patel, & Narayan, 2017; Popkin, Adair, & Ng, 2012) where about a third of the world's obese population live (Ng *et al*., 2014). Men have higher overweight prevalence in developed countries while the same is true for women in developing countries. Women, however, have a higher prevalence of obesity than men in both the developed and developing world (Kengne *et al*., 2017; Ng *et al*., 2014; Yatsuya *et al*., 2014). Cultural norms may partly account for the observed gender differences in global overweight/obesity prevalence in the developed and developing world (Yatsuya *et al*., 2014).

Yatsuya *et al*. (2014) performed an age-standardised analysis of the WHO's most recent Global Health Observatory Data Repository to evaluate the global prevalence of overweight and obesity according to the WHO's designated regions. The Americas ranked first with a global overweight/obesity prevalence of 61.9% and in most of the countries within this region, greater than 50.0% of the population was overweight or obese. Saint Kitts Nevis (SKN) (76.2%), Belize (71%) and the United States of America (USA) (69.4%) were the countries with the highest overweight/obesity prevalence in this region (Yatsuya *et al*., 2014). Intercountry disparities in adult obesity prevalence was existent. While countries like Belize and SKN witnessed a decrease in adult obesity prevalence from 2008 to 2016, USA increased in prevalence in the same period (CIA World Factbook, 2018). The obesity prevalence for USA was 39.8% for adults and 18.5% for the youth in 2016 (Hales, Carroll, Fryar, & Ogden, 2017) while the adult obesity prevalence in SKN and Belize was 22.9% and 24.1%, respectively, in 2016 (CIA World Factbook, 2018). Central and Latin America (part of the Americas) experienced a high rate of increase (1kg/m$^2$ rise per decade) in obesity prevalence in children/adolescents between the years 1975 to 2016 (Abarca-Gómez *et al*., 2017). There was generally a plateau in the prevalence of obesity in children and adolescents for all English-speaking rich countries including those in the Americas in the past decade. The mean child/adolescent BMI was, however, still high in most countries within this region, particularly Chile and the Bahamas, which recorded mean BMI between 22 to 24 kg/m$^2$ in 2016 (Abarca-Gómez *et al*., 2017).

Europe ranked second with a global overweight/obesity prevalence of 54.8% and the countries with the topmost prevalence of overweight/obesity in this region were Turkey (63.8%), Czech Republic (61.7%) and Malta (61.6%) (Yatsuya *et al*., 2014). In Eastern Europe there was virtually no change in obesity prevalence for girls and very little rise for boys (0.09 kg/m$^2$ per decade) over a period of four decades (1975-2016). Over the past decade there seemed to be a plateau in the proportion of obese children and adolescents in the entire Europe region while that of adults continued to increase (Abarca-Gómez *et al*., 2017). Despite the general regional rise in adult obesity prevalence over the last decade, certain countries within the region experienced either a decrease in prevalence (Czech Republic moved from a prevalence of 32.7% in 2008 to 26.0% in 2016) or a marginal increase in prevalence (Malta moved from a prevalence of 28.8% in 2008 to 28.9% in 2016) (CIA World Factbook, 2018). Others like Italy, Spain and England have plateaued in adult overweight/obesity prevalence in the last decade while Switzerland, France and Hungary saw a significant increase (OECD, 2017).

The Eastern Mediterranean region ranked third with a global overweight/obesity prevalence of 46.0%. There was a moderate co-efficient of variation in overweight/obesity prevalence for the different countries in this region. Kuwait had approximately 80.0% of its population being overweight or obese while Qatar followed with overweight and obesity rates being around 72.0%. Poor countries in this region, such as Afghanistan (11.8%) and Somalia (21.5%), had lower levels of overweight or obesity (Yatsuya *et al*., 2014). Over a period spanning 2008 to 2016, there seems to have been a doubling in the adult obesity prevalence in the poor countries (Somalia and Afghanistan) and marginal increases or decline in that of the rich countries (Kuwait, Qatar, Emirates, Saudi Arabia) (CIA World Factbook, 2018). Kuwait and Qatar had one of the highest global mean BMI (ranging from 22-24 kg/m$^2$) for children/adolescents in 2016. The prevalence of child/adolescent obesity was around 20.0% for Kuwait, Qatar and Saudi-Arabia (Abarca-Gómez *et al*., 2017).

The African region ranked fourth with a global overweight/obesity prevalence of 26.9% with marked heterogeneity in country-specific figures within this region. South Africa had almost 70.0% of its population being overweight or obese, followed by Seychelles (approximately 60.0% of its population) and then Swaziland (half of its population). Ethiopia, Eritrea and Burkina Faso recorded very low prevalence values ranging from 8.0%-13.0% (Yatsuya *et al*., 2014). Adult obesity prevalence was 28.3%, 16.5%, and 14.0%, respectively, for South Africa, Swaziland and Seychelles in 2016 and these were slightly lower than what they were in 2008. Ethiopia, Eritrea and Burkina Faso, however, tripled, quadrupled, and doubled their adult obesity prevalence, respectively, between 2008 and 2016, although these were still at lower magnitudes compared to those of South Africa, Swaziland, Seychelles (CIA World Factbook, 2018). Ethiopia, Niger, Senegal, Chad, Congo, Madagascar, Burkina Faso had one of the lowest global child/adolescent mean BMI or obesity rates in 2016 (Abarca-Gómez *et al*., 2017). Despite the fact that some countries still have low obesity rates for the youth, the general level of overweight children below the age of five years for the entire region was reported to have increased by about 50.0% since the year 2000 (World Health Organisation, 2018a). BMI increased in all the regions of Africa over a 34-year period (1980 to 2014) with the highest increase occurring in North and Southern Africa, and Central Africa recorded the least increase. The mean BMI for

North Africa and Southern Africa over the period were each higher than the mean global BMI over the same period (Kengne *et al.*, 2017).

The Western Pacific region was next to the African region, having a global overweight/obesity prevalence of 25.4%. There were wide variations in country-specific data in this region as well. Nauru (92.8%), Cook (90.6%) and Tonga Islands (88.1%) had very high levels of adiposity while Vietnam, Cambodia and Lao People's Democratic Republic had very low prevalence ranging from 10.0%-15.0% (Yatsuya *et al.*, 2014). Obesity prevalence in children/adolescents in this region was among the highest and increased at a rate of 0.95 $kg/m^2$ and 0.77 $kg/m^2$ per decade in girls and boys, respectively, between the years 1975 to 2016. While adult obesity prevalence seemed to have stalled in the past decade for countries within this region with very high adult obesity prevalence, child/adolescent prevalence continued to rise within these same countries over the period (Abarca-Gómez *et al.*, 2017). A country like Vietnam, however, continued to record significant growth in the adult overweight/obesity levels. The adult overweight/obesity prevalence in Vietnam was reported to be 17.4% in the year 2016 (Barquera, Pedroza-Tobias, & Medina, 2016). Child/adolescent obesity prevalence was, however, low for countries like Vietnam and Cambodia and ranged between 1.0%-2.0% and as high as 30.0% in Nauru and Cook Islands (Abarca-Gómez *et al.*, 2017).

South East Asia, with overweight/obesity levels around 13%, had the lowest global presence of overweight/obesity. There were, however, wide inter-country variations in the observed levels of overweight/obesity in this region. Maldives (40.7%) and Thailand (31.7%) had high levels of overweight or obesity while countries like Bangladesh (7.7%), Nepal (9.3%), and India (11.2%) had low prevalence (Yatsuya *et al.*, 2014). A much more recent analysis of adult overweight/obesity prevalence puts that of Bangladesh, India, Indonesia, Pakistan, and the Philippines at 16.1%, 19.7%, 21.2%, 21.1% and 21.5%, respectively (Barquera *et al*., 2016). The observed trend for these poor countries confirms earlier assertions by Ng *et al*. (2014) about the continuous rise in the levels of adiposity in developing countries. The prevalence of obesity in children/adolescents in 2016 for India and Bangladesh was among the lowest worldwide (Abarca-Gómez *et al.*, 2017), despite the relative rise in adult overweight/obesity over the years.

Over a period of four decades (1975-2016) global obesity prevalence generally increased in female and male children/adolescents by about 5.0% and 7.0%, respectively (Abarca-Gómez *et al*., 2017). Although overall obesity prevalence (both adult and youth) increased globally and, in most regions during the period, high income countries were at higher levels in 1975 and exhibited the lowest rate of increase over the period (30.0%-50.0% per decade) (Abarca-Gómez *et al*., 2017). The Southern Africa region had lower obesity prevalence in 1975 and the largest rate of increase (400.0% per decade) over the period (Abarca-Gómez *et al*., 2017). About half of the global adult population is estimated to be overweight or obese by the year 2030 if the observed global trend persists (Dobbs *et al*., 2014).

**2.2 The Health Risks Associated with Overweight/Obesity**

Overweight/obesity is reported to heighten the risk of premature death across the world. In analysing studies conducted in North America, Europe, East Asia, New Zealand and Australia, the hazard risk for all-cause mortality was 1.07 and 1.20 for WHO based overweight classifications of BMI; 25.0 kg/m$^2$ to less than 27.5 kg/m$^2$ and 27.5 kg/m$^2$ to less than 30.0 kg/m$^2$, respectively (Global BMI Mortality Collaboration, 2016). The hazard risk for all-cause mortality was 1.45 for BMI of 30.0 kg/m$^2$ to less than 35.0 kg/m$^2$, 1.94 for BMI of 35.0 kg/m$^2$ to less than 40.0 kg/m$^2$ and 2.76 for BMI of 40.0 kg/m$^2$ to less than 60.0

kg/m$^2$. Normal weight (BMI 20.0 kg/m$^2$ to < 25.0 kg/m$^2$) had the lowest hazard risk of 1.0 (Global BMI Mortality Collaboration, 2016).

The increasing prevalence of overweight or obesity is linked with increased risks for chronic conditions including insulin resistance, which leads to diabetes mellitus (type 2), certain cancers, CVDs, dyslipidaemia, hypertension, osteoarthritis, and poor mental health (Hruby & Hu, 2016), and this seems to be a global phenomenon. The global prevalence of cancers, diabetes, and CVDs for instance, increased by 44.0%, 30.6% and 24.8%, respectively, from 2005 to 2015 (Vos *et al.*, 2016). In Europe and North America, high BMI was found to increase the risk for high blood pressure, dyslipidaemia, type 2 diabetes and stroke (National Health Service Digital, 2016; Roka, Michimi, & Macy, 2015; Prospective Studies Collaboration, 2009). In the Asia Pacific Region, excess body weight significantly heightened the negative consequence of triglycerides on heart disease and significantly increased blood pressure across the population (Hirakawa *et al.*, 2016; Dua, Bhuker, Sharma, Dhall, & Kapoor, 2014). In Africa, a strong positive association between overweight/obesity and conditions like diabetes, hypertension, hypercholesterolemia and CVDs, has been reported across countries (Price *et al.*, 2018; Kengne *et al.*, 2017; Barquera *et al.*, 2016; Baker IDI Heart and Diabetes Institute, Ministry of Health and Quality Life, Gayan, Tuomilehto, Soderberg, & Alberti, 2015; Danquah *et al.*, 2012).

One of the preliminary formative investigations that established the relationship between increasing weight and diabetes was the Nurses' Health Study (Colditz *et al.*, 1990). In this research, women with BMI ranging from 23 kg/m$^2$ to 23.9 kg/m$^2$ had 3.6 times higher risk for type 2 diabetes compared to their counterparts with BMI lower than 22; while participants with BMI between 25 to 26.9 kg/m$^2$ had more than five times increased risk (Colditz *et al.*, 1990). Since then, several other studies have confirmed a positive relationship between excessive body weight and non-insulin dependent diabetes (Zhao, Laukknen, Li, & Li, G. 2017; Nordström, Pedersen, Gustafson, Michaëlsson, & Nordström, A. 2016; Gómez-Ambrosi *et al.*, 2011). The likelihood of developing type 2 dependent diabetes does not only increase with general increase in BMI but also with increases in the grade of obesity. This was confirmed in a study where adults with BMI > 40.0 had a higher risk for type 2 diabetes compared with those with BMI between 30.0-39.9 kg/m$^2$ (Vinciguerra, Baratta, Farina, Tita, Padova, Vigneri, & Frittitta, 2013). In another study, the Relative Risks (RR) for type 2 diabetes were 1.5, 2.5, 3.6 and 5.1 for individuals with BMI in the overweight, grade I, grade II and morbid obesity class range, respectively, compared to those with normal BMI (Ganz, Wintfeld, Li, Alas, Langer, & Hammer, 2014). Location of fat tissue accumulation in overweight/obesity also influences the risk for insulin resistance, which leads to the development of type 2 diabetes (Hsieh, Wang, & Chen, 2014; McLaughlin, Lamendola, Liu, & Abbasi, 2011). A standard deviation increase in fats around organ tissue increases the risk for insulin resistance by as much as 80.0% whereas a similar rise in subcutaneous fat tissue decreases the risk for insulin resistance by 48.0% (McLaughlin *et al.*, 2011). Excessive body weight increases the levels of circulating fatty acids and substances capable of causing inflammation (adipokines), which are believed to reduce the sensitivity of insulin receptors, leading to insulin resistance that promotes the on-set of type 2 diabetes (Freitas *et al.*, 2015).

Insulin resistance occurring in overweight/obese individuals has negative implications for lipid metabolism. When a fatty meal is eaten, the absorbed lipids in the form of triglycerides, free fatty acids and cholesterol are packaged along with phospholipids and proteins (apo protein B48) to form chylomicrons (Feingold & Grunfeld, 2018a; Klop, Wouter Jukema, Rabelink, & Castro Cabezas, 2013). These are transported in the blood along with Very Low Density Lipoproteins (VLDL), which are synthesised by the liver whenever dietary free fatty acids and triglycerides reach the liver after digestion and absorption of a fatty meal (Feingold & Grunfeld, 2018a; Klop *et al*., 2013). Chylomicrons and VLDL circulate in the blood and release their free fatty acids to the heart, skeletal muscles and adipose tissues as well as other tissues that need them for storage or energy utilisation via a lipolytic action by lipoprotein lipase (Feingold & Grunfeld, 2018a). The activity of lipoprotein lipase is increased in the presence of insulin and impaired when insulin resistance is prevalent (Feingold & Grunfeld, 2018a; Klop *et al*., 2013). Thus individuals with excess body weight are predisposed to having high blood triglyceride levels due to the impairment in lipolysis of circulating triglycerides as a result of insulin resistance.

Remnants of VLDL are channelled back to the liver through the LDL receptor, which goes through a recycling phase. This enhances the binding capacity of liver cells for larger LDL particles and leads to normal or slightly elevated concentrations of larger LDL particles (Feingold & Grunfeld, 2018a). However, the LDL receptor is reported to have a poor affinity for small dense LDL particles and thus concentrations of these tend to be higher compared to larger LDL particles (Feingold & Grunfeld, 2018a). HDL is synthesised by the liver and takes up cholesterol from peripheral tissues as well as from chylomicrons and VLDL back to the liver. In the process cholesterol esters formed within are exchanged for triglycerides within the circulation and these triglycerides are hydrolysed in the liver leading to the formation of smaller HDL particles (Feingold & Grunfeld, 2018a).

Overweight/obesity thus contributes to distortions in lipid metabolism resulting in dyslipidaemia, which is characterised by high concentrations of total cholesterol and triglycerides, sub-optimal concentrations of HDL, normal or slightly elevated LDL and elevated small dense atherogenic LDL particles (Standl, 2005).

Some studies have confirmed the association between excess body weight and dyslipidaemia. In a study by Qi, Ding, Tang, Li, Mao, and Wang, (2015), the odds of developing dyslipidaemia was 2.73 and 1.52 times higher in obese males and females, respectively, compared to their normal weight counterparts. Hussain, Ali, Kaleem, and Yasmeen, (2019) also demonstrated that obesity was negatively correlated with HDL concentration. Ge *et al*. (2015) reported the odds ratio for having low HDL concentration to be 1.27 and 1.56 for BMI 24-27.9kg/m$^2$ and $\geq$ 28kg/m$^2$, respectively.

Excessive body weight is implicated in the aetiology of metabolic syndrome, which is marked by the co-existence of three or more metabolic abnormalities (low HDL concentration, increased fasting blood sugar, triglycerides, blood pressure and a high waist circumference) leading to a heightened risk for type 2 diabetes and CVD (Han & Lean, 2016). In a study by Vinciguerra *et al*. (2013), the occurrence of metabolic syndrome was observed to progress significantly with increasing level of obesity. The proportions of adults with metabolic syndrome were approximately 47.0%, 57.0% and 74.0% for grade 1 to grade 2 obesity (BMI between 30-39.9kg/m$^2$ ), morbid obesity (BMI between 40-49.9kg/m$^2$ ), and super obesity (BMI $\geq$ 50kg/m$^2$), respectively (Vinciguerra *et al*., 2013). In another study, the prevalence of metabolic syndrome was higher in both individuals classified as normal weight (24.6%) or overweight (40.7%) by BMI standards, and who also had central obesity compared to those without central obesity (Lee, Hairi, & Moy, 2017).

Epidemiological research strongly demonstrate an increased risk for hypertension in the overweight/obese population compared to their normal weight counterparts. Roka *et al*. (2015) demonstrated that the odds of developing hypertension in overweight and obese individuals were 1.35 and 2.41 times higher, respectively, in comparison with individuals with normal weight. Similarly, both males and females with excessive body weight had a three times higher odds of developing either pre-hypertension or stage 1 hypertension and nine times higher odds of developing stage 2 hypertension when compared with those of normal weight (Dua *et al.*, 2014). The link between obesity and hypertension is explained by the increase that occurs in renal sodium reabsorption and the resultant impairment in the natriuresis process via the renin angiotensin system and the renal sympathetic nervous system ( Jiang, Lu, Zong, Ruan, & Liu, 2016).

A positive correlation exists between overweight/obesity and CVD (Thomsen & Nordestgaard, 2014). This observation could be possibly due to the existing link between conditions such as hypertension, elevated blood sugar, dyslipidaemia and adiposity (Feingold & Grunfeld, 2018a; Jiang *et al*., 2016; Thomsen & Nordestgaard, 2014). Fats around body organs are positively correlated with higher cardio-metabolic risk via the release of excess free fatty acids, which tend to increase the degree of accumulation of triglycerides in lean tissues (Neeland, Poirier, & Després, 2018; Ebbert & Jensen, 2013). In a study by Elffers *et al*. (2017), one standard deviation higher of visceral fat was associated with a 5.77 times and 1.42 times increase in the chances of developing at least one CVD risk factor for females and males, respectively. In another study, the prevalence of CVD was 0.3% in adults BMI between 30-39.9kg/m$^2$, 1.9% in those with BMI between 40-49.9kg/m$^2$ and 5.8 % in obese adults with BMI ≥ 50kg/m$^2$ (P<0.0001) (Vinciguerra *et al*., 2013). In a population study by Thomsen and Nordestgaard (2014), the risk for myocardial infarction was 1.26 and 1.88 times higher for overweight and obese individuals, respectively, in comparison with normal weight individuals. Similarly the risk for ischaemic heart disease was 1.08 and 1.45 times higher for overweight and obese individuals, respectively, in comparison with those with normal weight (Thomsen & Nordestgaard, 2014). The age adjusted rates of hospitalization for all CVD conditions together increased with increasing BMI from 20kg/m$^2$ (Joshy, Korda, Attia, Liu, Bauman, & Banks, 2014). The risks for haemorrhagic and ischaemic strokes were increased by 6.0% and 4.0% respectively for every unit rise in BMI (Csige, Ujvárosy, Szabó, István, Paragh, Harangi, & Somodi, 2018). A review of several epidemiological studies showed that obesity increased the odds of developing coronary artery disease by 20.0% (Riaz, Khan, Siddiqi, Usman, Shah, Goyal, & Khan, 2018). In analysing major studies across the globe, overweight and obese individuals, respectively, had 1.27 and 1.22 higher risk of developing acute myocardial infarction in comparison with those with normal weight (Zhu, Su, Li, Chen, Tang, & Yang, 2014).

Excessive body weight has been linked with a number of cancers. Overweight and obese individuals, respectively, were reported to have two times and three times greater risk of having endometrial cancer in comparison with those with normal weight (Setiawan *et al.*, 2013). Shaw, Farris, McNeil, and Friedenreich, (2016) showed that obese women were about three times more likely to develop endometrial cancer compared to their normal weight counterparts. In another study, obese adults with BMI 35kg/m$^2$ and above had more than a four times greater likelihood of having endometrial cancer in comparison with their counterparts with 25kg/m$^2$ (Dougan, Hankinson, Vivo, Shelley, Glynn, & Michels, 2015). In the same study by Dougan *et al.* (2017), increased weight of magnitude 2kg or more since age 18 resulted in a 2.54 times higher risk for endometrial cancer compared to those who were stable in weight since age 18. Breast cancer risk was higher in overweight post-menopausal women (RR=1.10, 95.0% C.I: 1.06-1.13) and obese post-menopausal women (RR=1.18, 95.0% C.I: 1.12-1.25) (Munsell, Sprague, Berry, Chisholm, & Trentham-Dietz, 2014). Apart from the increased risk for invasive breast cancer, BMI $\geq$ 35kg/m$^2$ was also associated with advanced tumour size (HR = 2.12, 95.0% C.I: 1.67-2.69) (Neuhouser *et al.*, 2015). Compared to normal weight individuals, the risk of liver cancer was found to be 1.2, 1.86, 2.41 and 2.17 times higher for overweight, grade 1, grade 2 and morbid obesity categories, respectively (Campbell *et al*., 2016). The risk for renal cell carcinoma was 1.16, 1.48, 2.03, 2.77 times higher for overweight/obese individuals with BMI of 25kg/m$^2$, 30kg/m$^2$, 35kg/m$^2$ and 40kg/m$^2$, respectively, in comparison with individuals with BMI of 18.5kg/m$^2$. For every unit increase in BMI, the likelihood of developing renal cell carcinoma increased by 4.0% and 5.0% for men and women, respectively (Wang & Xu, 2014). Glomerular hyper-filtration is common in overweight/obese individuals due to increased renal plasma flow and renal tubular overload, which in turn increases the risk of kidney damage (Tsuboi, Okabayashi, Shimizu, & Yokoo, 2017; Helal, Fick-Brosnahan, Reed-Gitomer, & Schrier, 2012). Damaged kidneys are more prone to renal cell cancer (American Cancer Society, 2018). Further, increased adiposity raises the levels of free oestrogen and free insulin growth factor 1, which increases cell multiplicity and reduces the rate of cell apoptosis in various organs such as the kidney, breast, prostate, and colorectum (Tracz, Szczylik, Porta, & Czarnecka, 2016; Gallagher & LeRoith, 2010). Bhaskaran, Douglas, Forbes, Dos-Santos-Silva, Leon, and Smeeth, (2014) observed that an increase in BMI accounted for 41.0% of uterine cancers and at least 10.0% of cancers of the liver, kidney, gall bladder and colon.

Elevated levels of adipokines in overweight /obese individuals due to hypoxia in adipose tissues causes some dysfunction in the upper airway neuromuscular control leading to sleep apnoea (Engin, 2017; Mafort, Rufino, Costa, & Lopes, 2016; Śmietanowska, Balcerzak, Cudnoch-Jędrzejewska, Wysocki, & Niemczyk, 2015). Other explanations for sleep apnoea occurrence in the obese include: enlargement of the soft tissues within and surrounding the airways of obese individuals causing a narrowing of the air way (Kato *et al*., 2018) as well as enlargement of abdominal fat tissues causing a decrease in lung capacity (Mafort *et al*., 2016), thus reducing the tension that builds up in the walls of the pharynx to keep the airway adequately opened. Further, leptin resistance in obesity likewise impairs the stable breathing process (Berger & Polotsky, 2018). In a research by Chen, Pensuksan, Lohsoonthorn, Lertmaharit, Gelaye, and Williams, (2014), adjusted odds ratio for sleep apnoea ranged from 1.62-1.69 for different models in overweight individuals and 19.5-26.5 for different models in obese individuals. Generally, obese individuals have a higher prevalence of obstructive sleep apnoea compared to normal weight individuals (Nousseir, 2019; Wosu *et al.*, 2014).

### 2.3 Obesity and its Co-morbidities in Ghana

Recent estimates put the national adult overweight (25.4%) and obesity (17.1%) prevalence at approximately 43.0% (Ofori-Asenso *et al.*, 2016). Past (1993-2014) demographic health surveys in Ghana reveal persistent yearly growth (13.0%-40.0%) in the prevalence of overweight and obesity among women in their reproductive age (GSS *et al*., 2015; GSS *et al*., 2009; GSS *et al.*, 2004; GSS & MI, 1994). Overweight and obesity were more prevalent in women (27.8% versus 21.9%, respectively) compared to men (21.8% versus 6.0%, respectively) and higher in urban (27.2% versus 20.6%, respectively) compared to rural areas of Ghana (16.7% and 8.0%, respectively) (Ofori-Asenso *et al*., 2016). The 2014 Ghana Demographic Health Survey report ranked Greater Accra as highest (57.3%) with regards to the regional prevalence of overweight/obesity among women aged 15-49 years, followed by Ashanti (45.4%), Western (43.1%), Central (40.7%), Eastern (38.5%), Brong Ahafo (34.6%), Volta (31.1%), Upper West (20.6%), Upper East (19.1%) and Northern (12.4%) (GSS *et al.*, 2015). The overweight/obesity regional hot spots were Greater Accra, Ashanti, Western, Central, Eastern, Brong Ahafo and Volta. These regions have more than 30% of the population of women being overweight/obese (GSS *et al.*, 2015).

Several predictors of overweight/obesity in Ghana have been identified. High maternal education and household socio-economic status, being female and being less physically active were predictive of obesity in Ghanaian school children (Aryeetey, Lartey, Marquis, Nti, Colecraft, & Brown, 2017). Age and number of children born to women were positively correlated with overweight/obesity in women (Agbeko, Kumi-Kyereme, Druye, & Osei Berchie, 2013). Sociocultural factors (wealth, educational status, employment status, urban residence) and behavioural factors (alcohol consumption, contraceptive use, watching of television) were positively correlated with excess body weight in women (Agbeko *et al*., 2013).

Overweight/obesity prevalence studies reflecting work done in the most recent years (2007-2016) reported higher obesity prevalence compared to those published earlier (1998-2006) and pointed to the increasing burden of the condition in Ghana (Ofori-Asenso *et al*., 2016). The growth in the occurrence of overweight/obesity is in tandem with the rising prevalence of obesity related health conditions as follows:

As far back as the year 2007, public hospital records of individuals with hypertension numbered over 505, 000, reflecting a 929.0% increase over what it was in 1988 (Ghana Health Service, 2008a). Hypertension was the second leading cause of outpatient morbidity in Greater Accra Region and the fifth for most other regions (Ghana Health Service, 2008b). The prevalence of the condition was 25.0% in urban areas and 20.0% in rural areas, and the national adult prevalence was estimated at 3.5 million (Bosu, 2010). Dosoo *et al*. (2019) reported a high prevalence (28.1%) of hypertension in the middle belt of Ghana, with majority (66.0%) of study participants being rural residents. Sanuade *et al*. (2018) estimated the national prevalence of hypertension in Ghanaian adults (15-49 years of age) to be 13.0%. Hypertension ranked 15 in the top 50 causes of death in Ghana in the year 2018 (World Life Expectancy, 2018).

The prevalence of diabetes was as low as 0.4% in Accra as far back as 1958 (Dodu, 1958). Later, in 2002, the age standardized prevalence in Accra was 6.1% (Amoah, Owusua, & Adjei, 2002). In Cape Coast the prevalence rose from 19.3% in 2005 to 22.3% in 2009 (Darkwa, 2011). The number of diabetes cases at the national level increased from 450,000 in 2014 (Ofori-Asenso & Garcia, 2016) to 518,400 in 2017 with the adult national prevalence estimated at 3.6% (International Diabetes Federation, 2017). Diabetes was ranked as the 8th cause of death in Ghana in 2018 (World Life Expectancy, 2018) and accounted for 2.0% of total deaths in the country in 2012 (World Health Organisation, 2014a).

In the year 2002, dyslipidaemia was diagnosed in a significant proportion of patients visiting a major hospital in Kumasi: almost half (45.0%) of the patients had high serum total cholesterol, 26.0% had elevated serum triglycerides, a third had low serum HDL and 72.0% had sub-optimal levels of serum LDL (Eghan & Acheampong, 2003). The prevalence of hyperlipidaemia in Accra and Kumasi ranged between 17.0% - 23.0% in the year 2007-2008 (Hill, Darko, Seffah, Adanu, Anarfi, & Duda, 2007; Owiredu *et al*., 2008). More than a third of males in peri-urban areas in Greater Accra Region had dyslipidaemia in 2015 (Vuvor, Asiedu, Saalia, & Owusu, 2016).

CVDs were the number one cause of mortality in health facilities and were responsible for about 15.0% of deaths in 2008 (Ghana Health Service, 2010). In Accra, CVDs moved from the ninth position in 1966 to the first in 1991 and 2001 in terms of ranking in the top nine causes of death (Agyei-Mensah & de-Graft Aikins, 2010). The WHO calculated the risk of death for persons in Ghana within the ages of 30-70 years from cancer, diabetes, CVD, and chronic respiratory disease together, to be 20.0% (World Health Organisation, 2014a). In the year 2018, stroke and CHD were the first and second cause of mortality, respectively, in Ghana (World Life Expectancy, 2018).

Overweight/obesity, poor diet and physical inactivity are some behavioural factors that increase the risk for several cancers including cancers of the breast, kidney, colon, oesophagus and endometrium. The prevalence of these behavioural risk factors is high in Ghana and continues to rise (Ministry of Health, 2011)**.** The top four most common cancers in Ghana in 2012 were cancers of the cervix, breast, prostate and liver (Ferlay *et al.*, 2013). Cancer of the cervix is the number one cause of cancer deaths and ranks 13th among the top 50 causes of death in Ghana. Cancers of the prostate, liver, breast, colon-rectum, ovary, stomach and lungs follow after cervical cancer with respect to cancer ranking in the leading causes of death in Ghana (World Life Expectancy, 2018). The incidence, mortality rate, and five year prevalence for cervical cancer were estimated around 3,052, 1,556 and 7,749, respectively, in 2012 (Ferlay *et al.*, 2013). In the period spanning 2010 and 2013, the incidence rates for cervical cancer in Greater Accra Region and Ashanti Region were 14.5 and 9.1, respectively, per 100,0000 person-years (Nartey, Hill, Amo-Antwi, Nyarko, Yarney, & Cox, 2017). The incidence versus mortality rates for breast cancer, prostate cancer and liver cancer were 2,260 versus 1,021, 912 versus 680 and 421 versus 395, respectively, in the year 2012. The five year prevalence for breast, prostate and liver cancers were estimated at 7,207, 2,367 and 1,329, respectively (Ferlay *et al.*, 2013). The prevalence of screen detected prostate cancer in Accra was around 7.0%, and was considered to be relatively higher compared to prevalence rates in white men. These results were suggestive of racial disparity in prostate cancer prevalence (Hsing *et al*., 2014)

Reduction of the prevalence of modifiable risk factors for Non-Communicable Diseases (NCD) such as overweight/obesity is a major component of Ghana’s strategy for the management, prevention and control of chronic NCDs (Ministry of Health, 2012). The Ghana zero hunger strategic review conducted in 2017 revealed that Overweight/Obesity was still a major challenge and recommended the need for a government led collaborative effort involving the citizens, donor and other organisations that promote national development to tackle the problem (World Food Program & The John A. Kufuor Foundation, 2017). In order for Ghana to be free from all forms of malnutrition including overweight/obesity by the year 2030, the Ghana zero hunger strategic review stressed the need for every child, woman and person with disability to have a right to food and good nutrition.

### 2.4 The Health Benefits of Weight Loss

The health rewards derived from intentional weight reduction have been widely documented. Earlier in 2002, Diabetes Prevention Program Research Group (2002) reported a 58.0% decrease in the incidence of diabetes in at risk participants who achieved a modest weight reduction. Hamman *et al*. (2006) found that every unit decrease in weight was accompanied by a 16.0% decrease in diabetes risk in at risk participants. Since then, Magkos *et al*. (2016) showed that weight loss resulted in improvement in glucose and insulin metabolism of insulin resistant patients. Additionally, weight loss was found to predict a reduction in type 2 diabetes incidence, according to Kim *et al*. (2018).

Short-term intentional weight reduction is reported to ameliorate the levels of several cardiovascular risk factors. In a study by Wing *et al*. (2011), diabetics with 5.0%-10.0% weight reduction had a four times higher odds of achieving a 0.5% point decline in glycosylated haemoglobin (HbA1c) concentration, 1.5 times higher odds of having a 5 mm Hg decline in blood pressure measurements, 1.7 times higher odds of having a 5 mg/dL increase in plasma HDL concentration (with HDL improvement being more marked in participants who were less overweight at baseline), and 2.2 times more likely to have a 40 mg/dL decrease in plasma triglyceride concentration compared to their weight stable counterparts. A higher weight reduction (10.0%-15.0%) further improved most of the biomarkers assessed in this study (Wing *et al*., 2011). Additionally, improvement in LDL concentration was weakly associated with the magnitude of weight reduction in the cohort after controlling for medication use, whereas that for all the other cardiovascular risk factors showed significantly strong associations (Wing *et al*., 2011). In another study, weight reduction was correlated with improved levels of glycosylated haemoglobin and fasting plasma glucose, total cholesterol, triglycerides concentrations and blood pressure measurements in type 2 diabetics. Weight reduction was also correlated with improvement in LDL concentration in this population (Horton, Silberman, Davis, & Berria, 2010). Participants of a 15 week weight reduction programme who initially had elevated (sub-optimal) plasma total cholesterol, LDL, HDL, triglycerides, and fasting sugar levels had significant improvements in these variables after weight loss (Brown *et al.*, 2016). The magnitude of improvement was proportional to the degree of percent weight loss such that participants with weight loss greater than 10.0% of baseline weight had the greatest reduction in total cholesterol, triglycerides, LDL and fasting blood glucose (Brown *et al.*, 2016). Additionally, the number of cardio-metabolic risk factors that improved in this cohort were higher in those who had more than 5.0% weight reduction; and those who achieved lower than 5.0% weight reduction had improvement in only plasma triglycerides concentrations (Brown *et al*., 2016).

Decreases in fasting blood sugar and lipids have also been observed in a general sample with a mix of normal and sub-optimal baseline levels of these CVD risk factors with higher weight losses yielding greater improvements in these parameters except for HDL where there was an unfavourable reduction in concentration (Brown *et al.*, 2016). In another study, participants without diabetes, coronary heart disease, or any major chronic disease experienced significant improvements in several CVD risk factors after undergoing a 12-14 week weight loss programme (Weiss *et al*., 2016). In healthy subjects, favourable changes in glucose, insulin, and HDL concentrations occurred after twelve months of weight reduction intervention (Tapsell *et al*., 2014).

In an observational study, women with at least 5.0% weight reduction had a lower risk of developing endometrial cancer compared to their weight stable counterparts (Luo *et al*., 2017). Further analysis revealed that among women who lost weight, intentionality of weight reduction was correlated with the highest reduction in risk for endometrial cancer (HR, 0.44; 95% C.I, 0.25 to 0.78) (Luo *et al*., 2017). Chlebowski and colleagues observed that a modest weight reduction (≥ 5.0%) was associated with a 12.0% lower potential for developing breast cancer; while a higher weight loss (≥ 15.0%) lowered the potential for its development by as much as 37.0% (Medical Xpress, 2017). Other weight reduction benefits include improvement in the recovery from non-alcoholic fatty liver diseases (Trovato, Catalano, Martines, Pace, & Trovato, 2015), and improvement in sleep apnoea symptoms (Havard Health Publishing, 2015).

Most of the studies investigating the health advantages of weight reduction are limited to short-term studies, creating a dearth in knowledge about those of long-term weight reduction. The Look AHEAD study is one of the few studies that investigated the effect of a healthy lifestyle on selected biomarkers (The Look AHEAD Research Group, 2010) over a longer period (four years). Improvements in glycosylated haemoglobin, systolic blood pressure and other CVD risk factors were found to be more pronounced in the first year than at later years possibly due to issues of weight regain and the strength of the impact of weight loss in the early stages of its achievement than at a later time (The Look AHEAD Research Group, 2010). In another study those who maintained their weight loss sustained improvements in cardio-metabolic risk factors with the greatest improvement occurring just after the weight loss intervention (Beavers *et al.*, 2013).

## 2.5 Potential Modifiers of Cardiovascular Related Health Benefits Derived from Weight Loss

### 2.5.1 Weight regain

Weight regain impacts negatively on health by reversing the cardio metabolic improvements derived from weight reduction. In a study by Berger, Huggins, Mccaffery, Jacques, and Lichtenstein, (2019), participants who maintained their weight loss three years after a lifestyle intervention, had better improvements in cardiometabolic risk factors compared to those who regained weight. Kroeger *et al.* (2014) also reported that modest weight regain (2-6%) resulted in the reversal of triglycerides, LDL and total cholesterol concentrations to baseline amounts while HDL increased with sustained decreases in visceral fat. In another study weight regainers had worsened plasma total cholesterol, LDL, and insulin as well systolic blood pressure readings within a year post weight loss compared to their baseline levels (Beavers *et al.*, 2013).

### 2.5.2 Macronutrient composition of diet consumed

The macronutrient composition of the diet has the potential of modifying blood lipids. Diets with low fat content were found to be more effective at lowering LDL cholesterol levels compared to those with low carbohydrate content (Feingold & Grunfeld, 2018b). Diets high in saturated fats increased total cholesterol, small, medium and total LDL cholesterol particles compared to diets low in saturated fats in patients with dyslipidaemia (Chiu, Williams, & Krauss, 2017). Diets with low carbohydrate content were more effective at increasing HDL and decreasing triglycerides levels compared to those with low fat content (Feingold & Grunfeld, 2018b). The Diogenes research revealed that a higher total protein intake improved blood total cholesterol and LDL cholesterol concentrations; while a higher plant protein in the form of non-cereal based protein improved systolic blood pressure readings during a 26 weeks weight maintenance phase (van Baak *et al.*, 2017). In a study by Rietman, Schwarz, Tomé, Kok, and Mensink, (2014) healthy individuals with prolonged intake of high protein diets had increased plasma glucose and insulin levels. In another study, a high protein, low fat diet led to elevation in plasma glucose concentrations and improved triglyceride concentration following a 12 week weight maintenance post weight loss (Claessens, Van Baak, Monsheimer, & Saris, 2009). High protein diets were shown to be more effective in improving plasma lipids compared to high carbohydrate diets (Kitabchi *et al*., 2013).

**2.5.3 Caloric restriction**

As early as the 1990s, investigations into the effect of caloric restriction on cardiovascular health had been ongoing. Caloric restriction was reported to independently reduce the level of insulin resistance in obese type 2 diabetics (Blackburn, 1995). Participants on a calorie restricted diet of 500 calories per day had significant favourable changes in glucose, glycosylated haemoglobin, total cholesterol, LDL, triglycerides and other cardio metabolic risk factors after a five week period (Claessens *et al*., 2009). Caloric restriction over a five month period resulted in the greatest improvement in cardio metabolic risk factors compared to readings for these parameters at twelve months post weight reduction (Beavers *et al*., 2013). In recent times, the outcomes of cardio metabolic risk factors post calorie reduction have been investigated. Caloric restriction was found to facilitate glucose disposal in participants through increased peripheral insulin sensitivity (Johnson *et al*., 2016). In animal studies, cardio protection in calorie restricted mice was evidenced by a reduced size of induced infarct compared to mice subjected to ad libitum food intake (Noyan *et al*., 2015).

### 2.5.4 Degree of weight reduction achieved during the weight loss phase

Wing *et al*. (2011) found that the chances of having favourable changes in cardiovascular risk factors were positively correlated with the degree of weight reduction achieved. Weight reduction targets of 3.0%-8.0% or 8.0%-20.0% below baseline weight were associated with favourable changes in systolic blood pressure (SBP), HDL, TG, even in the fourth year of lifestyle intervention (Wing *et al.*, 2016). Similarly higher categories of weight reduction was correlated with more favourable changes in triglycerides, LDL and HDL concentrations in participants who had at least two risk factors for metabolic syndrome (Vetter *et al.*, 2013). Brown *et al*. (2016) also showed that 10.0% or more weight loss resulted in better improvement in LDL concentration compared to having less that 5.0% weight loss.

### 2.5.5 The role of physical activity in improving lipid profile

Physical activity has been shown to improve lipid status in individuals who are physically active. Physical activity, along with weight reduction, in the intervention group of the Look Ahead Study showed sustained improvements in HDL concentrations right from the weight reduction phase until the end of the weight maintenance phase and better improvements in blood pressure, total cholesterol, and triglycerides compared to the control group (The Look AHEAD Research Group, 2010). In a prospective study, individuals with increased moderate to vigorous physical activity had clinically significant reductions in systolic blood pressure (Lamb *et al*., 2016). Additionally, those with increased cardiorespiratory fitness had improvements in their clustered cardio-metabolic risks at follow-up (Lamb *et al.*, 2016). In another study, exercisers had improved CVD risk factors (increased HDL and lower triglycerides) compared to sedentary counterpart (Bachi *et al.*, 2015). Physical activity independent of diet and other lifestyle changes has been documented to improve HDL levels as well as decrease the levels of small particle size LDL, which are protective against CVD (Wang & Xu, 2017).

**2.6 Commonly Used Weight Loss Methods**

Globally, the prevailing methods for weight loss are through self-help measures, and structured programmes (i.e. non-clinical and clinical based weight loss methods) (Medshape Weight Loss Clinic, 2018; Santos *et al*., 2017). Non-clinical based weight loss programmes are structured programmes that are offered outside the health care environment; while the clinical based weight loss programmes are structured programmes offered within the health care environment (Medshape Weight Loss Clinic, 2018). Commercial programmes commonly offer commercially operated weight loss services outside the healthcare environment. It appears that commercial weight loss programmes are synonymous to non-clinical based weight loss programmes. That notwithstanding, some commercial weight loss programmes are medically supervised outside the healthcare environment (Medshape Weight Loss Clinic, 2018; Obesity Action Coalition, 2018; Wee, 2015). A systematic review on weight loss attempts, with a global perspective, revealed common methods used for weight loss to be self-help measures and structured programmes (Santos *et al*., 2017). Wing and Phelan (2005) reported that 44.6% of participants of the American weight loss registry lost weight through self-help measures while 55.4% used the professional services from structured weight loss programmes (such as commercial weight loss programmes, physicians or nutritionists). Similarly in North East England, a substantial proportion (40%) of obese participants surveyed used professional weight loss services including commercial weight loss programmes (Evans, Sainsbury, Kwasnicka, Bolster, Araujo-Soares, & Sniehotta, 2018). A survey by Ayisi-Addo, Ayisi-Addo, S., and Ohemeng, (2016) revealed the top three commonly used methods for weight reduction among weight loss participants in Accra, Ghana, to be internet (self-help), commercial shakes from commercial weight loss programmes (non-clinical based structured programmes) and exercises (self-help).

### 2.7 Prevalence and Definition of Successful Weight Loss Maintenance

WLM success is generally defined as achieving and sustaining some amount of intentional drop in weight over a specified length of time (Evans *et al.,* 2019; Krashnewski *et al.,* 2010; Befort *et al*., 2008; Elfhag & Rossner, 2005). In an earlier study by Stunkard and McLaren-Hume (1959), only 2.0% of outpatients who had earlier lost 20 pounds were able to maintain this loss two years post weight loss. Many years later, Anderson *et al*. (2001) showed that most people who lost weight retained only a minority of their losses. At three and five years post weight loss intervention, participants had only 32.0% and 21.0% of initial losses retained, respectively (Anderson *et al*., 2001). More recent research works have, however, demonstrated that WLM, although challenging, is not completely elusive. The American weight loss registry showed that about 20.0% of individuals who achieved 10.0% or more weight reduction were able to keep the lost weight for at least twelve months (Wing & Phelan, 2005); and at five and ten years post weight loss more than 87.0% of participants had kept at least 10% weight loss (Thomas, Bond, Phelan, Hill, & Wing, 2014). In the NHANES population studies conducted in 1999-2006, 36.6% of the cohort were reported to have been successful at maintaining 5.0% weight loss (Kraschnewski *et al*., 2010), while NHANES's study cohort (1999-2002) observed that 58.9% of the participants kept their current weight within ±5.0% of the previous year's weight (Weiss *et al*., 2007). A population study conducted in German adults reported a WLM prevalence of 17.7% and 29.7% in overweight and obese adults, respectively (De Zwaan *et al*., 2008). The CARDIA population study, had 34.0% of respondents, being successful at WLM (Phelan *et al*., 2010). In structured behavioural lifestyle programmes, WLM prevalence of 24.0%-77.0% have been reported (Befort *et al*., 2008; Lowe *et al*., 2008; Gosselin & Cote, 2001). The observed wide variations in the proportions of people succeeding at WLM may be partly explained by the use of different definitions for WLM success in these studies. Some of these studies used a definition of losing at least 10.0% weight loss and keeping this loss for at least a year (Kraschnewski *et al*., 2010; De Zwaan *et al*., 2008; Wing & Phelan, 2005) others defined successful WLM to mean achieving at least a 5.0% weight loss below baseline weight at survey time (Evans *et al*., 2019; Befort *et al*., 2008; Lowe *et al*., 2008; Gosselin & Cote, 2001) or maintaining at least 75.0% to 95.0% of initial weight loss at survey time (Phelan *et al*., 2010; Anderson *et al*., 2001) or achieving less than ± 5.0% weight change at survey time with regards to weight at the end of the weight loss programme (Weiss *et al*., 2007). Additionally, methodological differences such as: the inclusion of participants with unintentional weight loss; the use of self-reported weights and life-time maximum weights in some of the studies; use of pre-packed meals and very low calorie diets in some of the structured lifestyle programmes; use of only participants who were very successful at the initial weight loss; differences in length of stay in weight reduction programmes; and length of time spent out of weight reduction treatment may have also contributed to the wide variation in success rates (Evans *et al*., 2019; Kruschitz, Wallner-Liebmann, Lothaller, Luger, & Ludvik, 2017; Kraschnewski *et al*., 2010; Befort *et al*., 2008; Lowe *et al*., 2008; Weiss *et al*., 2007; Anderson *et al*., 2001; Gosselin & Cote, 2001).

**2.8 Association of Demographic Factors with Weight Loss Maintenance**

Demographic factors have been established as important correlates of obesity, however, their associations with WLM have been inconsistent. Some studies have revealed that age, gender and marital status have no relationship with WLM success (Varkevisser *et al*., 2019; Abildso *et al*., 2014; Whybrow, Mcconnon, Gibbs, Raats, & Stubbs, 2011; Phelan *et al*., 2010). Other studies have however, proven otherwise. Rancourt *et al*. (2018) for instance, demonstrated that older adolescents took greater responsibility in maintaining their weight loss compared to their younger counterparts. Taking greater responsibility was linked to higher levels of internal motivation which is known to promote weight loss maintenance success (Rancourt *et al*., 2018). Svetkey *et al*. (2014) also demonstrated among the elderly, that being older was associated with greater success at WLM. A review on the association of gender with WLM after a behavioural treatment reported mixed results (Stroebele-benschop, Damms-machado, Milan, Hilzendegen, & Bischoff, 2013). In this review, four studies did not find any association between gender and WLM. Two studies had men being better at WLM than women; while in two other studies, women were better compared to men. These were based on non-surgical weight loss (Stroebele-Benschop *et al*., 2013). Kraschnewski *et al*., (2010) showed that women, older adults (75-84 years old), individuals with educational status below high school level and those unmarried had higher odds of being successful at WLM. Differences in sampling methods (i.e. population studies versus self-selected cohort-based samples), the use of varying sample size, treatment type and time, and the inclusion of participants with unintentional weight loss in some of the studies may have partly contributed to the differences in findings. Knowing whether demographic factors predict WLM or not will help guide the selection of individuals with baseline demographic profiles that would more likely promote greater success in WLM, and pre-empt the use of alternative therapies for those whose demographic profile make them less likely to succeed at WLM.

## 2.9 Association of Physical Activity and Behavioural Strategies with Weight Loss Maintenance Success

Physical activity combined with a dietary regimen that promotes caloric deficit are universally endorsed behaviours, employed as the standard treatment for obesity, with the resultant effect being weight reduction and its sustenance (Santos *et al*., 2017; Garvey *et al.*, 2016; Jensen *et al*., 2014). The World Health Organisation describes physical activity to be any form of movement of the body that is accomplished by skeletal muscles and utilises energy in the process (World Health Organisation, 2018b). Physical activity could be a planned activity, or be accomplished by carrying out leisure, house chore, or occupational activities or derived from transporting self from one place to the other (World Health Organisation, 2018b). Physical activity leads to increased energy utilisation, which helps to favourably contribute to weight reduction or weight sustenance (Magosso, Magosso, N.S.S. & Robert-Pires, 2017; Swift *et al*., 2014). On a daily basis, 30 minutes of moderate intensity or 15 minutes of vigorous intensity physical activity impacts positively on health-related parameters. However, to be able to sustain lost weight for a long time, adequate levels of physical activity (>150 minutes/week) is recommended (Cox, 2017; Swift *et al*., 2014). Some studies confirmed that individuals who were successful at WLM were sufficiently physically active (≥ 60 minutes/day) with regards to the length of time devoted to physical activity (Kruseman *et al*., 2017; Abildso *et al*., 2014; Befort *et al*., 2008; Kruger, Blanck, & Gillespie, 2008). Members of the American National Weight Control Registry (NWCR) that were successful at keeping their weight loss reported engaging in long hours (approximately one hour per day) of moderate physical activity (Wing & Phelan, 2005). The NWCR is a registry that provides one of the most extensive preliminary data on WLM. Similarly, increased physical activity among obese patients at risk for diabetes resulted in successful WLM (Gilis-Januszewska *et al*., 2018). In another study, neither moderate nor vigorous activity predicted WLM and the explanation given by authors was the inadequacy of time spent on these activities by participants (Svetkey *et al*., 2012). Participants were observed to have spent less than 225 minutes/week in physical activity as was the case of members of the NWCR (Svetkey *et al*., 2012; Wing & Phelan, 2005). Physical activity of vigorous intensity can produce greater energy expenditure and weight loss compared with that of moderate intensity if matched for session time (Swift *et al*., 2014). In another study vigorous intensity activity resulted in a higher maximum heart rate compared to moderate intensity activity when time matched for twenty minutes (Santos *et al*., 2019). These could have positive implications for WLM success. In a study by McGuire, Wing, Klem, and Hill, (1999), the number of times that moderate activity was performed did not differ between those successful at keeping lost weight and regainers; but that for strenuous (vigorous intensity) activity as well as the number of sweat episodes occurring during physical activity were significantly higher in successful weight loss maintainers compared to regainers.

One study showed that being physically active either before embarking on weight loss programme or after a weight loss programme predicted successful maintenance of lost weight (Abildso *et al.*, 2014). Most of the studies reporting a relationship between maintenance of lost weight and physical activity have done so with reference to physical activity engaged in at the post weight loss phase (Svetkey *et al.*, 2012; Befort *et al.*, 2008; Wing & Phelan, 2005; McGuire *et al.*, 1999).

Behavioural strategies facilitate the positive changes desired in physical activity and dietary intake for weight loss and its sustenance to be achieved (Stroebele-benschop *et al.*, 2013). These strategies have their foundations in behaviour change theories such as the Social Cognitive Theory (Tougas, Hayden, McGrath, Huguet, & Rozario, 2015) and the Transtheoretical Model (Romain, Caudroit, Hokayem, & Bernard, 2018), which in addition to providing the framework for understanding human behaviour, also provide the guidelines for promoting behavioural change. Behavioural strategies include self-monitoring, stimuli control, problem solving and goal setting.

Logging of physical activity is a self-monitoring behavioural strategy that has been found to predict WLM success. This was confirmed in a study by Befort *et al*. (2008) where keeping a log of exercise activities was significantly associated with successful WLM. Self-weighing and logging of dietary intake are other self-monitoring activities that favour WLM. Regular self-weighing (once weekly or once daily or more often) resulted in successful WLM compared to irregular self-weighing (Varkevisser *et al*., 2019). Self-weighing less than once a week decreased the odds of being successful at WLM compared to weighing weekly but not daily (Abildso *et al*., 2014). Nearly 75% of participants of NWCR weighed themselves at least once per week (Wing & Phelan, 2005). Consistency with tracking of dietary intake has been shown to improve success at WLM (Varkevisser *et al*., 2019; Ingels, Misra, Stewart, Lucke-wold, & Shawley-brzoska, 2017). In a research by Peterson *et al*. (2014), participants who self-monitored their dietary intake consistently had reduced odds of regaining weight a year after the weight reduction treatment. Dietary self-monitoring behaviours such as limiting snacking (Abildso *et al*., 2014) and food portion size reduction (Varkevisser *et al*., 2019; Abildso *et al*., 2014) predicted WLM success. Self-monitoring leads to self-evaluation and the desire to make adjustments to meet set goals (Peterson, Middleton, Nackers, Medina, Milsom, & Perri, 2014).

In a report by Varkevisser *et al*. (2019) decreased exposure to fast foods (stimuli control) was a determinant of successful WLM. Kruger *et al*. (2008) showed that adults who controlled their exposure to fast foods and abstained from eating at these outlets were more successful at WLM compared to those who consumed foods from these outlets at least twice per week. Consumption of five or more servings of fruits and/or vegetables per day (goal setting) has been shown to be associated with successful WLM (Nour, Lutze, Grech, & Allman-farinelli, 2018; Befort *et al*., 2008; Kruger *et al*., 2008). Nour *et al*. (2018), reported that consumption of more than four servings of vegetables/day reduced the risk of weight gain. Kruger *et al*. (2008) showed that participants who consumed five servings or more of fruits and vegetables in a day were successful at WLM. Befort *et al*. (2008) observed that consuming five servings or more of fruits and vegetables in a day was associated with WLM success. Problem solving is another behavioural strategy that helps with WLM. For instance, opting for low fat foods instead of their high fat versions (Varkevisser *et al*., 2019;

Kruseman *et al*., 2017; Montesi *et al*., 2016; Befort *et al*., 2008), consumption of low calorie foods instead of high calorie versions (Varkevisser *et al*., 2019; Montesi *et al*., 2016; Befort *et al*., 2008) and the daily consumption of breakfast instead of irregular breakfast consumption (Brikou, Zannidi, Karfopoulou, Anastasiou, & Yannakoulia, 2016; Montesi *et al*., 2016) were associated with WLM success.

### 2.10 Psychosocial Factors and Weight Loss Maintenance

Psychosocial factors are variables that relate to one's psychological state and social environment and have the potential of impacting one's health and behavioural outcomes either positively or negatively (Lee, Lamichhane, Jung, Moon, Kim, & Kim, 2016; Long & Cumming, 2013). Psychosocial factors have been implicated in WLM (Valek, Greenwald, & Lewis, 2015; Teixeira, Jutta, Williams, Gorin, & Lemieux, 2012). One example of a psychosocial factor is the number of previous weight loss attempts, which has a rather complex relationship with WLM. Repeated previous attempts at losing weight reflects a history of repeated weight loss failure and has been reported to be associated with feelings of dietary helplessness, binge eating, body image distortion, body image dis-satisfaction and low self-concept (Carraça, Santos, Mata, & Teixeira, 2018; Santos *et al.*, 2017). These impact negatively on WLM outcomes (Varkevisser *et al*., 2019; Kwasnicka, Dombrowski, & White, 2016; Valek *et al*., 2015; Pacanowski, Senso, Oriogun, Crain, & Sherwood, 2014). Carraça *et al*. (2018) demonstrated that fewer weight loss attempts was predictive of successful WLM. Myers, Mcvay, and Champagne, (2013) likewise demonstrated that having fewer assisted weight loss attempts such as fewer attempts with dietician assistance or commercial weight loss programmes, not using herbal or dietary supplements in weight loss attempts and having greater maximum weight loss in weight loss attempts predicted greater weight loss. Fabricatore, Wadden, Moore, Butryn, Heymsfield, and Nguyen, (2009), however, showed that neither the type of weight loss methods (i.e. the use of short-term diets (≤ 3 days) or diets for longer periods) used in previous weight loss attempts nor the amount of weight loss achieved in previous weight loss attempts predicted weight loss success at one year. Additionally, the number of weight loss attempts did not have any bearing on WLM, according to a study by Kiem, Wing, Mcguire, Seagle, and Hill, (1997) that described the characteristics of members of the NWCR who were successful at WLM. In this research, 91.0% of participants who had been successful at losing and maintaining their weight had had previous weight loss attempts with regains until recruited for the study. Success in WLM at the time of the survey was attributed to a greater social or health reason or both and goes to demonstrate that a high level of determination to succeed at the time of embarking on weight loss outweighs the negative effect of numerous previous attempts at losing weight on WLM success (Kiem *et al*., 1997). A holistic synthesis of the above studies (the inconsistencies in findings notwithstanding) seems to suggest that the types of weight reduction methods used in previous weight reduction attempts (i.e. whether assistance was sought or not, the use of herbal or dietary supplements), the amount of weight reduction achieved in previous weight reduction attempts, and the strength in one's commitment to weight reduction at any point in time, and not only the mere number of attempts made, may be important determinants of WLM success.

Self-efficacy is the exhibition of confidence in one's capability to carry out tasks. Confidence in carrying out tasks linked to targeted behaviour change promotes successful adoption of behaviour and the realisation of the desired outcome (FAO, 2015). A high level of exercise self-efficacy was reported as a determinant of WLM success (Varkevisser *et al*., 2019). In a study by Kruger *et al*. (2008), adults who reported being confident at behavioural strategies such as calorie counting, portion control at meal times and others were more likely to be successful at WLM compared to those who reported a lack of confidence. In the research carried out by Abildso *et al*. (2014), respondents who perceived continuation of a physical activity routine and sticking with diet changes as easy were more likely to succeed at WLM compared to those who had perceptions of these being difficult.

Social support is an important psychosocial factor affecting weight reduction and its sustenance (Greaves, Poltawski, Garside, & Briscoe, 2017; Karfopoulou *et al.*, 2016). Social support provides some stress relief by making available people who are seen as confidants of the individual needing the support and provides some functional support from these individuals. Supporting functionally includes giving compliments and partaking in recommended healthy behaviours. These are deemed very helpful in promoting WLM success (Karfopoulou *et al.*, 2016).

Behaviour change theories posit that individuals initiate a behaviour based on long-term outcome expectations and are motivated to sustain the behaviour based on satisfaction with current behaviour outcomes (Kwasnicka *et al.*, 2016). The effect of weight loss satisfaction on long-term weight reduction, however, has been mixed. Jeffery *et al.* (2006) found no significant association between weight loss satisfaction and long-term weight loss; while Calugi *et al.* (2017) and Montesi *et al.* (2016) reported that a high level of satisfaction with weight loss results improved the degree of sustenance of the lost weight. A conceptual model proposes that the best way of promoting maintenance of health behaviours initiated is to improve satisfaction with current outcomes of the behaviour (Rothman, Balwin, Hertel, & Fuglestad, 2011). Satisfaction with current outcomes of behaviour change is expected to improve through a change in cognition for evaluating current behaviour change outcomes. It is believed that a comparison of current outcomes with the undesirable outcomes occurring in the past, before the new behaviour was initiated, can enhance satisfaction (Rothman *et al.*, 2011). Jeffery *et al.* (2006), however, argued that this model may not, in reality, be able to bring about the needed change in cognition for participants adopting the new behaviour, thus defeating the goal of satisfaction enhancement.

Unrealistic weight loss expectation has been reported to be linked to high numbers of people quitting their weight loss programmes before their due programme end dates (Pétré *et al.*, 2018). This was confirmed by Abildso *et al*. (2014) who found that participants who perceived their early weight loss progress as excellent were often unsuccessful at keeping their lost weight. This might be due to the underestimation of the needed vigilance and self-restraint required for maintenance of the initial high weight losses, leading to subsequent drop out from treatment programmes (Abildso *et al*., 2014). Unmet goals or the lack of satisfactory progress towards set goals often generates high levels of disappointment leading to thwarting of initial aspiration to reach for the set goal; and therefore the less likelihood of achieving and sustaining weight loss (Hall & Kahan, 2018; Kozica, Lombard, Teede, Ilic, Murphy, & Harrison, 2015). Data from clinical trials, however, do not confirm the above finding. Clinical data have not found any significant correlation between unrealistic weight goals and attrition (Calugi *et al*., 2017; Dalle Grave *et al*., 2015). It appears that unrealistic weight goals have different effects on attrition depending on whether the individuals setting these goals are participants of clinical trials or are within the real world setting such as in weight loss programmes. In the real world setting, where these individuals pay to be part of weight loss programmes or to have additional contact with therapist, the likelihood of abandoning programmes become higher when initial weight loss goals are unlikely to be met (Calugi *et al*., 2017; Dalle Grave *et al*., 2015).

### 2.11 Perceived Barriers to Successful Weight Loss Maintenance

Perceived barriers to behaviour change are deemed as one's evaluation of the potential challenges that come up in the pursuance of a new behaviour and have been documented as being critical for behaviour initiation and its maintenance (Kelly, Martin, Kuhn, Cowan, Brayne, & Lafortune, 2016; Kwasnicka *et al*., 2016; Scott, Oman, & John, 2015).

Individuals who perceive fewer barriers to undertaking a targeted health behaviour will be more likely to adopt the new behaviour and sustain it (Kwasnicka *et al.*, 2016).

Barriers to the adoption of a new behaviour persist during maintenance of the behaviour and, in such situations, a high level of self-regulation is needed to facilitate better coping skills and maintenance of new behaviour (Kwasnicka *et al.*, 2016). Lack of social support has been reported as one of the important perceived barriers to WLM (Greaves *et al.*, 2017; Karfopoulou *et al.*, 2016; Lemstra, Bird, Nwankwo, Rogers, & Moraros, 2016). Social support has a structural and functional component. Structurally, persons to give the needed support ought to be available; and functionally, compliments for desirable behaviour and active participation by these individuals go a long way in promoting better weight maintenance outcomes (Karfopoulou *et al.*, 2016). In the same way that obesity has been found to spread through social networks, new healthy lifestyles are also picked up by the social contacts of those following these new healthy behaviours referred to as the ripple effect (Karfopoulou *et al.*, 2016; Bishop, Irby, Isom, Blackwell, Vitolins, & Skelton, 2013). Locational or situational barriers, such as being at a party or having to eat out of home tend to disrupt an individual's routine activities of healthy eating and have the potential of impacting negatively on weight and health status (Al-mohaimeed *et al.*, 2017; Sharma & Agrawal, 2017). The cost of healthy eating, such as the high price of healthy foods, the undesirable taste of healthy foods, and the long hours involved in preparing healthy foods, have been cited as common barriers to healthy eating in different populations (Garcia *et al.*, 2018; Menezes, Diez Roux, & Souza Lopes, 2018; Pinho *et al.*, 2018; Musaiger *et al.*, 2014). Similarly, food craving or the lack of self-control to eat appropriately is perceived by obese populations to sabotage their healthy eating practices (Greaves *et al.*, 2017; Welsh *et al.*, 2013).

Different populations however prioritise these barriers differently. For instance, while obese persons attending counselling sessions in Iran perceived that not receiving social support was the third priority barrier to healthy eating, young adults in a university in Kuwait rated low the importance of lack of social support as a barrier to healthy eating (Musaiger *et al*., 2014; Sharifi, Mahdavi, & Ebrahimi-Mameghani, 2013).

Personal factors such as showing no interest nor motivation for physical activity has been identified as a major physical activity related barrier to WLM success (Sharma & Agrawal, 2017; Kelly *et al*., 2016). According to Kwasnicka *et al*. (2016), a lack of motivation negatively affects self-regulation of that behaviour and will lead to poor maintenance of the behaviour. Similarly, lack of enjoyment in performing a behaviour can lead to abandonment of that behaviour (Kwasnicka *et al*., 2016). Lack of time and place for exercise, financial costs, having no one to exercise with, feeling too tired to exercise, presence of foot pain or feeling too heavy to exercise are major barriers to physical activity documented in literature (Al-Mohaimeed *et al*., 2017; Sharma & Agrawal, 2017; Kelly *et al*., 2016; Musaiger *et al*., 2014; Sharifi *et al*., 2013). Resource availability (e.g. availability or lack of time), the built environment (e.g lack of a place for exercise), social environment (e.g having no one to exercise with), the cost of physical activity (e.g feeling too tired to exercise) and the personal circumstance of the individual pursuing the behaviour (presence of foot pain or feeling too heavy to exercise) are important components of the behaviour change process and are critical for behaviour initiation and sustenance (FAO, 2015).

### 2.12 Programme Based Factors and Weight Loss Maintenance

Several factors prevalent during the weight loss programme itself (programme based factors) have been reported to influence WLM outcomes. These include factors such as the magnitude of weight loss achieved during this period. Varkevisser *et al*. (2019) reported that higher initial weight losses promoted successful WLM. Pekkarinen, Kaukua, & Mustajoki, (2015) showed that the percent of weight loss achieved during the weight loss programme was significantly correlated with percent of weight loss achieved in later weeks after the weight loss programme ($r = 0.63, P < 0.0001$). Sawamoto *et al.* (2017) also demonstrated that larger weight reduction during the weight loss programme (measured as change in body weight) was significantly associated with successful WLM at twelve months (OR = 0.69, 95.0% C.I 0.54-0.83, P<0.001) and twenty four months (OR = 0.84, 95.0% C.I 0.72-0.94, P<0.01). Befort *et al.* (2008) reported that individuals who achieved 24% weight reduction or more had greater odds of achieving WLM success. Another programmatic factor, namely prolonged stay in weight loss treatment, improved WLM outcomes in several studies (Jiandani *et al.*, 2016; Montesi *et al.*, 2016; Abildso *et al.*, 2014). Jiandani *et al.* (2016) established a positive association between treatment time and weight loss achieved within a three months to twenty months period ($r = 0.38, P < 0.001$). Montesi *et al.* (2016) reported that extended care approach with monthly or more regular contact with weight loss participants reduced the amount of weight regained during the weight maintenance period. Similarly, Abildso *et al.* (2014) showed that a shorter stay in treatment (six to twelve months) decreased the odds of successful WLM compared to a longer stay beyond twelve months (OR = 0.55, 95.0% C.I = 0.32-0.94, P<0.05).

Increased attendance to weight loss sessions made participants more accountable to their actions thus improving weight loss outcomes (Lemstra *et al.*, 2016; Pekkarinen *et al.*, 2015; Fitzpatrick *et al.*, 2014). There is however scarcity of literature on the impact of regular attendance to weight loss sessions on WLM success except for that reported by Pekkarinen *et al.* (2015). Pekkarinen *et al.* (2015) showed that a higher frequency of attendance to weight loss sessions resulted in higher weight loss during the weight loss period and several months after the weight loss programme.

### 2.13 Association between Post Weight Loss Treatment Time and Weight Loss Maintenance Status

Post programme factors such as the PTT is known to significantly predict WLM success. In one study, participants who had stayed out of the weight loss programme for a period of half a year to one year were about three times more likely to be successful at weight loss compared to those who had been out of the weight loss programme for more than two years (Abildso *et al.*, 2014). In another study, participants who had been out of treatment for half a year to one year were about 14% below their starting weight compared to 6 % for those who had been out of treatment for more than two years (Befort *et al.*, 2008). Post treatment time could be decreased by introducing longer weight maintenance programmes (Befort *et al.*, 2008) and developing programme schemes that allow continued membership such as the lifetime membership programme by the Weight Watchers Programme (Lowe *et al.*, 2008).

# CHAPTER THREE

## 3.0 METHODS

**Preamble**

This chapter outlines the methods applied in this study by providing detailed information on the study design and setting, the site selection process, sample size determination, sampling process, inclusion and exclusion criteria, ethical consideration, recruitment, instrumentation, data collection and data analyses. Data collection, was carried out from February, 2017 to February, 2018.

### 3.1 Study Design

This was a retrospective cohort design involving participants who had formerly enrolled in a commercial weight loss programme between 2008 and 2016.

### 3.2 Study Setting

NWLP is a commercial weight loss programme that was established in 2008 and is located in Achimota, a suburb of Accra, Ghana. The programme is run by professional nutritionists. Participants of this programme usually enrol in the weight loss programme either for health or cosmetic reasons. NWLP uses organised and individualised diet plans (ranging from 1000 – 1900 calories) alongside behavioural strategies to achieve weight loss in its members. Physical activity is highly encouraged in the programme.

Participants are expected to track their weight at the NWLP office and have a one-on-one encounter with an NWLP nutritionist once weekly. During these visits, weight loss progress is reviewed, dietary challenges are discussed, and disruptive behaviours that lead to weight regain are addressed by discussing coping strategies and managing negative thoughts that tend to sabotage the weight loss process. All this is done with the participant being the lead person in the problem-solving process. At the time of first enrolment (first bout of weight loss), the participant selects a particular programme duration (ranging from two to six months) based on the nutritionist's recommendation and affordability of the programme cost. Once the initial programme enrolled in expires, participants are able to make subsequent programme or bout renewals until their weight goals are achieved.

At the time of enrolment, participants are routinely oriented on the following topics: what Body Mass Index (BMI) is, its significance and implications for health, healthy BMI range, the factors that impact on BMI. Potential barriers to weight loss and its maintenance are also discussed during review sessions. Diet behaviours endorsed by NWLP include eating breakfast daily, keeping a food log, limiting/avoiding intake of common high fat foods, limiting the use of oils in cooking foods, counting calories for pre-packed foods, limiting the frequency of snacking, limiting/avoiding intake of fizzy drinks, fruit juices and alcohol, having consistent eating patterns across weekdays and weekends, limiting food amounts at meal times, using shake powders to replace meals sometimes, limiting/avoiding restaurant meals, limiting/avoiding eating out of home, having five servings or more of fruits and vegetables in a day, and at least once weekly self-weighing. Physical activity related behaviours endorsed by NWLP include engaging in some form of leisure time activity or planned activities at least three times per week and logging of physical activity. The programme added a WLM phase in the year 2011 and since then participants have had the option of signing on to the maintenance phase after successfully achieving a professionally guided desired weight goal. The WLM phase promotes the principles espoused during the weight loss phase. Structured personalised meal plans that promote WLM are also given.

### 3.3 Study Site Selection

Study site refers to the facility from which previous weight loss participants were selected for the study. Study site was selected after a preliminary rapid survey to investigate the types of commercial weight loss programmes available in the country and the availability of data in these programmes. The presence of baseline and end of weight loss programme weights of participants were important pre-requisites for inclusion of a weight loss facility in the study, as this study reported on the magnitude of weight loss achieved at the end of the weight loss programme and on percent weight loss retained. A list of 13 commercial weight loss programmes was generated through an internet search (Google, Facebook), and interviews with dieticians, nutritionists, weight loss experts, as well as previous participants of various weight loss programmes.

Four of the thirteen identified commercial weight loss programmes were not available for interview and three no longer existed. The remaining six commercial weight loss programmes were examined in the preliminary rapid survey study. Of these programmes, only NWLP had baseline and end of programme anthropometric data, which are important components of the data needed to compute weight loss at end of programme and percent weight loss retained after the weight loss programme. NWLP was therefore selected as the study institution. Previous participants of this weight loss institution were then selected from the participant register of NWLP and followed up in their homes or offices.

## 3.4 Sample Size Determination and Sampling of Study Participants

### 3.4.1. Sample size determination

Sample size calculation for the study was dependent on the primary outcome of the study, which was the prevalence of WLM success. WLM success in this study was defined as the proportion of participants who achieved $\geq 5.0\%$ weight loss at least six months post weight loss intervention. The criterion of $\geq 5.0\%$ weight loss is known in literature to bring about several health benefits (Brown *et al*., 2016; Cefalu *et al*., 2015; Jensen *et al*., 2014; Wing *et al*., 2011). A pilot study performed using 32 participants from the study population gave a proportion (p) of 15.6% of the pilot sample being successful at WLM.

The sample size (n) was determined using the following formula: $n = \frac{Z^2_{\alpha/2} pq}{d^2}$ (Jaykaran & Tamoghna, 2013)

Where:

$Z_{\propto/2}$ is the two tailed critical value at 5.0% significance level = 1.96

$P = 0.156$ based on the prevalence of WLM success in a pilot sample.

$q = (1 - p) = 0.844$, d = margin of error = 0.05

Based on the above formula a minimum sample size of 202 was determined. Assuming a 60.0% non-participation rate (comprising 45.0% non-consent rate and 15.0% further exclusions based on the identification of participants with exclusion criteria during invitation to study and questionnaire administration) the sample size was determined to be 505.

### 3.4.2. Sample size determination for the sub-sample for biomarker analyses

The sample size (n) was determined based on the following formula: $n = Z^2_{\propto/2}\sigma^2 / d^2$ (Jaykaran & Tamoghna, 2013)

Where:

$Z_{\propto/2}$ is the two tailed critical value at 5.0% significance level = 1.96

σ = 1.26, was the standard deviation for total blood cholesterol concentration in a cluster community study (Amoah, 2002).

d = margin of error of the mean for total cholesterol concentration = 5% of 4.7mmol/L = 0.235 (Amoah, 2002).

Based on the above formula a sample size of 111 was determined.

### 3.4.3 Sampling of study participants

A total of 1164 individuals signed up for the NWLP between 2008 and 2016 and these individuals were assessed for study eligibility. Two hundred and sixty-two of these individuals were excluded based on reasons highlighted in figure 3.1, leaving 902 individuals eligible for the study. From the eligible pool for the study, ten were selected for questionnaire pre-testing while thirty-two were randomly selected (using stratification based on the year of enrolment) for the pilot study. The remaining pool of 860 individuals were subjected to proportionate stratified random sampling to select 505 individuals that were invited to participate in the study (Figure 3.1). Stratification was based on the year of initial enrolment into NWLP. The year of initial enrolment into the NWLP had a positive correlation with PTT, which is an independent predictor of WLM success (Befort *et al.*, 2008).

In carrying out proportionate stratified random sampling, the sampling fraction was determined as the number of individuals invited to the study (n = 505) divided by the remaining pool of individuals (n = 860) (Figure 3.1). The sampling fraction was then multiplied by the count of the remaining pool of individuals present in each year of enrolment to determine the number of individuals to be randomly picked from each enrolment year. Computer generated random numbers were used to select participants for each enrolment year. Sixty-two individuals were further excluded at the time of making phone calls due to having both invalid phone numbers and email addresses. Out of the 443 individuals remaining, 250 consented to the study. Twenty individuals were further excluded from the 250 who consented to the study due to the detection of one or more exclusion factors when they were visited (Figure 3.1). This brought the final number of individuals who finally took part in the study to 230 which was above the minimum sample size of 202 (Figure 3.1). Out of the 230 participants of the study, a sub-sample of 112 were selected for the blood study using proportionate stratified random sampling based on the initial year of enrolment into the NWLP. The sampling fraction was determined as follows: sample size (n = 112) for blood parameter investigation divided by total number of participants who completed the administered questionnaires (n = 230) (Figure 3.1). The sampling fraction was multiplied by the number of participants who completed the administered questionnaire for each enrolment year to determine the number of individuals to be randomly picked for each enrolment year. Computer generated random numbers were used to select participants for each enrolment year.

Figure 3.1 below depicts the sampling flow chart for the study participants.

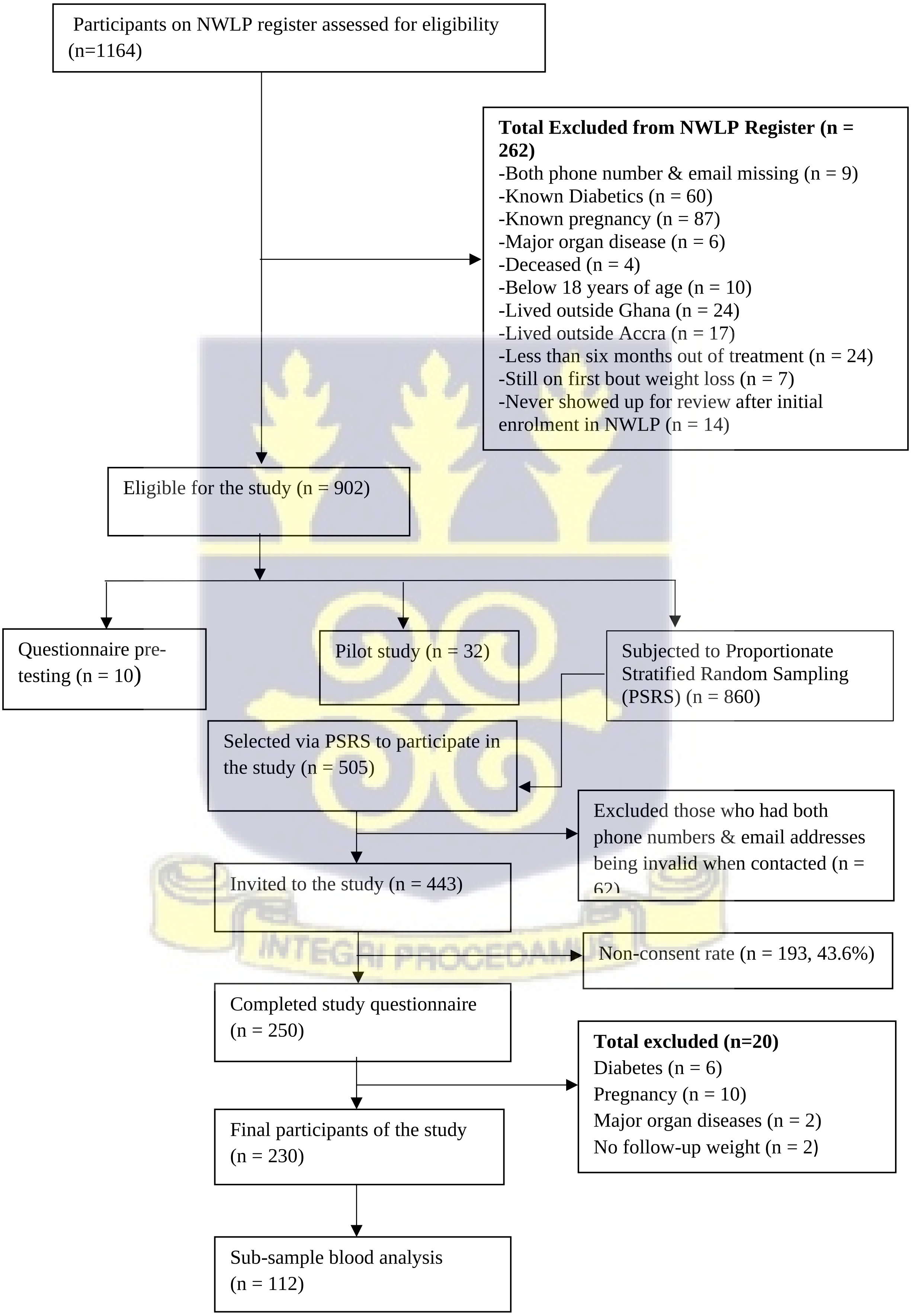


**Figure 3.1: Sampling flow chart**

### 3.5 Inclusion and Exclusion Criteria

Participants were included in the study if age and BMI at the time of enrolment into the NWLP were 18 years or older and 25kg/m$^2$ or higher, respectively. Participants were excluded from the research if they: had both details of phone number and email address in NWLP database missing or invalid; were non-residents of Accra or Ghana at the time of the study; had not completed the first weight loss bout of NWLP; had a time lapse from completion of their first bout of weight loss to survey period that was less than six months; never showed up at the NWLP centre for review after their first bout enrolment into NWLP; were not able to walk for exercise at the time of the study (self-reported); ever became pregnant during or after their first bout of weight loss with NWLP; had thyroid disease; and had any form of cancers, Human Immunodeficiency Virus (HIV), psychiatric illness, anorexia/ bulimia, diabetes, major organ disease(s) and any other disease that could lead to involuntary changes in body weight during/after the first bout of weight loss. Information on inclusion and exclusion criteria were verified through the NWLP database and/or questionnaire responses, and during phone calls to selected participants for initial verbal consent to participate in the study.

### 3.6 Ethical Consideration

The Institutional Review Board of the Noguchi Memorial Institute for Medical Research (NMIMR), University of Ghana, Accra, Ghana, approved the study (Ethical approval/certificate: Appendix B, Re: study ref #:NMIMR-IRB CPN 004/16-17). Participants voluntarily signed a consent document that explained the study procedure and intent (Appendix C: consent form).

### 3.7 Recruitment

Participants were initially contacted via email to announce the study intent as being an NWLP programme evaluation and health behaviour survey. Those who did not have valid e-mail addresses were sent phone text messages. Follow-up phone calls were made a week later to seek verbal consent and set appointment dates. Participants who were not reached during the follow-up phone contact were again followed up daily for up to seven days for the opportunity to set appointment dates for visits. All participants who were not reached after seven days of continuous phone calls, together with those whose phone numbers were found to be incorrect, were contacted via e-mail to seek consent, an appointment date and an alternative phone number. In the initial verbal consent seeking, it was explained to the participants that they were free to refuse enrolment into the study, and that, participation in the study was not a pre-requisite for future access to NWLP services.

Consenting participants were called a day before their appointment date to confirm availability. Participants who were unlikely to be available for their set appointment date were asked to suggest another date for meeting. Consenting participants were visited either at the workplace or home and taken through consent document and their written consent was obtained. The questionnaire was then administered via an interview. As part of the interview, participants were asked to recall medications (including lipid lowering and weight loss medications) they were or had been using after their first bout of NWLP if any, and their responses recorded. This was necessary to allow for the control of used medications that could modify lipid concentrations and/or weight status during the statistical analyses phase. The consent form had a section that informed participants that sub-sampling for blood draw was going to take place after the questionnaire administration and that participants were free to accept or decline the blood draw activity. Out of the 230 who completed the study questionnaire, 112 were randomly sub-sampled and consented to blood draw. They were called on the phone and appointments scheduled with them for a trained and certified phlebotomists together with the study investigator to draw their fasting blood samples at their work place or home between the hours of 6am to 10.30am.

### 3.8 Instrumentation and Data Collection

#### 3.8.1 Questionnaire pre-testing

The complete interviewer administered structured questionnaire containing demographic information as well as pre, during and post - weight loss treatment questions was pre-tested among 10 participants out of the entire NWLP cohort eligible for the study. The major issue that needed to be addressed after the pre-testing was replacing some of the responses of the behavioural questions with 'never/seldom/sometimes/often/always' instead of using 'yes/no'. A typical example is the question: 'Are you currently exercising in the gym? The response options of 'never/seldom/sometimes/often/always' made way for those who, although not regular at the gymnasium, did visit sometimes, to give a more appropriate response of 'sometimes' rather than answering 'no'.

Questions that pertained to perceived barriers to WLM success were developed via a literature search to establish the common perceived barriers to healthy eating and physical activity (Garcia *et al.*, 2018; Pinho *et al.*, 2018; Zorbas, Palermo, Chung, Iguacel, Peeters, Bennett, & Backhole, 2018; Al-Mohaimeed *et al.*, 2017; Calugi *et al.*, 2017; Karfopoulou *et al.*, 2016; Metzgar *et al.*, 2015; Musaiger *et al.*, 2014; Seguin, Connor, Nelson, Lacroix, & Eldridge, 2014; Sharifi *et al.*, 2013; Marcy, Britton, & Harrison, 2011). To identify other healthy eating and physical activity related barriers to WLM success that were not included in those identified from literature, the following two questions were asked: What is the one thing that makes it most challenging for you to eat healthy to maintain your weight? What is the one thing that makes it most challenging for you to be physically active to maintain your weight? After all these barriers were identified and compiled, repetitive barriers, unfamiliar and unclear words were eliminated and, where necessary, replaced with words that made the identified barriers from literature more meaningful. For instance, 'I cannot follow my diet when I am blue' was replaced with 'Is depression a barrier that makes it hard for you to stick to a healthy eating plan thus preventing you from keeping your weight? Together sixteen healthy eating related barriers and seven physical activity related barriers were put together as the final questions on perceived barriers to WLM success as presented in questionnaire used for the current study. One of the healthy eating related barriers (i.e. 'frequent feeling of hunger') was a stand-alone barrier item with no other barrier items to fit its construct of 'adverse effects of WLM diet'. It was therefore not subjected to Categorical Principal Component (CATPCA) analysis unlike the remaining 15 healthy eating related barrier items. Responses to healthy eating and physical activity related barriers were rated on a four-point Likert scale of 1- not applicable, 2-not a barrier, 3-somewhat a barrier, 4-a very important barrier. Not applicable was included as it was detected during the pre-testing to be a viable response.

### 3.8.2 Pilot study

Fifteen of the sixteen healthy eating related barriers and all seven of the physical activity related barriers were pilot tested for inter-item reliability in January, 2017. Thirty-two participants were selected out of the number eligible for the study using a proportionate stratified random sampling technique based on year of initial enrolment into NWLP (Figure 3.1). The Cronbach's alpha yielded a moderate inter-item reliability of 0.66. The reliability of these items confirmed the appropriateness of subjecting these items to further analyses such as CATPCA, which was needed to help identify the summarised components of perceived barriers to WLM success in this study. In the absence of WLM data in Ghana or other African countries, it was necessary to determine the prevalence of WLM success in the pilot sample to help with sample size estimation. The proportion of participants who were successful at WLM in the pilot sample was 15.6%.

### 3.8.3 Standardization of data collection process

To allow for uniformity in the data collection process and obtain quality data, research assistants were trained on the study objectives and methods and the right techniques to apply through demonstration and role playing. The researcher participated in the data collection and closely supervised the data collection process.

### 3.8.4 Data collection and measurements

An interviewer-administered structured questionnaire containing mostly closed ended and a few open-ended items in sections categorized in a chronological order (i.e. pre, during, and post-programme) as they related to the NWLP was used. Each section had a lead heading that prompted the respondent about the specific period being assessed. The questionnaire sections and the relevant items per section are described in detail below:

#### 3.8.4.1 Pre-programme factors

The first section of the survey assessed baseline demographic information, physical activity and number of previous weight reduction attempts.

***Baseline demographic information***

Demographic information relating to baseline age, marital status, educational level, gender and employment status were assessed. These were checked for correctness by comparing them with what was available in the NWLP database as these were collected at the time of initial enrolment into the programme. Any discrepancy in information was resolved through further clarification with the respondent. The responses received provided an opportunity to gather baseline information for respondents who failed to provide these at the time of initial enrolment into NWLP.

***Pre-programme physical activity***

Physical activity was assessed using the World Health Organisation (WHO) reference of achieving a minimum of 150 minutes moderate activity or 75 minutes of vigorous activity per week. The questionnaire provided the WHO definitions for moderate and vigorous activity. Participants were asked to assess the frequency of days in a typical week that they did a minimum of 30 minutes moderate activity or 15 minutes vigorous activity in the six months preceding their enrolment into the NWLP. Because of the retrospective nature of this item, responses were categorized into sedentary (0 days of moderate or vigorous activity) versus any activity (≥ 1day of moderate or vigorous activity) to help minimise recall bias or misclassification if any.

***Weight loss attempts***

The number of weight reduction attempts before initial enrolment into NWLP was assessed. Responses in the continuous variable form were recorded and used for further analysis.

**3.8.4.2 During programme factors**

The second section of the survey sought participants' evaluation of in-programme factors such as perceptions of weight loss progress in the first month of programme, perceived effort and success during the weight loss programme, and perceived difficulty of initial health behaviour change. In-programme physical activity was also assessed.

***Perception of initial weight loss***

Participants' perception of initial weight loss progress was assessed by asking them to rate their weight loss during the first month of the weight loss programme as excellent, good, acceptable, poor, or disappointing. For analytical purposes responses were re-grouped into excellent/good, acceptable, or poor/disappointing.

***Perception of effort and success during the weight loss programme***

Participants were asked to numerically rate their perceived effort during the weight loss programme from 0 (least) to 100 (most) and success during weight loss programme from 0 (worst) to 100 (most). Responses for effort and success were compared by grouping into two categories for analysis (effort > success and effort ≤ success).

***Perceived difficulty of initial health behaviour change***

Participants' perceived difficulty of changing initial health behaviour was assessed by asking participants to rate three items: 1. The difficulty in altering diet routine at the start of the weight reduction programme; 2. The difficulty in starting an exercise routine at the start of the weight reduction programme; 3. The difficulty in losing weight at the start of the programme. These were rated using a six-point Likert scale where 1 meant extremely easy and 6 meant extremely difficult. Responses were re-categorised as easy (responses 1–3) versus difficult (responses 4–6).

***In-programme physical activity***

Physical activity comprising both leisure time activities and planned exercises was assessed using the World Health Organisation (WHO) reference of achieving a minimum of 150 minutes moderate activity or 75 minutes of vigorous activity per week. Participants were asked to refer to the WHO definitions for moderate and vigorous activity given in the questionnaire and assess the number of days in a typical week that they achieved a minimum of 30 minutes moderate activity or 15 minutes vigorous activity while on the NWLP. Due to the retrospective nature of the item, responses were categorised into sedentary (0 days of moderate or vigorous activity) versus any activity (≥ 1 day of moderate or vigorous activity) to help minimise recall bias if any.

#### 3.8.4.3 Post-programme factors

The final section of the questionnaire assessed post-programme factors such as physical activity, weight management behaviours, perceived competence in carrying out weight management behaviours and perceived barriers to WLM success.

***Post programme physical activity***

Physical activity was assessed using the WHO reference of achieving a minimum of 150 minutes moderate activity or 75 minutes of vigorous activity per week. Participants were asked to refer to the WHO definitions for moderate and vigorous activity given in the questionnaire and assess the frequency of days in a typical week of the past month that they did a minimum of 30 minutes moderate activity or 15 minutes vigorous activity. The type of activity, its duration per day and number of days it was performed were to be indicated. These were analysed into their respective activity type (i.e. moderate or vigorous intensity) and their corresponding duration (calculated in minutes) per week. Duration was further classified as 0 minutes, 1-149 minutes and ≥ 150 minutes for moderate activity and 0 minutes, 1-74 minutes and ≥ 75 minutes for vigorous activity. Duration for total activity (moderate to vigorous intensity) per week per participant was calculated by combining the corresponding duration for vigorous and moderate intensity activities if any (Office of Disease Prevention and Health Promotion, 2018). The total activity duration/week was further classified as none, 1-149 minutes, and ≥ 150 minutes.

***Weight Management Behaviours***

Behaviours assessed included: frequency of self-weighing (never, <1 time per week, ≥ 1 time weekly but not daily, and daily), which was further categorised as never, <1 time per week, ≥ 1 time weekly for purpose of analysis; and current method of weight control (trying to lose weight using diet and physical activity, trying to lose weight using diet or physical activity, trying to maintain weight using diet and physical activity, trying to maintain weight using diet or physical activity, neither trying to lose nor maintaining weight), which was further categorised as trying to lose or maintain weight with diet and physical activity, trying to lose or maintain weight with diet or physical activity and neither trying to lose nor maintain weight for analysis, frequency of consuming breakfast (daily, not daily), logging of physical activity (yes, no), and currently exercising at a gymnasium (Never/seldom/ sometimes/often/always).

Diet based behavioural strategies were assessed by asking participants to indicate applicable strategies at the time of the survey. Strategies such as keeping a food log or journal and counting of calories were coded as never/seldom/sometimes/often/always and further categorised as never/seldom, sometimes, and often/always for analytical purposes.

Other diet based behavioural strategies (limiting the amount of oils/fat consumed, limiting or avoiding snacking throughout the day, limiting or avoiding snacking in the evenings, limiting food portion size at meals, limiting or avoiding juices [explained to participant as home-made or pre-packed juice], limiting or avoiding fizzy and sweetened drinks, limiting or avoiding alcohol, maintaining consistent eating patterns across weekdays and weekends, using a shake to replace meal sometimes, eating restaurant meals less than once per week, eating out of home meals less than once per week, eating five or more servings of fruits and vegetables per day) were coded yes/no depending on whether the participant endorsed the behaviour or not. Probing for details on fruit and vegetable intake was done by asking a question on how many cups (240ml) each of fruits and vegetables they consumed per day. A sample cup (240ml) was shown to participants at the time of the interview. Half a cup of raw or cooked non-leafy vegetable was considered a serving, and for leafy vegetables, one cup was considered a serving. One medium size of whole fruits such as oranges, tangerines, apple, English pears, bananas, peaches, kiwis were considered a serving. Half cup of chopped large fruits (pineapples, watermelon, other melons, papayas) and small fruits (berries, cherries) were considered a serving (Agudo, 2005). The total servings for fruits and vegetables consumed per day was then estimated. Alcohol intake was objectively assessed by probing about how often a drink of alcohol (5 ounce wine or 12 ounce beer or 1.5 ounce spirit) was consumed. The amount of oil/fats consumed was objectively assessed by probing about the most commonly consumed oily meals/foods (as recalled from the NWLP list of high fat meals/foods) and how often it was consumed. To generally assess whether a participant was avoiding or limiting a specific behaviour, participants were asked a probing question on how often that behaviour was practised and were given the possible options to choose from as: ≥ once per day/2-6 times per week/once per week/less than once per week/never. Limiting a behaviour was defined as engaging in that behaviour less than once per week and avoiding a behaviour was defined as never engaging in that behaviour.

Weight management behaviours were selected based on those that participants were exposed to during the weight loss programme and are supported by the existing literature on WLM success (Varkevisser *et al*., 2019; Hetherington & Blundell-Birtill, 2018; Montesi *et al*., 2016; Abildso *et al*., 2014; Phelan *et al*., 2010; Befort *et al*., 2008).

***Perceived competence in carrying out weight management behaviours***

Participants' perception of their competence in carrying out the listed weight management behaviours was assessed by asking them to rate their competence in carrying out those activities as excellent, good, acceptable, poor or disappointing. For analytical purposes, responses were re-grouped into excellent/good, acceptable, or poor/disappointing.

***Perceived barriers to weight loss maintenance success***

Participants' perceptions of barriers to WLM success were assessed by 15 items on healthy eating and 7 items on physical activity.  Participants were asked whether they perceived any of the healthy eating or physical activity related items as barriers preventing them from keeping their weight. Response options were: 1 (not applicable), 2 (not a barrier), 3 (somewhat a barrier), 4 (a very important barrier). These barriers were subjected to CATPCA, which reduced the larger set of barrier items each for healthy eating and for physical activity into fewer unrelated components (constructs).

***Other barriers to weight loss maintenance success***

Perceived frequent feeling of hunger when on a weight management diet as well as the perception that managing weight is difficult were two other barriers to WLM success that were assessed individually as stand-alone barrier items without adding them to those subjected to CATPCA. This was because single barrier items for a given construct are not suitable for principal component analysis. Participants were asked whether they perceived these as barriers preventing them from keeping their weight. Response options were: 1 (not applicable), 2 (not a barrier), 3 (somewhat a barrier), 4 (a very important barrier).

***Post-programme weight loss attempts***

The number of weight reduction attempts after ending the first bout of NWLP was assessed in its continuous variable form.

**3.8.4.4 Anthropometric measurements and programme based data collection**

***Baseline, end of programme and survey time weight and height measurements***

The NWLP routinely takes and records pre programme (baseline) weight and standing height measurements of programme members on the very first day of enrolment. Measurements of weekly weights as members come in for their weekly review visits and weights at the end of the programme are routinely recorded.

NWLP records are in the form of manual entries in clients' folders and electronic entries into a secure database from which further computations are done. Baseline and end of programme body weights, baseline and end of programme Body Mass Index (BMI), weight loss at the end of the programme, percent weight loss at the end of the programme, percent weight loss categorised as clinically significant (≥5.0%) or non-clinically significant (<5.0%), were extracted from the NWLP database for consenting participants of this study. Survey time weight and height measurements of consenting participants were likewise taken at the time of this study. Participants were weighed in their usual clothing and had no shoes on. Items such as phones, jewellery, coins, and all other objects in the pockets of participants were off loaded prior to weighing. A calibrated Camry digital weighing scale (Camry Electronic Limited, 4 Kang Le Road S., Zhaoqing, Guangdong, China, Model EF954, ISO 9001 certified) was used for weight measurements. Height measurements were taken with participants standing bare feet with heels together and head in a horizontal Frankfort plane. Height was measured using a Healthometer stadiometer (Health O Meter, 11800 South Austin Avenue Unit B, Alsip, IL 60803, United States of America). Weights were measured in kilograms to the nearest 0.1kg and height in centimetres to the nearest 0.1cm. BMI was derived from the formula: weight in kilograms divided by the square of height in metres.

***Programme based data collection***

NWLP data and computations included consenting participants' programme start and end dates, number of visits made, number of required visits per programme duration chosen, number of visits made as a percentage of number of visits required, programme duration chosen (in months), and length of stay in the programme (in weeks). Date of consenting participants' last visit while on the weight loss programme to the date of survey was used to calculate PTT in months.

#### 3.8.4.5 Biochemical measurements

***Lipid profile determination***

Venous blood (5ml) was drawn from the antecubital vein by standard venipuncture process. Three millilitre of blood was put into serum separator tubes. Drawn fasting blood samples in the serum separator tubes were labelled with serial numbers and transported on ice to the Mamprobi Polyclinic Laboratory. Blood samples were centrifuged at 2,500 revolutions per minute for five minutes and serum samples extracted for analysis. Serum samples that were not analysed immediately after centrifugation were stored in eppendorf tubes at negative 20$^{o}$C until the time of analysis. All samples stored were analysed within 48 hours after collection.

Selectra Pro S automated chemistry analyser (manufactured by ELITech Clinical Systems SAS-Zone industrielle-61500 SEES France) was used in determining the Total Cholesterol (TC), High Density Lipoprotein (HDL), and Triglycerides (TG) concentrations. Selectra Pro S machine determines the concentrations of several blood parameters using the enzymatic colorimetric method, a standard method for lipid determination (Basit *et al*., 2015). This method uses reagents that contain a mixture of enzymes and compounds to act on specific substrates, resulting in a coloured end-point compound (end point indicator) whose concentration is determined using colorimetric principles based on Beer-Lambert's law (which relates absorbance to concentration). The end point indicator in this case was a compound called quinone-imine whose concentration was measured at a wavelength of 500nm and at a temperature of 37$^{o}$C. Low Density Lipoprotein (LDL) concentration was calculated from that of TC, HDL and TG using the formula: $\mathrm{LDL} = \mathrm{TC} - (\frac{\mathrm{TG}}{2.2} + \mathrm{HDL})$ (Emokpae & Nwagbara, 2017). Concentrations of TC, HDL, LDL, TG were measured in mmol/L. Manufacturer's control sample (Elitrol 1) was run for all the tests before the test samples were analysed. Instrument calibration was done with Elitech 1 solution whenever control readings were out of the manufacturer's control reference range or whenever reagents were replaced. Readings for test samples were compared with manufacturer's test reference values. The suitability of Selectra Pro S for testing the concentrations of lipids in research has been successfully demonstrated by Emokpae and Nwagbara (2017) and Basit, Fawwad, Munir, Siddiqui, Siddiqui, & Basit, A. (2015).

Manufacturer's test reference range were as follows:

*TC (mmol/L)*: Values less than or equal to 5.20 mmol/L were considered normal values and those above 5.20mmol/L were considered high.

*LDL* (*mmol/L*): Values less than or equal to 2.59 mmol/L were considered optimal while those above 2.59 mmol/L were considered sub-optimal.

*HDL* (*mmol/L*): Values below 1.03mmol/L were considered low and posed a high risk for heart disease. Values greater than or equal to 1.03 mmol/L were considered normal.

*TG* (*mmol/L*): Values less than 1.7mmol/L were considered normal. Those greater than or equal to 1.7mmol/L were regarded as high.

***Fasting blood sugar determination***

Fasting blood glucose (FBG) concentrations of participants were assessed on the field using the Accu-Chek performa glucometer along with test strips (manufactured by Roche Diabetes Care Incorporated, 9115 Hague Rd., Indianapolis, IN 46256, United States of America).

A drop of blood from the syringe used in accessing venous fasting blood for lipid analysis was put directly onto the test strip. The results were read within 4-5 seconds after inserting the test strip in the machine. The assay is based on the principle that glucose in the blood reacts with an electrode containing glucose oxidase in the test strip that oxidises glucose into gluconolactone. This further reacts with a mediator, ferricyanide, in the test strip to produce ferrocene, which releases electrons that constitute an electric current that the meter reads as the blood glucose concentration. The electric current generated corresponds to glucose concentration in the blood. Fasting glucose results were recorded in a booklet against the corresponding serial codes assigned to each participant. Accu-Chek glucose readings are known to correlate well with those of laboratory chemistry analysers (Parmar, Chauhan, & Ullal, 2013) making them suitable to be used in research settings.

Manufacturer's test reference range was as follows:

*FBG (mmol/L)*: Values below 3.60mmol/L were interpreted as hypoglycaemia. Normal values ranged between 3.60-6.49mmol/L. Values greater than or equal to 6.50mmol/L were considered as hyperglycaemia.

***Glycosylated haemoglobin (HbA1c) determination***

An aliquot (2 ml) of the 5ml venous blood drawn was put in EDTA tubes in the field and transported on ice to the laboratory for glycosylated haemoglobin concentration determination. Whole blood samples that were not analysed immediately were stored in EDTA tubes at $2^{o}C$ – $8^{o}C$ until the time of analysis. All samples stored were analysed within 48 hours after collection. The Clover A1c self-system (Infopia Co. Ltd., 132, Anyangcheondong-ro, Dongan-gu, Anyang-si, Gyeonggi-do, 14040, Korea) was used to determine the percentage of glycosylated haemoglobin in whole blood samples of participants. The system consists of a cartridge and a reagent pack. The reagent pack consists of a reaction solution and a washing solution. The reaction solution comprises of an agent that lyses the red blood cells and releases the haemoglobin and a boronate resin that binds the glycosylated haemoglobin (Akinlade, Rahamon, Edem, Ige, & Arinola, 2016). In the laboratory, 4µL of whole blood was collected using the sample collecting area of the reagent pack. The reagent pack with the blood sample was then inserted into the cartridge where lysing of red blood cells occurs with subsequent binding of glycosylated haemoglobin by boronate resin. Total haemoglobin concentration is measured as the cartridge rotates the blood sample to a position that allows for photometric reading to occur. The cartridge rotates a second time allowing the washing solution to come into contact with the blood sample, washing out the non-glycosylated haemoglobin from the sample. Photometric measurement of glycosylated haemoglobin then occurs. The machine then gives the final output, which is the concentration in percentage of glycosylated haemoglobin via the formula:

$A * \left[\frac{HbAIC}{Total\ Haemoglobin} * 100\right] + B$ where A is the slope and B is the intercept. These factors are internally applied by the machine.

Manufacturer's test reference range for glycosylated haemoglobin:

*HbA1c (%):* Non diabetic: <6.0% and Diabetic: ≥ 6.0%

**3.9 Data Analyses**

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 20, Armonk, NY: IBM Corp. Normality of data was determined using histograms and the Shapiro Wilk test, where $P > 0.05$ confirmed normality of data. Mean±SD was used to describe continuous variables that were normally distributed and median and interquartile range (IQR) for non-normally distributed continuous variables. Frequencies and percentages were used to summarize categorical variables.

CATPCA (allows for optimal scaling of categorical variables) with varimax rotation was performed separately for healthy eating related barrier items and physical activity related barrier items. The suitability of the entire matrix (both healthy eating and physical activity related barriers) for CATPCA was assessed via the use of the Kaiser-Meyer-Olkin measure of Sampling Adequacy (IBM, 2018). The KMO for the entire matrix was 0.739 reflecting a good level of factorability of the matrix. Extraction of components was done only when components had eigenvalues above one. A component loading cut off of 0.4 was applied such that items with loadings below 0.4 were excluded. Items under each component were checked for consistency with the construct defined by the component. Each extracted component constituted a composite variable for which a summary median Likert score reflective of the number of items within the composite variable was calculated for each participant. The median Likert score for each composite variable (extracted component) was then determined. Priority barriers for the CATPCA extracted components of participants were defined as components with median Likert score greater than or equal to 2.50, based on rating of responses of each barrier item on a four point (1-4) Likert scale. Priority barriers for individual barrier items of respondents that were not subjected to CATPCA followed a similar definition as that for the CATPCA extracted barrier components. For the purposes of multivariate binary logistic regression analysis, each extracted component was further re-categorised as 'a barrier' or' not a barrier'. Scores less than 2.50 were defined as 'not a barrier' and those greater than or equal to 2.50 were defined as 'a barrier', where 2.50 was the median for the four point Likert scale used for each barrier item. For the stand-alone barrier items that were not subjected to CATPCA, Likert scale response options 1 or 2 were re-coded as not a barrier and 3 or 4 re-coded as a barrier for the purposes of multivariate binary logistic regression.

To determine the predictors of WLM success, the independent variables relevant for the various stages (pre, during and post) of the weight loss programme were considered. A bivariate analysis was carried out between each independent variable and the dependent variable (WLM success as a dichotomous variable). Only independent variables significantly ($P<0.05$) associated with the dependent variable were selected for potential inclusion in the logistic regression model (backward stepwise multivariate binary logistic regression). Prior to backward stepwise multivariate binary logistic regression analysis, pairwise correlations were performed for the selected independent variables for the purposes of identifying those that were strongly collinear with other predictor variables. Pearson's correlation was used to test the strength of association for paired continuous variables. Point bi-serial correlation was used for paired continuous variables versus dummy coded categorical variables. Variable pairs with correlation coefficient greater than 0.6 at $P<0.05$ (Prado *et al.*, 2017) were deemed to be strongly correlated. Cramer's V test was used for paired categorical variables and test values $\geq$ 0.25 at $P<0.05$ were deemed to have strong association (Akoglu, 2018). In the event that a pair of variables were identified to be significantly associated with each other, the variable that contributed the least to the variance in the dependent variable during the bivariate analysis was dropped.

All the variables at the different phases of the weight loss programme (pre, during and post) which were significant at $P<0.05$ during the bivariate analysis, and were not collinear with other variables were fourteen in number. These were altogether subjected to a backward stepwise multivariate logistic regression analysis to arrive at the final model. Categorical independent variables were as follows: achieving $\geq$10.0% weight loss in the weight loss programme (yes or no), total physical activity minutes accumulated per week (none, 1-149 minutes, 150 minutes or more), logging of physical activity (yes or no), limiting food portions at meal times (yes or no), competence in carrying out weight management behaviours (poor or disappointing, acceptable, good or excellent), PTT (less than 3 years or 3 years and above), counting calories (never or seldom, sometimes, often or always), weight control method (neither losing nor maintaining, losing or maintaining with diet or physical activity or with both), frequency of self-weighing (never, less than once a week, greater than or equal to once a week), lack of social support as a barrier to WLM success (yes or no), cost of healthy eating as a barrier to WLM success (yes or no), environmental physical activity barriers to WLM success (yes or no). Continuous independent variables were as follows: length of stay in weight loss programme and percent of required weight loss review visits made. Adjusted odds ratios (AORs) and 95.0% Confidence Intervals (CI) were used to report on successful WLM in this study. The degree of predictability of the final model was assessed using the Receiver Operator Characteristic (ROC) curve.

Multiple linear regression analysis was applied in testing the association between WLM success and the concentrations of lipids/glucose biomarkers (TC, LDL, HDL, TG, FBG, HbA1C). The biomarkers were each considered as dependent variables while WLM success (a dichotomous variable) was the independent variable of interest. The regression model was adjusted for selected covariates known from literature to be significantly associated with lipid metabolism (Palmisano, Zhu, Eckel, & Stafford, 2018; Chiu *et al.*, 2017; Wang & Xu, 2017; Feingold & Grunfeld, 2016; Trapp *et al.*, 2015; Kroeger *et al*., 2014; World Health Organisation, 2014b; Makhoul *et al*., 2012; Marhoum, Abdrabo, & Lutfi, 2013). The categorical covariates considered were: consuming at least five servings of fruits and vegetables per day (yes or no), limiting intake of restaurant meals (yes or no), limiting out of home eating (yes/no), limiting the amount of fats or oils consumed (yes or no), limiting alcohol intake (yes/no), limiting food portions during meals (yes/no), total physical activity minutes accumulated per week being ≥ the median (yes/no), gender (male or female), usage of lipid lowering medication (yes or no), hypercholesterolemia status (yes/no). The continuous covariates considered were: BMI at study time, age at study time, PTT, and percent weight loss achieved at the end of the programme. The fourteen covariates above, together with the variable, WLM success (yes or no), were put in each biomarker regression model. The covariates with t-statistic significant at $P<0.1$ in each biomarker regression model analysis were then selected as the relevant covariates to control for in that model.

Additional exploratory analyses were carried out to determine the proportion of blood study participants with normal lipids/glucose levels, the proportion not practising selected desirable weight management behaviours and those using lipid lowering medication.

# CHAPTER FOUR

# 4.0 RESULTS

### Preamble

This chapter reports the findings of the study on prevalence, perceived barriers, predictors and associated biomarkers of WLM success among previous participants of a commercial weight loss programme. The findings are reported in the following format: Pre, during and post weight loss characteristics of participants, principal components of perceived healthy eating and physical activity related barriers to WLM success, predictors of WLM success, the blood lipids, glucose and glycosylated haemoglobin concentrations of SWLM and UWLM. The findings presented are based on analyses of data for 230 participants who gave their consent to be part of the study. The non-consent rate was 43.6% (Figure 3.1). The findings of the blood data analysis for the sub-sample of 112 participants are also presented.

## 4.1 Characteristics of Participants at the Time of Initial Enrolment into the Weight Loss Programme

The characteristics of participants at the time of initial enrolment into the weight loss programme are presented in Table 4.1. The age range of participants at the time of initial enrolment was from 18 to 74 years, and the mean was 39.7±9.2 years. Majority (73%) of participants were within the age range of 31-50 years at the time of initial enrolment into the weight loss programme. The mean height and weight of study participants on the day of initial enrolment into the NWLP were 1.65±0.08m and 96.5±16.3kg, respectively. The mean BMI at the time of initial enrolment into the programme was 35.4±5.4kg/$m^2$ with 85.7% and 14.3% being obese and overweight, respectively. Most of the obese participants (69.1%) either belonged to grade 1(BMI of 30-34.9kg/$m^2$) or grade 2 (BMI of 35-39.9kg/$m^2$) obese category at the time of initial enrolment into the programme. Majority were females (81.3%), had tertiary education (93.0%) and more than half (71.3%) were married at the time of initial enrolment into the programme.

**Table 4.1: Characteristics of participants at the time of enrolment into the weight loss programme (n=230)**

| Characteristic | Mean ± SD/ n (%) |
|---|---|
| Age (years) | 39.7±9.2 |
| **Age category (years):** | |
| 18-30 | 37 (16.1) |
| 31-50 | 168 (73.0) |
| ≥ 51 | 25 (10.9) |
| Weight (kg) | 96.5±16.3 |
| Height (m) | 1.65±0.08 |
| Baseline BMI ($kg/m^2$) | 35.4 ± 5.4 |
| **BMI category ($kg/m^2$):** | |
| Overweight | 33 (14.3) |
| Grade 1 obesity (30.0-34.9) | 81 (35.2) |
| Grade 2 obesity (35.0-39.9) | 78 (33.9) |
| Morbid obesity (≥40.0) | 38 (16.6) |
| **Gender:** | |
| Male | 43 (18.7) |
| Female | 187 (81.3) |
| **Marital status:** | |
| Not married | 66 (28.7) |
| Married | 164 (71.3) |
| **Educational status:** | |
| Below tertiary | 16 (7.0) |
| Tertiary | 214 (93.0) |
| **Engaged in physical activity in the six months prior to entering NWLP** | |
| No | 76 (33.0) |
| Yes | 154 (67.0) |
| **Previous weight loss attempts:** | |
| None | 83 (36.1) |
| One or more | 147 (63.9) |
| **Employment status:** | |
| Not employed | 5 (2.2) |
| Employed | 217(94.3) |
| Student | 8 (3.5) |

NWLP: Nutriline Weight Loss Programme

### 4.2 Characteristics of Participants During the Weight Loss Programme

Table 4.2 shows the characteristics of participants during the weight loss programme. The percent weight loss achieved at the end of the weight reduction programme ranged from 3.0% to 9.9% with the median being 6.4%. Majority (63.0%) of participants achieved a clinically significant weight loss (≥ 5.0% weight loss) at the end of the weight loss programme. The mean length of stay in the weight loss programme was 11.9±7.4weeks. Completers of the weight loss programme comprised 38.3% of the study participants.

**Table 4.2: Characteristics of participants during the weight loss phase (n=230)**

| Variable | n (%)/Median [IQR] |
|---|---|
| Proportion who achieved ≥ 10.0% weight loss at the end of NWLP | 58 (25.2) |
| Proportion who achieved ≥ 5.0% weight loss at the end of NWLP | 145 (63.0) |
| **Engaged in physical activity during the weight loss programme:** | |
| No | 80 (34.8) |
| Yes | 150 (65.2) |
| **Number of weight loss bouts:** | |
| One bout | 163 (70.9) |
| Repeated bouts | 67 (29.1) |
| **Completers of programme:** | |
| No | 142 (61.7) |
| Yes | 88 (38.3) |
| **Perceived first month weight loss progress:** | |
| Poor/disappointing | 19 (8.3) |
| Acceptable | 26 (11.3) |
| Good/excellent | 185 (80.4) |
| **Rating of weight loss effort versus success:** | |
| Effort>success | 53 (23.0) |
| Effort ≤ success | 177 (77.0) |
| **Perceived difficulty in changing diet routine at the start of programme:** | |
| Easy | 106 (46.1) |
| Difficult | 124 (53.9) |
| **Perceived difficulty in starting an exercise routine at the start of programme:** | |
| Easy | 113 (49.1) |
| Difficult | 117 (50.9) |

NWLP: Nutriline Weight Loss Programme

**Table 4.2 continued: Characteristics of participants during the weight loss phase (n=230)**

| Variable | n (%)/Median [IQR] |
|---|---|
| **Perceived difficulty in losing weight:** | |
| Easy | 145 (63.0) |
| Difficult | 85 (37.0) |
| Percent weight loss at the end of NWLP | -6.4 [-9.9-(-3.0)] |
| Percent attendance to required review sessions | 50.0 [25.0-83.3] |
| | **Mean±SD** |
| Length of stay in weight loss programme (weeks) | 11.9±7.4 |
| BMI at the end of NWLP (kg/m$^2$) | 32.7±5.3 |

NWLP: Nutriline Weight Loss Programme

### 4.3 Characteristics of Participants after the Weight Loss Programme

Table 4.3 shows the characteristics of participants after they had completed the weight loss programme. The prevalence of WLM success was 23.9%. Seventeen percent of the study cohort retained at least 95.0% of losses previously attained during the weight loss programme. The proportion of participants who enrolled in the weight maintenance programme was 5.7%.

**Table 4.3: Characteristics of participants after the weight loss programme (n=230)**

| Variable | n (%) |
|---|---|
| Proportion successful at WLM | 55 (23.9) |
| Proportion retaining ≥ 95.0% of weight loss achieved at the end of NWLP | 39 (17.0) |
| Proportion who participated in NWLP maintenance programme | 13 (5.7) |
| **Frequency of self-weighing:** | |
| None | 65 (28.3) |
| Less than once per week | 69 (30.0) |
| Once per week or more | 96 (41.7) |
| **Weight control method:** | |
| Never tried to lose nor maintain weight | 36 (15.7) |
| Losing or maintaining weight with diet or physical activity | 93 (40.4) |
| Losing or maintaining weight with diet and physical activity | 101 (43.9) |
| **Frequency of breakfast consumption:** | |
| Daily | 143 (62.2) |
| Not daily | 87 (37.8) |
| **Logging of physical activity:** | |
| No | 192 (83.5) |
| Yes | 38 (16.5) |
| **Exercising at the gymnasium at the time of the study:** | |
| Never/seldom | 185 (80.5) |
| Sometimes | 12 (5.2) |
| Often/always | 33 (14.3) |
| **Keeping a food log:** | |
| Never/seldom | 209 (90.9) |
| Sometimes | 13 (5.6) |
| Often/always | 8 (3.5) |
| **Limiting fats and oils:** | |
| No | 178 (77.4) |
| Yes | 52 (22.6) |
| **Counting calories:** | |
| Never/seldom | 183 (79.6) |
| Sometimes | 30 (13.0) |
| Often/always | 17 (7.4) |
| | **Median [IQR]** |
| Minutes of moderate activity accumulated per week | 17.5 [0.0-120.0] |
| Minutes of vigorous activity accumulated per week | 0.0 [0.0-90.0] |
| Minutes of total activity (moderate and vigorous) accumulated per week | 100.0 [0.0-200.0] |
| PTT (months) | 57.0 [23.0-85.0] |
| Percent weight regained with reference to end of programme weight | 7.7 [2.9-11.4] |
| | **Mean ±SD** |
| BMI at study time (kg/m$^2$) | 35.2±6.0 |

NWLP=Nutriline Weight Loss Programme
WLM= Weight Loss Maintenance

**Table 4.3 continued: Characteristics of participants after the weight loss programme (n=230)**

| Variable | n (%) |
|---|---|
| **Limit or avoid snack during the day:** | |
| No | 142 (61.7) |
| Yes | 88 (38.3) |
| **Limit or avoid snack in the evenings:** | |
| No | 93 (40.4) |
| Yes | 137 (59.6) |
| **Limit or avoid juices:** | |
| No | 106 (46.1) |
| Yes | 124 (53.9) |
| **Limit or avoid sweetened or fizzy drinks:** | |
| No | 60 (26.1) |
| Yes | 170 (73.9) |
| **Limit or avoid alcohol:** | |
| No | 39 (17.0) |
| Yes | 191 (83.0) |
| **Maintain consistent eating patterns throughout the week:** | |
| No | 152 (66.1) |
| Yes | 78 (33.9) |
| **Use of shake to replace meals sometimes:** | |
| No | 193 (83.9) |
| Yes | 37 (16.1) |
| **Limit or avoid restaurant meals:** | |
| No | 90 (39.1) |
| Yes | 140 (60.9) |
| **Limit or avoid out of home eating:** | |
| No | 169 (73.5) |
| Yes | 61 (26.5) |
| **Consume 5 servings of fruits and vegetables per day:** | |
| No | 130 (56.5) |
| Yes | 100 (43.5) |
| **Limit food portions at meal times:** | |
| No | 57 (24.8) |
| Yes | 173 (75.2) |
| **Perceived competence in carrying out prescribed diet and physical activity behaviours:** | |
| Poor/disappointing | 58 (25.2) |
| Acceptable | 95 (41.3) |
| Good/excellent | 77 (33.5) |
| **PTT:** | |
| $\leq$ 2 years | 62 (27.0) |
| > 2 years - < 5 years | 61 (26.5) |
| $\geq$ 5 years | 107 (46.5) |

Figures 4.1, 4.2 and 4.3 show the post weight loss programme physical activity characteristics of respondents. More than 60.0% of respondents were either not engaging in any form of physical activity or insufficiently active (not achieving ≥ 150 minutes per week of moderate or total [moderate plus vigorous] activity or ≥ 75 minutes per week of vigorous activity).

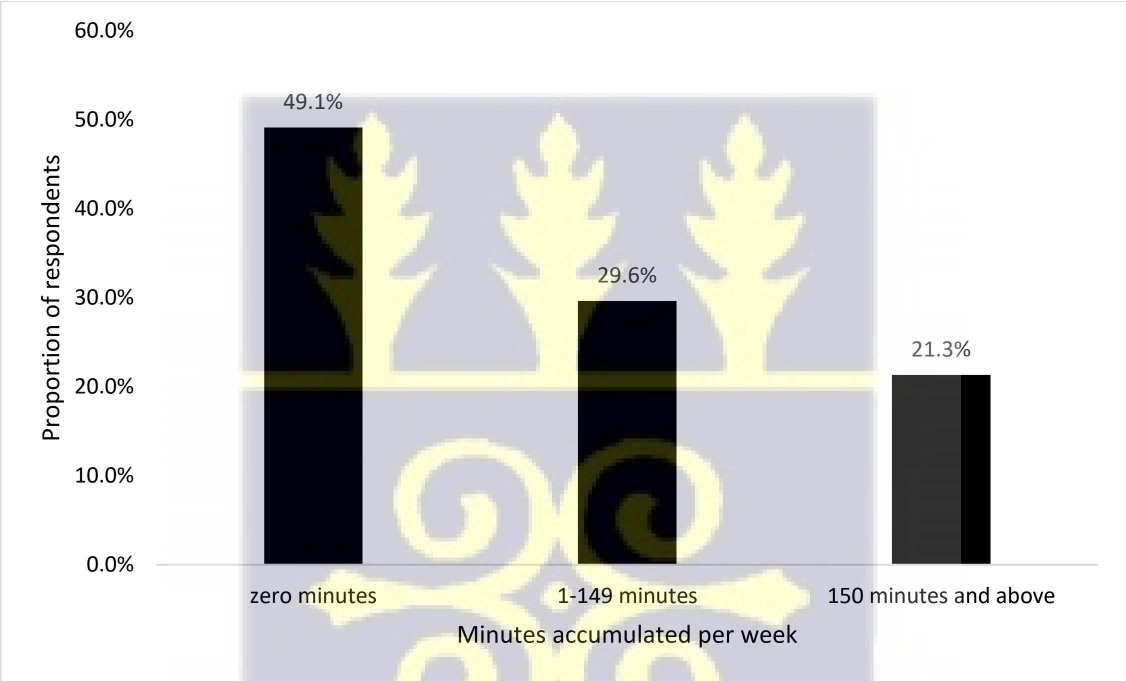


**Figure 4. 1: Respondents engaging in moderate intensity physical activity (n=230)**

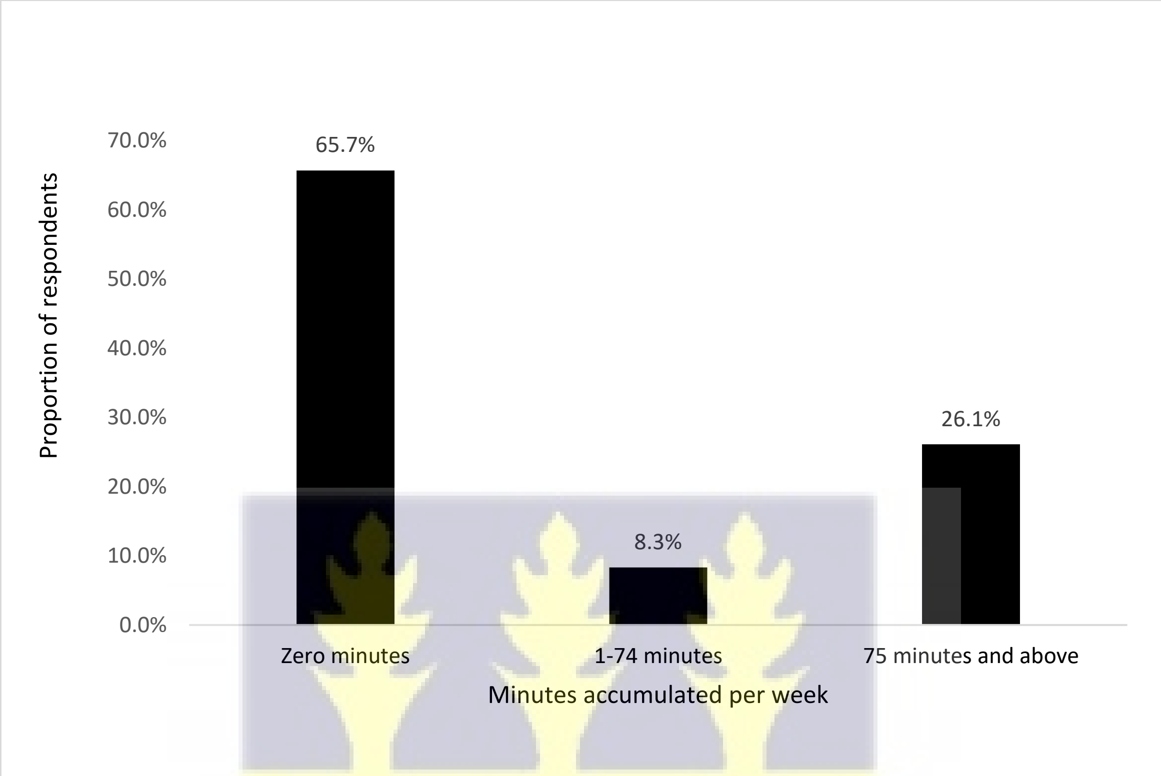


**Figure 4.2: Respondents engaging in vigorous intensity physical activity after the weight loss programme (n=230)**

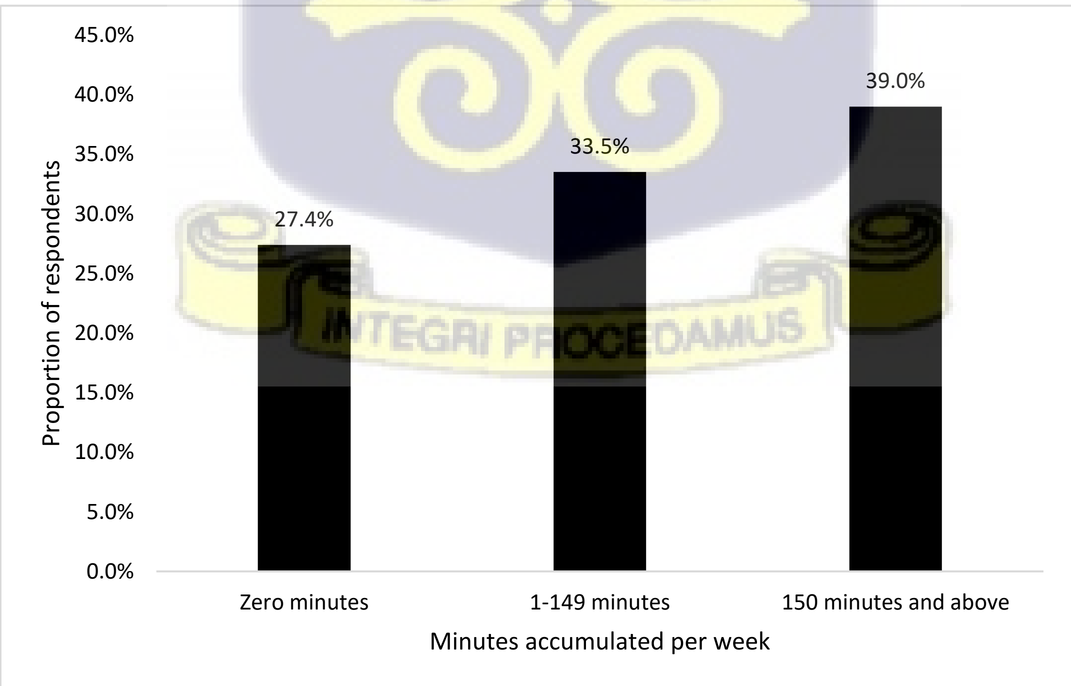


**Figure 4. 3: Respondents engaging in moderate to vigorous physical activity after the weight loss programme (n=230)**

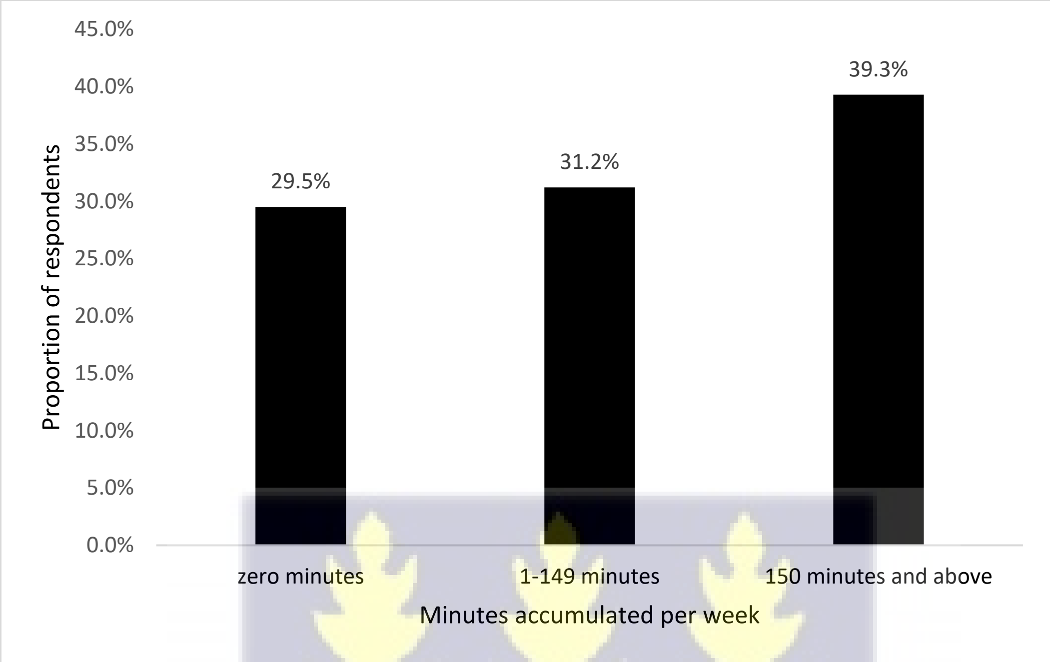


**Figure 4.4: Blood study respondents engaging in moderate to vigorous physical activity after the weight loss programme (n=112)**

## 4.4 Principal Components of Perceived Healthy Eating and Physical Activity Related Barriers to Weight Loss Maintenance

CATPCA of the 15-item healthy eating related perceived barriers to WLM success resulted in five distinct extracted components each with eigenvalue > 1. Together, these five components explained 66.9% of the total variance in the data (Table 4.4). The perceived healthy eating related barrier components to WLM success extracted were locational factors, cost of healthy eating, food craving, emotional factors and lack of social support. None of the items under each component had a component loading of ≤ 0.4 which was the cut off point for including an item under its corresponding extracted component. Thus all the 15 items originally in the questionnaire were retained after the extraction of components and their corresponding items. CATPCA of the 7 item physical activity related perceived barriers to WLM success resulted in three distinct extracted components each with eigenvalue > 1. The three extracted components explained 65.6% of the total variance in the data (Table 4.5). The perceived physical activity related barrier components to WLM success extracted were cost of physical activity, environmental and personal factors. None of the items under each component had a component loading of ≤ 0.4 which was the cut off point for including an item under its corresponding extracted component. Thus all the 7 items originally in the questionnaire were retained after the extraction of components and their corresponding items.

The perceived healthy eating related barrier components that were of priority importance to participants were locational barrier (relates to the food environment), cost of healthy eating and food craving (Table 4.6). Priority perceived healthy eating related barrier items for the participants were being on a trip, stress and being unable to follow healthy eating plan when sweets, chocolates, ice-cream, cakes and biscuits were available. The median Likert scores for these barrier items were 3.00 [2.00-4.00], 3.00 [2.00-4.00], 2.50 [2.00-3.00], respectively (appendix D). The perception that managing weight was difficult was a priority stand-alone barrier item to WLM for the participants. The median Likert scores for this barrier item was 3.00 [2.00-4.00] (Appendix F). Priority physical activity related barrier component for the respondents was cost of physical activity (Table 4.7). Environmental and personal factors were less important physical activity related barriers for the respondents. Priority perceived physical activity related barrier item for the respondents was feeling too tired to exercise (median Likert score was 3.00 [2.00-3.00], Appendix E).

**Table 4.4: The components of perceived healthy eating related barriers to weight loss maintenance success*(n=230)**

| Perceived healthy eating related barriers to WLM success | [b]Component loadings |
|---|---|
| **Component 1: Lack of social support (Eigenvalue = 3.97, 26.5% variance )** | |
| Lack of support or pressure from friends is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.84 |
| Lack of family support is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.82 |
| Injury to self or family is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.67 |
| The fact that my food pattern differs from that of family is a barrier that kept me from following a healthy eating plan for weight maintenance. | 0.63 |
| **Component 2: The cost of healthy eating (Eigenvalue = 2.01, 13.4% variance)** | |
| Healthy eating is too expensive and this is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.79 |
| Healthy foods are not delicious and this is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.78 |
| Healthy eating is too time consuming and this is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.70 |
| Healthy eating is too boring and this is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.54 |
| **Component 3:Locational barrier (Eigenvalue = 1.74, 11.6 % variance )** | |
| Being at a party is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.83 |
| Being on a trip is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.78 |
| Eating out is a barrier that kept me from following a healthy eating plan for weight maintenance. | 0.76 |

*Component extraction procedure: Categorical Principal Component Analysis with varimax rotation. Component loading cut off point was 0.4.
[b]Component loadings represent the correlation co-efficient of each item with its corresponding extracted component.
WLM –weight loss maintenance

**Table 4.4 Continued: The components of perceived healthy eating related barriers to weight loss maintenance success*(n=230)**

| Perceived healthy eating related barriers | [b]Component loadings |
|---|---|
| **Component 4: Emotional barriers (Eigenvalue =1.29, 8.6% variance )** | |
| Depression is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.89 |
| Stress is a barrier that kept me from following a healthy eating plan for weight maintenance | 0.85 |
| **Component 5: Food craving (Eigenvalue = 1.02, 6.8% variance)** | |
| Whenever sweets, chocolates, candies, ice-cream, cakes, biscuits are available I am unable to follow a healthy eating plan and this is a barrier that kept me from maintaining my weight | 0.84 |
| Preference for junk foods whenever they are available and my inability to resist them is a barrier that kept me from maintaining my weight. | 0.81 |

*Component extraction procedure: Categorical Principal Component Analysis with varimax rotation. Component loading cut off point was 0.4.
[b]Component loadings represent the correlation co-efficient of each item with its corresponding extracted component.

**Table 4. 5: The components of perceived physical activity related barriers to weight loss maintenance success* (n=230)**

| Perceived physical activity related barriers | ¶Component loadings |
|---|---|
| **Component 1: Personal factors (Eigenvalue =2.34, 33.4% variance )** | |
| Heavy body weight is a barrier that kept me from being physically active for weight maintenance | 0.81 |
| Lack of interest in being physically active or exercising regularly is a barrier that kept me from maintaining my weight | 0.76 |
| Foot or other body pain is a barrier that kept me from being physically active for weight maintenance | 0.56 |
| **Component 2: The cost of physical activity (Eigenvalue =1.15, 16.5% variance)** | |
| Exercise is too time consuming and this is a barrier that kept me from being physically active for weight maintenance | 0.81 |
| Feeling too tired to exercise is a barrier that kept me from being physically active for weight maintenance | 0.79 |
| **Component 3: Environmental factors (Eigenvalue = 1.11, 15.8 % variance )** | |
| Not having anyone to exercise with is a barrier that kept me from being physically active for weight maintenance | 0.84 |
| Lack of a place to do physical activity is a barrier that kept me from being physically active for weight maintenance | 0.83 |

* Component extraction procedure: Categorical Principal Component Analysis with varimax rotation. Component loading cut off point was 0.4.

¶Component loadings represent the correlation co-efficient of each item with its corresponding extracted component.

**Table 4.6: Prioritisation of healthy eating related barriers to weight loss maintenance success based on median scores (n=230)**

| Component | ¶ Median score [IQR] |
|---|---|
| Locational barrier | 2.50 [2.00-3.00] |
| Food craving | 2.50 [2.00-3.00] |
| Cost of healthy eating | 2.50 [2.00-3.00] |
| Emotional barrier | 2.00 [2.00-3.00] |
| Lack of Social Support | 2.00 [2.00-2.50] |

¶ The median scores were calculated by finding the median Likert score for each component.
Median Likert score ≥ 2.50 was considered a priority barrier

**Table 4.7: Prioritisation of physical activity related barriers to weight loss maintenance success based on median scores (n=230)**

| Component | ¶Median score [IQR] |
|---|---|
| Cost of physical activity | 2.50 [2.00-3.00] |
| Environmental factors | 2.00 [2.00-3.00] |
| Personal factors | 2.00 [2.00-2.00] |

¶ The median scores were calculated by finding the median Likert score for each component. Median Likert score ≥ 2.50 was considered a priority barrier

### 4.5 Pre, During and Post Weight Loss Predictors of Weight Loss Maintenance Success

Table 4.8 shows results of the final predictive model for WLM success. None of the pre weight loss phase characteristics assessed (demographic factors, number of previous weight loss attempts, and pre-programme physical activity) predicted weight loss maintenance success. At the weight loss phase, the odds of being successful at WLM was about seven times higher (AOR=6.72, P<0.001) among those who lost 10.0% or more of their baseline weight compared to those who did not. At the post weight loss phase, the odds of being successful at WLM was more than three times higher among those who logged their physical activity compared to those who did not (AOR =3.52, P=0.004) and those who limited their food portions at meal times compared to those who did not (AOR=3.51, P=0.039). Those who perceived their competence in carrying out behaviours needed for WLM as good/excellent were about six times more likely to be successful at WLM compared to those who perceived their competence as poor/disappointing (AOR=5.93, P = 0.004). Those who had completed their weight loss programme three or more years ago at the time of the survey had 54.0% reduced odds of being successful at WLM compared to those who had done so in less than three years (AOR=0.46, P = 0.041). The receiver operator characteristic (ROC) curve corresponding to the final model predicting WLM success gave an area under the curve (AUC) value of 0.827 (Figure 4.5). The final model accounted for 39.1% (Nagelkerke R square) of the variance in WLM success. The omnibus test of model coefficient gave a chi square test statistic: $\mathcal{X}^2(6) = 69.479$, P<0.001. The Hosmer Lemeshow goodness of fit for the final model predicting WLM success gave a chi square test statistic: $\mathcal{X}^2(7) = 9.197$, P = 0.239, showing the model had a good fit for the data.

**Table 4.8: Final predictive model for weight loss maintenance success (n=230)**

| Variable | AOR (95% Confidence Interval) | P-value |
|---|---|---|
| **≥10% weight loss in the weight loss programme** | | |
| No | 1.00 | <0.001 |
| Yes | 6.72 (3.15-14.31) | |
| **Log physical activity post weight loss** | | |
| No | 1.00 | 0.004 |
| Yes | 3.52 (1.49-8.32) | |
| **Limit food portions at meal times post weight loss** | | |
| No | 1 | 0.039 |
| Yes | 3.51(1.07-11.57) | |
| **Perceived competence in carrying out diet behaviours behaviours post weight loss** | | |
| Poor/disappointing | 1.00 | 0.010 |
| Acceptable | 2.83 (0.82-9.76) | 0.100 |
| Good/excellent | 5.93 (1.74-20.19) | 0.004 |
| **PTT** | | |
| < 3 years | 1.00 | 0.041 |
| ≥ 3 years | 0.46 (0.20-0.91) | |

AOR= Adjusted odds ratio for backward stepwise multivariate binary logistic regression

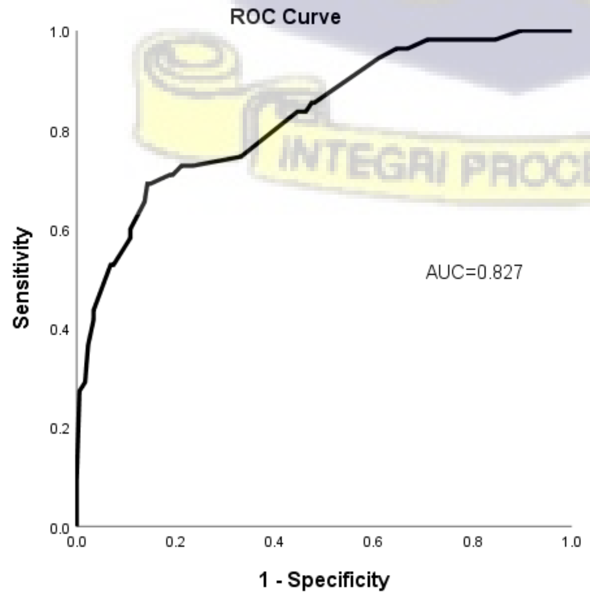


**Figure 4.5: Receiver Operator Characteristic (ROC) curve showing AUC for the model predicting WLM success.**

### 4.6 Blood Lipids, Glucose and Glycosylated Haemoglobin Concentrations of Successful and Unsuccessful Weight Loss Maintainers

Results of the adjusted blood lipids/glucose regression models revealed that SWLM compared to UWLM had 0.57 units decrease in the predicted concentration of TC and 0.23 units decrease in the predicted concentration of TG when covariates were held constant. The adjusted mean concentrations for TC and TG were 6.26±0.18mmol/L versus 5.69±0.24mmol/L, P = 0.013 and 1.34±0.07mmol/L versus 1.11±0.10mmol/L, P = 0.021 for UWLM versus SWLM, respectively. There were no significant associations between WLM success and LDL, HDL, FBG and HbA1c concentrations. The adjusted mean LDL, HDL, FBG and HbA1c concentrations for UWLM versus SWLM were: 4.37±0.17mmol/L versus 4.04±0.22mmol/L, 1.26±0.07mmol/L versus 1.15±0.09mmol/L, 4.68±0.10mmol/L versus 4.66±0.19mmol/L and 5.77±0.08% versus 5.67±0.11%, respectively (Table 4.9). Upon re-categorising SWLM into those who achieved 5.0%-9.9% and those who achieved ≥10.0% weight loss at survey time, participants who had ≥10.0% weight loss compared to UWLM had significantly lower LDL in the adjusted model (3.86±0.31mmol/L versus 4.46±0.18mmol/L, respectively, P = 0.046) (Table 4.10). SWLM who achieved ≥10.0% weight loss had a 0.59 units reduction in predicted LDL concentration compared to UWLM, when covariates were held constant (Table 4.10). This new re-categorisation for SWLM did not yield any significant results for HDL, FBG and HbA1c and so these were not included in results shown in table 4.10. Table 4.11 reveals the proportion of participants achieving normal levels of the various biomarkers. Very few participants (8.9%) had optimal LDL levels and less than half (40.2%) had normal TC levels.

Table 4.12 presents the proportion of blood study participants who practised certain dietary behaviours after the weight loss programme. A greater percentage of respondents practised the desirable behaviour of limiting food portions at meal times. Majority of participants were neither limiting fats and oil intake nor reducing the frequency of eating out of home. More than half of the participants had less than five servings of fruits and vegetables in a day. Approximately 13.0% of blood study participants reported using lipid lowering medication of which 9.8% were UWLM and 2.7% were SWLM.

**Table 4.9: Association between weight loss maintenance success and fasting blood lipids, glucose and glycosylated haemoglobin concentrations**

| Variable | Mean ± SD | | Beta coefficient (95% C.I) | P-value |
|---|---|---|---|---|
| | **SWLM (n=26)** | **UWLM (n=86)** | | |
| **TC** (mmol/L) | | | | |
| Unadjusted | 5.17±0.99 | 5.59± 1.06 | -0.433 (-0.897 to 0.030) | 0.067 |
| Adjusted[1] | 5.69±0.24 | 6.26±0.18 | -0.568 (-1.012 to -0.124) | 0.013 |
| **LDL** (mmol/L) | | | | |
| Unadjusted | 3.58±0.92 | 3.87±0.99 | -0.282 (-0.715 to 0.150) | 0.199 |
| Adjusted[2] | 4.04±0.22 | 4.37±0.17 | -0.333 (-0.736 to 0.069) | 0.104 |
| **HDL**(mmol/L) | | | | |
| Unadjusted | 1.22±0.38 | 1.17±0.32 | 0.049 (-0.099 to 0.197) | 0.512 |
| Adjusted[3] | 1.15±0.09 | 1.26±0.07 | -0.112 (-0.299 to 0.074) | 0.235 |
| **TG** (mmol/L) | | | | |
| Unadjusted | 0.79±0.28 | 1.17±0.51 | -0.378 (-0.585 to -0.172) | <0.001 |
| Adjusted[4] | 1.11±0.10 | 1.34±0.07 | -0.231 (-0.425 to -0.036) | 0.021 |
| **FBG** (mmol/L) | | | | |
| Unadjusted | 4.48±0.72 | 4.73±1.00 | -0.248 (-0.668 to 0.173) | 0.245 |
| Adjusted[5] | 4.66±0.19 | 4.68±0.10 | -0.026 (-0.458 to 0.406) | 0.904 |
| **HbA1c** (%) | | | | |
| Unadjusted | 5.52±0.39 | 5.59±0.59 | -0.073 (-0.316 to 0.171) | 0.555 |
| Adjusted[6] | 5.67±0.11 | 5.77±0.08 | -0.101 (-0.333 to 0.131) | 0.389 |

SWLM = Successful weight loss maintainers, UWLM = Unsuccessful weight loss maintainers
C.I= Confidence Interval
Comparison of successful and unsuccessful weight loss maintainers was based on multiple linear regression analysis (UWLM was the reference category)
[1]: Adjusted for gender (male/female), usage of lipid lowering medication (yes/no), consumption of ≥ 5 servings of fruits and vegetables per day (yes/no), and limiting intake of restaurant meals (yes/no)
[2]: Adjusted for gender (male/female), usage of lipid lowering medication (yes/no) and limiting intake of restaurant meals (yes/no)
[3]: Adjusted for gender (male/female), usage of lipid lowering medication (yes/no), PTT, consumption of ≥ 5 servings of fruits and vegetables per day (yes/no), and percent weight loss at the end of weight loss programme
[4]: Adjusted for gender (male/female), PTT, BMI at study time and limiting the amount of fats and oils consumed (yes/no)
[5]: Adjusted for PTT and BMI at study time
[6]: Adjusted for gender (male/female) and age at study time

**Table 4.10: Associations of various categories of weight loss maintenance with LDL cholesterol concentration**

| WLM Categories | Mean±SD | | Beta coefficient (95% C.I) | | | |
|---|---|---|---|---|---|---|
| | UM | AM² | UM | P-value | AM² | P-value |
| <5.0% | 3.86±0.97 | 4.46±0.18 | 0.00 | - | 0.00 | - |
| 5.0-9.9% | 3.93±1.11 | 4.56±0.26 | 0.07 (-0.46 to 0.60) | 0.797 | 0.11(-0.37 to 0.58) | 0.658 |
| ≥10.0% | 3.30±1.06 | 3.86±0.31 | -0.56 (-1.20 to 0.09) | 0.093 | -0.59 (-1.17 to -0.01) | 0.046 |

C.I = Confidence Interval
WLM= Weight loss maintenance
<5% WLM=Reference category
UM= Unadjusted model
AM=Adjusted model
²: Adjusted for gender (male/female), usage of lipid lowering medication (yes/no) and limiting intake of restaurant meals (yes/no)

**Table 4.11: Proportion of blood study participants with normal levels of fasting blood lipids and glucose (n=112)**

| Variable | n (%) |
|---|---|
| TC (≤ 5.2 mmol/L) | 45 (40.2) |
| LDL (≤ 2.59 mmol/L) | 10 (8.9) |
| HDL (≥ 1.03 mmol/L) | 67 (59.8) |
| Triglyceride (< 1.70 mmol/L) | 101 (90.2) |
| FBG (3.60-6.40 mmol/L) | 102 (91.1) |
| HbA1c (< 6.0%) | 97 (86.6) |

**Table 4.12: Dietary behaviours and lipid lowering medication usage of blood study participants (n=112)**

| Variable | n (%) |
|---|---|
| Not limiting fats/oils | 86 (76.8) |
| Not limiting out of home eating | 82 (73.2) |
| Not having five servings of fruits and vegetables per day | 61 (54.5) |
| Limiting food portions at meal times | 85 (75.9 ) |
| Lipid lowering medication usage status: | |
| Yes | 14 (12.5) |
| of which: SWLM | 3 (2.7) |
| UWLM | 11 (9.8) |
| No | 92 (82.1) |
| No response | 6 (5.4) |

SWLM = Successful weight loss maintainers, UWLM = Unsuccessful weight loss maintainers

# CHAPTER FIVE

## 5.0 DISCUSSION

**Preamble:**

This chapter discusses the objectives of the study in relation to the results obtained and is presented along the following thematic areas: The prevalence of WLM success among participants, perceived barriers to WLM success, predictors of WLM success, and the association of WLM success with selected cardiovascular related biomarkers.

### 5.1 The Prevalence of Weight Loss Maintenance Success among Participants

Approximately 24% of participants were successful at WLM. It is encouraging that this proportion of participants were successful at WLM in the midst of escalating overweight/obesity prevalence in Ghana over the years (GSS *et al.*, 2015; GSS *et al.*, 2009). This could be partly due to the recognition by participants of the potential health threats and the health gains associated with adiposity and deliberate weight reduction, respectively, and a heightened motivation to maintain lost weight. In a study carried out in the Accra Metropolis by Benkeser *et al.* (2012), more than half of participants surveyed desired to be thinner to improve their health. This demonstrated a high level of awareness of the health benefits of weight loss.

The prevalence of WLM success in this study was however less than that reported in earlier studies that used a similar definition for WLM success (Befort *et al.*, 2008; Lowe *et al.*, 2008). In the study by Befort *et al.* (2008), 76.5% of the cohort were at least 5.0% below their baseline weight at follow up while 42.0% maintained 95.0% or more of their weight loss. This might have been made possible in part by the following factors: all participants fully completed a 3 months weight loss programme and had a maintenance programme lasting between 6-21 months. Overall the mean treatment time for weight loss and maintenance was approximately 12 months. In this study, completers were only 38.3% and the mean length of stay in weight loss treatment was approximately 3 months with no formal weight maintenance programme for the majority of participants (only 5.7% participated in a weight maintenance programme after weight loss). Additionally participants in the study by Befort *et al.* (2008) were compelled to attend at least 75.0% of the required meetings to remain in the study and approximately sixty eight percent of the cohort completed both weight loss and weight maintenance phases of the programme. The supervised attendance to meetings contributed to an increased treatment time for participants which undoubtedly enhanced their weight loss and WLM outcomes. A longer stay in treatment is known to promote better weight reduction and weight maintenance outcomes (Jiandani *et al*., 2016; Montesi *et al*., 2016). The use of very low energy diets and pre-packed foods for weight loss and maintenance in a significant proportion of study participants (Befort *et al*., 2008) might have promoted higher weight loss results leading to better prognosis for weight loss maintenance success (Varkevisser *et al*., 2019; Kruschitz *et al*., 2017). Further, WLM success was evaluated over a shorter PTT period (14 months) compared to a median period of 57 months in this study. Additionally, participants were allowed to self-report their follow-up weights. This might have led to inflated weight loss results in the study participants. Self-reported weights in obese individuals are subject to under reporting (Tang, Aggarwal, Moudon, & Drewnowski, 2016).

In the study by Lowe *et al*. (2008), 50.0% of participants were successful at maintaining 5.0% weight loss below baseline weight at 5 years PTT. Participants of this study were lifetime members of the Weight Watchers Programme who had achieved their weight goal. Lifetime members represented the most successful weight losers of the programme. These were highly motivated to improve their health and hence might have had a higher likelihood of succeeding at WLM. All the participants had a six week WLM programme which might have enhanced their skills in keeping their lost weight. All lifetime members were also entitled to once-monthly free weigh-in beyond the maintenance phase provided they stayed within 0.9kg of their desired target weight. This was an incentive and might have generated the needed motivation to keep lost weight. Additionally, the maintenance phase and the free monthly weighing beyond the maintenance period were opportunities to extend length of stay in treatment which is known to improve WLM outcomes (Jiandani *et al*., 2016; Montesi *et al*., 2016).

The results of this study however, compares to that of Gosselin and Cote (2001) who demonstrated that 24% of participants were successful at WLM in a commercial weight loss setting. Gosselin and Cote (2001) included individuals who stayed in treatment for one month and constituted the majority of participants. Similarly in the current study, there was the inclusion into the study of enrollees of weight loss programme who made as low as one review visit post enrolment. Additionally both completers (38.3%) and non-completers of the programme were part of the study. The mean length of stay in the programme for participants of this study was quite short (approximately 3 months). According to Byrne, Barry, and Petry, (2012), programme participants who stayed briefly in treatment often did so because of low motivation to attend weight loss review sessions which are intended to facilitate weight loss. In the study by Gosselin and Cote (2001) and in the current study, there were no programme incentives to motivate participants or regulations to ensure that participants stayed longer in treatment as was the case for the studies by Befort *et al*. (2008) and Lowe *et al*. (2008). Lack of motivation to stay longer in treatment might be a plausible reason for the brief stay in treatment by participants of this study. Weight loss interventions must seek to introduce packages/incentives to motivate clients to stay longer in weight loss treatment.

The impact of aging on WLM success must also be recognised. Although the median PTT for the current study was 57 months (4.75 years), there were individuals who had been out of treatment for as long as 5-9 years (comprised 46.5% of participants). Such long periods out of treatment could have a negative impact on the ability to maintain lost weight due to the down regulation of basal metabolic rate with aging (Abizanda, Romero, Sánchez-Jurado, Ruano, Ríos, & Sánchez, 2016). For such individuals, a significant proportion of weight regained after treatment could be due to the impact of aging on metabolism. These individuals might have had higher magnitudes of weight regain if they had not participated in the weight loss programme.

**5.2 Perceived Barriers to Weight Loss Maintenance Success.**

It is important to understand the perceived healthy eating and physical activity related barriers to WLM success for people who previously went through a commercial weight loss programme. This will facilitate the development of strategies to improve dietary compliance and physical activity levels for WLM. There were five perceived healthy eating related barriers and three perceived physical activity related barriers identified. One of the prioritised healthy eating related barriers that prevented the participants from successfully maintaining their weight loss was locational barrier. Participants reported that their ability to eat healthy to maintain their weight was negatively affected when they were at parties, on trips, or ate outside of their homes. This finding is in keeping with reports from other studies (Zorbas *et al.*, 2018; Sharma & Agrawal, 2017; Sharifi *et al.*, 2013) which showed that locational barrier posed a significant challenge to healthy eating for people in different parts of the world. According to Sharma and Agrawal (2017) and Seguin *et al.* (2014), eating out of home was one of the common perceived barriers to healthy eating. Out of home meals are generally unhealthy and constitute a barrier to healthy eating (Trapp *et al.*, 2015). Zorbas *et al.* (2018) also found that unhealthy foods were readily available across most global settings and posed a major challenge to healthy eating. Urbanisation and the adoption of western lifestyle has promoted an obesogenic environment in Ghana (Bonah, 2016). The existing obesogenic food environment in Ghana promotes the sale of high energy dense foods in out of home food outlets (fast foods, including global food chains, and local street food vendors) and the marketing and sale of sugar sweetened beverages, high calorie snacks and highly processed foods in convenience stores and supermarkets (Bonah, 2016; Dake, Thompson, Ng, Agyei-mensah, & Codjoe, 2016). The widespread availability of unhealthy foods both within and outside Ghana, therefore lends support to the findings of this study where eating out and being on trip were perceived as barriers to healthy eating. Parties (social gatherings) provide the environment for high energy dense foods and fatty foods to be served (Sharma & Agrawal, 2017). The Ghanaian culture places more emphasis on providing rich and high energy dense foods during social gatherings to boost social status and strengthen relationships rather than a focus on the nutritional content of the meal. It is therefore common to have high energy dense foods served at social gathering and parties in Ghana (Hagan, Nsiah-Asamoah, Hormenu, Pollmann, & Schack, 2018). Moreover, external food cues present during social gathering/parties trigger a strong physiological desire to eat, usually excessively, notwithstanding the internal state of hunger or satiety (termed food craving), according to the externality theory of overeating behaviour (Ferrer-garcia, Gutiérrez-maldonado, & Pla, 2015). This issue of external food cue reactivity is also related to another priority barrier component (food craving) that was identified in this study. This finding was consistent with that reported in a systematic review, where food craving was identified as a major barrier to WLM success (Greaves *et al.*, 2017). Participants in this study stated that their preference for junk and other high calorie foods when they were available and their inability to resist these foods made it impossible for them to stick to a healthy eating plan for WLM. The fact that locational factors and food craving were perceived as priority barriers post weight loss, suggest the need to identify participants with high external food cue reactivity and train them in coping planning as part of relapse prevention. Coping planning will help them anticipate a high risk food situation and put in the necessary coping strategies to prevent a lapse (Greaves *et al*., 2017; Kwasnicka *et al*., 2016). Reducing the frequency of consuming the craved food is a form of coping planning which has been shown to reduce food craving (Apolzan *et al*., 2017). Relapse prevention combines dealing with negative thoughts and the adoption of new behavioural and lifestyle change strategies to help individuals self-regulate the new behaviour of not easily yielding to highly tempting food situations (Kwasnicka *et al*., 2016; Kyriazes, 2014).

The cost of healthy eating was another priority barrier component identified in this study. Specifically, the participants indicated that healthy eating was expensive, healthy foods were not delicious, too time consuming to prepare and boring. This finding supports that in literature where the high price of healthy diets were reported as a significant challenge to healthy eating particularly for low income populations (Kelly *et al*., 2016; Sharifi *et al*., 2013; Marcy *et al*., 2011). Menezes *et al.* (2018) also reported a strong positive association between the perception that healthy eating is affordable and the consumption of fruit and vegetable and vice versa. Fruits and vegetables which are important components of healthy diets were reported to be poorly consumed in the urban centres of Ghana due to poor distribution and the resultant high cost of these products (Amo-Adjei and Kumi-Kyereme, 2015). There is the need to improve the distribution of fruits and vegetables in urban centres to help reduce costs. Seasonality in fruit and vegetable availability and costs are also key challenges to healthy eating in the developing world (Wijesinha-bettoni, Kennedy, Dirorimwe, & Muehlhoff, 2013). This calls for mass education on seasonal food availability calendars across the different regions of Ghana and how these can be used to improve dietary diversity and reduce costs of foods purchased for consumption. Knowledge of what foods to buy, how to combine foods from the food groups to ensure a balanced diet, when and where to buy nutritious foods at affordable price are skills that participants need to develop.

Home-cooked meals tend to be healthier than out-of-home meals (Trapp *et al*., 2015). This may be partly due to the fact that cooking from home allows the consumer to self-select healthy ingredients and cooking practices to meet health goals. It is however common to associate better taste with unhealthy meals (Zorbas *et al*., 2018) and out-of-home meals (van der Horst, Brunner, & Siegrist, 2010; Kruger, Blanck, & Gillespie, 2006) than with home-cooked meals. It is no wonder healthy foods were perceived by participants of this study as not delicious and boring. According to Kwasnicka *et al.* (2016), behaviour that is not enjoyed is not likely to be sustained. Garcia *et al.* (2018) and Pinho *et al.* (2018), reported that the perceived taste of healthy foods predicted healthy meal preparation or its consumption. A systematic review by Guillaumie, Godin, and Vézina-Im, (2010), also reported that perceived taste of vegetables (a component of healthy foods) was a significant predictor of vegetable intake. Accordingly, those who perceived vegetables not to be tasty were less likely to consume them (Guillaumie *et al*., 2010). Healthy eating among participants of this study is therefore unlikely to be sustained if it was not perceived as an enjoyable practice. The perception by participants of this study that healthy eating was time consuming might point to the prevalence of time scarcity among participants. Majority of participants of this study were employed and therefore more likely to have busy work schedules and little time available for home meal preparation. The amount of hours spent on a paid job was reported to strongly correlate with the frequency of consuming convenience foods (van der Horst *et al*., 2010). More so, Monsivais, Aggarwal, and Drewnowski, (2014) discovered that prolonged length of time spent in food preparation correlated positively with better diet quality and negatively with frequency of consumption of out of home meals (more convenient and less healthy). Home meal preparation therefore promotes healthy eating, and is a time consuming chore that is less attractive to time constrained individuals (Monsivais *et al.*, 2014; van der Horst *et al.*, 2010). The lack of cooking skill has been described as an important barrier to home cooking and healthy eating (Menezes *et al.*, 2018; Murray *et al.*, 2016; van der Horst *et al.*, 2010). Practical cooking sessions on healthy eating during the weight loss and maintenance phases of weight management programmes may assist participants in developing the requisite skills to prepare tasty and healthy meals in a timely fashion.

Stress and depression have often been associated with obesity, emotional eating, and unsuccessful WLM in a number of studies (Tyrrell *et al.*, 2019; Richardson *et al.*, 2015; Trief, Cibula, Delahanty, & Weinstock, 2014; Sharifi *et al.*, 2013; Marcy *et al.*, 2011). Participants in the current study however, did not perceive emotional factor (stress and depression) as a priority barrier to healthy eating for WLM success. A plausible reason for the low rating for emotional factor (stress and depression) as a healthy eating related barrier to WLM success could be under-reporting in study respondents for the depression barrier item. This was evident from the low median Likert score for the depression barrier item compared to stress item. Depressed individuals are often stigmatised in society (Yokoya, Maeno, Sakamoto, & Goto, 2018; Wainberg *et al.*, 2017; Boerema *et al.*, 2016) and for this reason participants of this study might have concealed their depression status if any. More over participants of this study had a face-to-face interaction with the interviewer and thus had little privacy in their responses to questions asked, including that on depression. The face-to-face interview thus could have promoted under-reporting of depression as a barrier to WLM success in participants. Stress was however one of the major barrier items that was highly perceived as a factor negatively affecting WLM success in this study. This is consistent with findings by Trief *et al.* (2014), where participants with high levels of perceived stress had lower percent weight loss both in the short (6 months) and long-term

(2 years). In a review by Bongers and Jansen (2016) on emotional eating, it was evident that participants who scored themselves highly on stress eating often did so because they worried about their unhealthy eating habits, and perceived that they had little control about their eating habits. Stressed individuals are thus susceptible to comfort eating. Stress also dissipates the energy and will-power needed to self-regulate desirable behaviours (Kwasnicka *et al.*, 2016) needed to sustain WLM. Strategies such as self-talk and the use of other activities to self-distract rather than deriving comfort from food are effective ways of managing stress to achieve WLM success (Greaves *et al*., 2017). Stress management sessions may need to be a part of weight loss programmes to help participants cope better with stress after their programme ends.

Lack of social support was not a priority barrier component to healthy eating in this study. Participants indicated that lack of support or pressure from friends, lack of family support, injury to self or family, differing food patterns of family were not priority healthy eating barriers that impeded their WLM progress. Contrary to findings of this study, lack of social support has been demonstrated as an important factor that impacts negatively on weight loss and its maintenance (Al-mohaimeed *et al*., 2017; Greaves *et al*., 2017; Karfopoulou *et al*., 2016; Lemstra *et al*., 2016). Lack of social support has been shown to particularly be a barrier to healthy eating for most married women as well as women with children (Ingstrup *et al*., 2019; Andajani-Sutjahjo, Ball, Warren, Inglis, & Crawford, 2004). This was not so in the case of this study, although majority of the study's participants were women, married, and within the child bearing age group. Having been through a face to face weight loss programme these participants may have learnt to derive more social support from the nutrition therapists and peers in the weight loss programme. Thus, the study participants might have become less dependent on family and friends for social support overtime and hence the low rating for lack of social support as an important barrier. Additionally, individuals perceived to be excessively overweight in Ghana are stigmatised by the Ghanaian public (Aryeetey, 2016). The fear of being stigmatised by society could have made participants of the study shy away from friends and family, keeping as secret their WLM efforts, and thus not seeking any support from their social network. It is also likely that participants received the needed social support from family and friends and therefore did not perceive it as a barrier. The form of social support received by participants if any, will be worth investigating in the future, given the fact that majority (76.1%) were not successful at WLM. Karfopoulou *et al*. (2016) demonstrated that while compliments from friends and family promoted WLM, support in the form of verbal instructions, reminders and encouragement to engage in healthy lifestyle promoted weight regain. In a study by Kiernan *et al*. (2012), social support in the form of verbal reminders, instructions and encouragement were unfortunately perceived by weight regainers as criticisms or needless reminders and often resulted in further weight regain rather than weight loss.

The cost of physical activity was a priority physical activity related barrier component to WLM success in this study. Participants mentioned that exercises were too time consuming and they felt too tired after exercising. Lack of time and feeling tired after exercise have been reported as major barriers to exercise in active workers, students or obese weight conscious individuals (Al-mohaimeed *et al*., 2017; Kelly *et al*., 2016; Sharifi *et al*., 2013; Kruger *et al*., 2006). Simple strategies of incorporating leisure time physical activities into daily routine such as parking a few miles away from desired location to allow some amount of walking to the desired destination, using the staircase instead of the elevator, walking the dog, washing one's own car, along with self-monitoring of these events and relaxation techniques could go a long way in improving time management, easing tiredness and increasing enjoyment of physical activity. Environmental barrier component (lack of a place to do physical activity, not having any one to exercise with) was not a priority barrier.

Although access to a safe and right environment or facilities for physical activity continues to be a challenge for some countries (Kelly *et al*., 2016; Sharifi *et al*., 2013), participants of this study did not perceive this as a barrier to WLM success. The cost of physical activity seemed to outweigh environmental barriers to physical activity for WLM success. Personal factor (having a heavy body weight, lack of interest in being physically active, foot or other body pain) was not perceived to be a priority barrier to physical activity for WLM success. Contrary to findings of this study, pain and heavy body weight have been cited as important barriers to physical activity in a number of people (Boutevillain, Dupeyron, Rouch, Richard, & Coudeyre, 2017; Sharifi *et al*., 2013). A large proportion of this study's participants were either not involved in any post programme physical activity or not engaging in sufficient duration of physical activity per week. This might imply that most participants did not do enough physical activity to experience any pain. In addition, time factor and tiredness may have outweighed issues of heavy weight and lack of interest in being physically active among the participants.

The perception that the weight management process was difficult was a priority perceived barrier item to WLM success. Prioritisation of the perception that the weight management process was difficult might be a reflection of the low level of self-efficacy among participants regarding their perceived ability to maintain their lost weight. Burke *et al*. (2015) and Latner, McLeod, O'Brien, and Johnston, (2013) demonstrated that a high level of self-efficacy in starting and sustaining lifestyle changes improved WLM. Building the self-efficacy levels of participants regarding the requisite lifestyle behavioural changes needed for weight reduction and its maintenance might promote better WLM.

### 5.3 Predictors of Weight Loss Maintenance Success

The AUC for the final model predicting WLM success demonstrated that the model had good predictability for successful and unsuccessful weight loss maintainers. Pre-programme enrolment factors were not predictive of successful WLM. This finding has important public health implications as it points to the fact that WLM success is not limited to people with specific baseline characteristics relating to demography, number of previous weight loss attempts, and physical activity habits. This finding is consistent with that by Abildso *et al*. (2014) where baseline demographic background, number of previous weight loss attempts and baseline physical activity were not predictive of successful WLM. Similarly, Varkevisser *et al*. (2019) in a systematic review reported that baseline demographic characteristics did not predict WLM success. Achieving at least a 10.0% weight loss below baseline weight at the weight loss phase was predictive of successful WLM in this study. This is consistent with findings from literature which indicate that higher magnitudes of weight loss increase the chances of successful WLM (Varkevisser *et al*., 2019; Sawamoto *et al*., 2017; Pekkarinen *et al*., 2015; Nackers, Ross, & Perri, 2010) and suggestive of the need to device strategies to help participants achieve higher weight loss targets during the weight loss phase. At the post weight loss phase, limiting of food portions at meal times emerged as one of the factors predictive of successful WLM. This agrees with findings by Kiem *et al*. (1997) that reported this behaviour as a major practice by participants during WLM. Limiting food portions is an aspect of dietary self-monitoring that leads to reduced calorie intake for effective weight control (Hetherington & Blundell-Birtill, 2018; Rolls, 2014; Gibbs, Kinzel, Gabriel, Chang, & Kuller, 2012). Logging of physical activity, a self-monitoring behaviour, also emerged as one of the post weight loss factors that predicted successful WLM. This was confirmed by Perenc, Radochońska, and Zaborniak-Sobczak, (2015) and Befort *et al*. (2008) as an important self-monitoring behaviour that promotes weight loss and its maintenance. Although post weight loss physical activity in this study did not predict WLM success, logging of post weight loss physical activity did. A large proportion of the respondents had either no physical activity or insufficient minutes of physical activity per week during the post weight loss phase and this might partly explain why physical activity did not predict WLM success. Longer duration (at least 300 minutes per week) of physical activity has been recommended for successful WLM (Swift *et al*., 2014). Additionally, it is possible that those who logged their post weight loss physical activity were also engaged in other self-monitoring activities such as logging of dietary intake and self-weighing. Self-monitoring activities have been reported as important factors that promote WLM success (Varkevisser *et al*., 2019; Ingels *et al*., 2017). Those who believed that they were good/excellent at performing weight management behaviours were more likely to succeed at WLM. Thus higher levels of self-efficacy for diet and physical activity behaviours during the post weight loss phase were important predictors of successful WLM in this study. This compares with what has been reported in literature about the role of self-efficacy in improving weight loss and WLM outcomes (Abildso *et al*., 2014; Wingo *et al*., 2013). Additionally, a longer stay out of treatment reduced the odds of successful WLM and was consistent with findings from literature (Abildso *et al*., 2014; Befort *et al*., 2008). Shorter stay out of treatment implies a longer stay in treatment. This is consistent with documentation on the positive association of long stay in treatment with WLM success (Jiandani *et al*., 2016; Montesi *et al*., 2016).

### 5.4 Association of Weight Loss Maintenance Success with Cardiovascular Related Biomarkers

This section discusses the association between WLM success with blood lipids and glucose parameters. The cardiovascular related biomarkers studied were TC, LDL, HDL, TG, FBG and HbA1c.

There were no significant associations between successful WLM and HDL, FBG and HbA1c concentrations. In most cases, these results were not consistent with studies by Brown *et al*. (2016), Hamdy *et al.* (2017), Wing *et al*. (2016) and The Look AHEAD Research Group, (2010) who demonstrated that ≥5.0% weight loss below baseline weight was significantly associated with improvements in blood lipids and glucose concentrations. The levels of improvement observed in these studies (Hamdy *et al.*, 2017; Brown *et al.*, 2016; Wing *et al.*, 2016; The Look AHEAD Research Group, 2010) however, were greatest during the phase of active weight loss or shortly after and decreased overtime. Fasting glucose levels have been shown to be much more responsive to short-term than long-term weight loss (Delahanty *et al*., 2014). Hamdy *et al.* (2017) also demonstrated that HbA1c levels were most favourable just after weight loss and worsened (increased) subsequently even after maintaining a loss of ≥7.0% below baseline weight. It is therefore likely that any potential improvements in the parameters assessed in this study might have been more noticeable just after the weight loss intervention and subsequently eroded over time for all participants including those who were successful at WLM. Additionally, most of these studies (Hamdy *et al.*, 2017; Wing *et al.*, 2016; The Look AHEAD Research Group, 2010) were also carried out in diabetics who are more likely to have elevated baseline values for parameters such as fasting blood glucose, HbA1c, and lipids. Thus the likelihood of having significant improvement in these blood parameters after achieving WLM will be higher in such a high risk group compared to a non-diabetic group (as used in this study). This was confirmed by Brown *et al.* (2016), where participants with higher baseline cardio-metabolic parameters had greater improvements in these parameters after successful weight loss compared to those with normal baseline cardio-metabolic parameters.

Other possible explanations for the lack of significant difference in levels of FBG, HbA1c and HDL are as follows: changes in participants' macronutrient composition of diet after the weight loss such as embarking on high protein diets could also partly contribute to the lack of significant difference in glucose and HbA1c levels for SWLM and UWLM. In a study by Rietman *et al.* (2014), healthy individuals with prolonged intake of high protein diets had increased plasma glucose levels and insulin resistance. HDL levels may not have been significantly higher in SWLM compared to UWLM in this study, due to the low levels of physical activity generally observed among participants. Increased physical activity activates the production of adenosine tri-phopshate binding cassette transporter A1 (Wang & Xu, 2017). This transporter in turn facilitates the movement of cholesterol and phospholipids to apo-lipoproteins (apo A-1 and apoE), leading to the formation of HDL (Ahn & Kim, 2016; Feingold & Grunfeld, 2018a; Wang & Xu, 2017).

In this study, LDL concentration was significantly lower in SWLM who achieved 10.0% or more weight loss compared to UWLM. This is consistent with findings by Brown *et al.* (2016) who demonstrated that 10.0% or more weight loss favoured improvements in LDL concentration compared to having less than 5.0% weight loss. Vetter *et al.*, (2013) also demonstrated that having 10.0% weight loss at the 24$^{th}$ month significantly improved LDL levels compared to having 5.0% to <10.0% weight loss or <5.0% weight loss. Weight loss is known to result in increased levels of LDL receptors which facilitate the movement of LDL from the blood into the liver cells thus resulting in reduced levels of blood LDL (Klop *et al.*, 2013). It is therefore possible that a higher expression of LDL receptors in SWLM with 10.0% or more weight loss might partly be responsible for the observed lowering of LDL levels in this group. TC was significantly improved in SWLM compared to UWLM. TC concentration is the total amount of cholesterol found in VLDL, LDL and HDL. VLDL is a major carrier of endogenous TG and is thus positively correlated with TG concentration (Klop *et al.*, 2013). The significant difference observed in adjusted TC concentration observed for SWLM and UWLM might therefore be partly explained by the fact that the adjusted TG (an indirect measure of VLDL) and LDL concentrations were significantly lower in SWLM and SWLM with 10.0% or more weight loss, respectively. Improvement in LDL and TC occurred only in the adjusted model where lipid lowering medication were adjusted for among other covariates. The greater use of lipid lowering medication in UWLM might have been partly responsible for the lack of significant difference in the levels of LDL and TC for UWLM and SWLM initially observed in the unadjusted model in this study. This confounding effect of lipid lowering medication usage has been confirmed in other studies (Alpert, 2013; The Look AHEAD Research Group, 2010). Statins work by blocking the activity of the enzyme 3-hydroxy-3-methyl-glutaryl co-enzyme A reductase, which results in a decrease in liver cholesterol synthesis and an increase in the clearance of serum LDL resulting in an overall reduction in plasma cholesterol levels (Feingold and Grunfeld, 2016). The significant difference observed in TG concentrations for SWLM and UWLM in this study are consistent with reports by Brown *et al*. (2016) and Delahanty *et al*. (2014). TG seems to be one of the lipids that is most sensitive to the slightest drop in weight. In the study by Brown *et al.* (2016) weight loss below 5.0% resulted in significant improvements in TG. Report by Delahanty *et al*. (2014) also showed that TG improvement was sensitive to WLM. These reports corroborate the findings of this study regarding the significantly lower TG (both adjusted and unadjusted models) observed in participants successful at WLM. In the current study very few (approximately 13.0%) participants used lipid lowering medications even though majority had elevated levels of TC, sub-optimal LDL levels and a significant proportion had low HDL levels. This is suggestive of the need to intensify education on the importance of knowing one’s blood cholesterol status and taking medications to improve lipid levels when warranted. The high proportion of participants with elevated TC levels and sub-optimal levels of LDL call for further investigations into other potential factors that could impact negatively on lipid levels such as post weight loss dietary intakes. It must be noted that very few (5.7%) participants of this study embarked on a weight maintenance programme after completion of their weight loss programme. A formal weight maintenance programme for all participants post weight loss, may likely reduce the incidence of dietary and physical activity recidivism by promoting compliance with endorsed lifestyle strategies promoted during the weight loss programme. After the weight loss programme, most of the participants in the blood study were not limiting unhealthy behaviours such as consumption of oily foods and eating out of home. Additionally, more than 50.0% were not consuming the recommended daily servings of fruits and vegetables. Such poor dietary behaviours might have had the potential of worsening blood lipids concentrations as the levels of these parameters in an individual are known to correlate well with recent dietary intakes (Foster *et al.*, 2010). Although the majority of the participants of this study practised limiting their food portions which is a healthy practice, lowering total and saturated fats in the diet, limiting out of home eating and having enough fruits and vegetables servings on a daily basis might be more important in lowering blood lipids.

The dietary behaviours observed in this study are in keeping with the findings of the RODAM study, where diets of Ghanaian urban dwellers were highly processed and high in fats (Galbete *et al.*, 2017). Diets that contain high levels of saturated fatty acids tend to increase blood levels of total and LDL cholesterol (Chiu, 2017). Foods eaten out of home are usually low in fruits and vegetables and significantly contribute to calories, sugar, salt, and saturated fatty acids (Cohen and Bhatia, 2012). The presence of flavonoids and other antioxidants in fruits and vegetables promotes a reduction in cholesterol levels and CVD risk (World Health Organisation, 2014b). Introduction of healthy meal catering services after the weight loss programme might improve participants' access to healthy meals and compliance to healthy eating guidelines. Although it behoves on the consumer to eat healthy, opting for healthy food choices however, will be challenging if these options are not easily available (Cohen and Bhatia, 2012). It is also necessary to include LDL-p (LDL particle number) as part of future lipid profile tests as this gives an idea about the LDL particle size (small dense or large particle size) that predominates a particular blood sample (Gunnars, 2017). High LDL particle number suggests the predominance of small particle LDL while low LDL particle number suggests otherwise (Gunnars, 2017). The conventional LDL-c, as was used in this study, lumps both sub-fractions of LDL together and gives the total concentration (Gunnars, 2017). Distinguishing between the two sub-fractions of LDL will reveal the type of LDL sub-fraction that dominates for SWLM and UWLM. Large particle LDL is known to be less susceptible to oxidation and therefore carries less CVD risk compared to the small dense particle LDL (Ivanova, Myasoedova, Melnichenko, Grechko, & Orekhov, 2017). Whether the improved levels of blood lipids (TC, TG, LDL) observed among SWLM provides protection against the future incidence of CVD morbidity and mortality is worth investigating prospectively.

To the best of my knowledge this study on WLM is the first of its kind in Ghana and has added new knowledge that can improve WLM outcomes of commercial weight loss programmes. The results of this study, unlike that of randomised controlled studies is more reflective of real life situation since the study was conducted among free living participants. The use of real measured weights and not self-reported weights excludes the bias of under-reported weights which characterises several weight loss maintenance studies.

The findings of this study may generalise more to participants of the NWLP. There are however, general applications for health promotion policies and programmes directed towards lifestyle change.

### 5.5 Limitations

Due to the retrospective nature of the study, recall of physical activity performed before and during the weight loss programme was carried out by focusing on participants' engagement or non-engagement in physical activity rather than dwelling on the time spent and type of activities performed which they were unlikely to remember. This was done to minimise the possibility of recall bias or misclassification.

Dietary intake post weight loss was not assessed at the survey time. This would have helped reveal the possible association between these dietary components and the prevailing concentrations of blood parameters measured. This study however investigated important dietary behaviours such as consumption of five portions of fruits and vegetables per day, and whether participants limited consumption of oily foods and restaurant meals. These dietary behaviours are important factors known in literature to impact the concentration lipid biomarkers.

LDL particle number was not estimated as part of the lipid profile tests in this study. This would have been helpful in further indicating the dominating LDL sub-fractions (small dense LDL particles or large LDL particles) in the samples analysed. Small dense LDL particles are more susceptible to oxidation and therefore poses a higher risk for heart disease. LDL-c which was estimated in this study, is however, globally used in assessing LDL status and together with HDL status can give an indication of heart disease risk.

# CHAPTER SIX

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the main conclusions for the study and proposes recommendations for interventions, policies and future studies.

### 6.1 Conclusions

The prevalence for WLM success was 23.9%. This study identified the perceived healthy eating related barriers to WLM success to be locational factors, cost of healthy eating, food craving, emotional factors and lack of social support. Of these, locational factors, cost of healthy eating and food craving were perceived as priority barriers to WLM success. The perceived physical activity related barriers to WLM success were the cost of physical activity, environmental factors and personal factors. Of these, cost of physical activity was perceived as a priority barrier to WLM success.

Pre- weight loss demographic profile, weight loss attempts and physical activity habits did not predict successful WLM. Achieving 10.0% or more weight loss during the weight loss phase increased the odds of being successful at WLM. At the post weight loss phase, limiting of food portions, logging of physical activity, a good/excellent perceived competence in carrying out weight management behaviours increased the odds of WLM success. On the other hand being out of weight loss treatment for 3 years or more decreased the odds of WLM success. Successful weight loss maintainers had significantly lower levels of serum TC and TG but not HDL, FBG and HbA1c. Additionally, SWLM who had 10.0% or more weight loss had significantly lower LDL compared to UWLM.

## 6.2 Recommendations

**Recommendations for commercial weight loss interventions**

Interventions for WLM may target high percentage weight loss (≥10%) during the weight loss phase and switch to self-monitoring strategies and self-efficacy training for desirable weight management behaviours at the post weight loss phase. There is the need to institute prolonged weight maintenance programmes and schemes for life time membership to discourage staying out of weight loss treatment for longer periods (≥ 3 years). Interventions must take into account the perceived barriers to WLM success (particularly those related to cost of healthy eating and physical activity, food craving and locational factors) when developing counselling messages to promote WLM success.

Training in relapse prevention as part of self-regulation skills are needed to help participants deal better with food craving, stress, and out of home food situations during the weight maintenance phase of weight loss programmes. Meal preparation skills training is needed to make healthy meals prepared at home more tasty, attractive, and less time consuming. Affordable healthy meal catering services are needed as a form of social liberation, improving the availability and accessibility of healthy meals for time constrained individuals who desire to maintain their weight loss.

**Recommendations for policies**

Policies that favour lowering of the prices for healthy foods such as fruits and vegetables are needed. Policies are needed to drive public campaigns that demonstrate body relaxation techniques to ease tiredness and how to fit leisure time physical activity into daily routine. These will go a long way in making physical activity less tiring and enjoyable. Public campaigns that promote regular contact with qualified medical professionals for laboratory and other health checks are needed.

**Recommendations for future studies**

Dietary intake during the post weight loss phase is worth investigating to provide answers to the current findings on blood parameters investigated, particularly that of the sub-optimal LDL status of majority of participants. A prospective study that explores the progressive changes in blood lipids and glucose concentrations as participants move through the various phases (before, during and post) of the weight loss programme will give a better insight into the metabolism of these biomarkers. Further studies are needed to determine other predictors aside those identified in this study that may significantly contribute to the unexplained variance in WLM success. Future studies are needed to prospectively establish the relationship between successful WLM and the incidence of CVD morbidity and mortality. Additionally, more studies are needed to ascertain the long-term outcomes of various commercial weight loss programmes in Ghana and the factors associated with WLM success for participants of these programmes.

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# APPENDICES

## Appendix A: field questionnaire

**Note:** We would be grateful if you take some time off your busy schedule to complete this questionnaire. The questionnaire is to help us gather information for the evaluation of the Nutriline Weight Loss Program (NWLP) and your health behaviour.

Name: Code:

1. Age at enrolment into NWLP:

2. Marital status at enrolment: single/married/divorced/widow(er)

3. Occupation at enrolment time:

4. Highest level of Educational attained at enrolment time: $1^0$ /$2^0$ /$3^0$

5. Currently able to walk for exercise: Yes/No

6. Medically fit: Yes/No

7. Currently enrolled in NWLP: Yes/No

8. Currently enrolled in Nutriline Maintenance Program: Yes/No

9. I have been pregnant at least once since completing the NWLP: Yes/No

10. I have had a thyroid disease before/during/since completing the NWLP and/or currently have a thyroid disease: Yes/No

11. I have had Diabetes before/during/since completing the NWLP and/or currently have Diabetes: Yes/No

12. I have had cancer and/or HIV before/during/since completing the NWLP and/or currently have cancer: Yes/No

13. I have had psychiatric illness before/during/since completing the NWLP and/or currently have psychiatric illness Yes/No

14. I have had anorexia or bulimia before/during/since completing the NWLP and/or currently have anorexia/bulimia Yes/No

15. I have had a major organ disease (specify)________________________________before/ during/since completing the NWLP and/or currently have this condition Yes/No

16a. Have you suffered from any other health condition before/during/since completing the NWLP and/or currently have the condition. Yes/No

16b. If you answered yes to question 16a, specify the condition _____________________

**World Health Organisation's definition of moderate physical activity:** This requires a moderate amount of effort and noticeably accelerates the heart rate. Examples of moderate activities include: brisk walking, dancing, cycling less than 10 miles/hour, gardening, domestic chores, traditional hunting & gathering, active involvement in games/sports with children, walking domestic animals, general building tasks like roofing, thatching, painting, carrying/moving moderate loads (<20kg)

**World Health Organisation's definition of vigorous physical activity:** This requires a large amount of effort and causes rapid breathing & substantial heart rate. Examples of vigorous activities include: running, walking/climbing briskly uphill, fast cycling, aerobics, fast swimming, competitive sports/games example traditional games, football, hockey, basketball. Heavy shovelling or digging ditches, carrying or moving heavy loads (>20kg)

**The following questions will assess the pre- weight loss program phase of the Nutriline Weight Loss Program (NWLP)**

17. How many days in a typical week did you do at least 30 min moderate activity or 15 min vigorous activity in the six months prior to your first time enrolment in the NWLP
    A. 0 days B. ≥ 1 day
18. What is the number of weight loss attempts you made before finally enrolling in the NWLP?

**The following questions will assess the In-program weight loss phase of the NWLP**

19. How do you rate your weight loss progress during the first month of the weight loss program?
    A. Excellent B. Good C. Acceptable D. Poor E. Disappointing
20. On a scale of 0 (least) to 100 (most) how do you rate your effort during the weight loss program?
21. On a scale of 0 (worst) to 100 (most) how do you rate your success during the weight loss program?
22. How many days in a typical week did you do at least a 30 min moderate activity or 15 min vigorous activity while on the NWLP?
    A. 0 days B. ≥ 1 day
23. How difficult was it to change your diet routine at the start of the weight loss program? Rate your answer using a six point scale from 1(extremely easy) to 6 (extremely difficult)
24. How difficult was it starting an exercise routine at the start of the weight loss program? Rate your answer using a six point scale from 1(extremely easy) to 6 (extremely difficult)
25. How difficult was it losing weight at the start of the weight loss program? Rate your answer using a six point scale from 1(extremely easy) to 6 (extremely difficult)

**The following questions will assess the post- weight loss program phase of the NWLP**

26. How many days in a typical week of the past month did you do at least 30 min moderate activity or 15 min vigorous activity? Type of activity:
    Duration per day: number of days per week:
27. How many times do you currently weigh yourself? A. never B. <1 time per week C. ≥1time weekly but not daily D. daily
28. What method are you using to control your weight now? A. trying to lose weight using diet **and** physical activity B. trying to lose weight using diet **or** physical activity C. Trying to maintain weight using diet **and** physical activity D. Trying to maintain weight using diet **or** physical activity E. Neither trying to lose nor maintain weight
29. How frequently do you eat breakfast? A. daily B. not daily
30. Do you log physical activity? Yes/No
31. Are you currently exercising in the gym? 1. Never 2. Seldom 3. Sometimes 4. Often 5. Always
32. Do you keep a food log/journal? 1. Never 2. Seldom 3. Sometimes 4. Often 5. Always
33. Do you limit the amount of fat/oil consumed? Yes/No
34. Do you count calories? 1. Never 2. Seldom 3. Sometimes 4. Often 5. Always
35. Do you limit or avoid snacking throughout the day? Yes/No
36. Do you limit or avoid snacking in the evenings? Yes/No
37. Do you limit your food portion size at meals? Yes/No
38. Do you limit or avoid juices? Yes/No
39. Do you limit or avoid fizzy and sweetened drinks? Yes/No
40. Do you limit or avoid alcohol? Yes/No
41. Do you maintain consistent eating patterns across weekdays and weekends? Yes/No
42. Do you use shakes to replace your meals sometimes? Yes/No
43. Do you eat restaurant meals less than once per week? Yes/No
44. Do you eat out of home meals less than once per week? Yes/No
45. Do you eat at least 5 servings of fruits and vegetables per day? Yes/No
46. How do you assess your competence in carrying out the above behaviours listed in questions **29 to 45**? A. Excellent B. Good C. Acceptable D. poor E. Disappointing
47. Current weight (kg): ________ % fat________% hydration________ Please step on the available scale and weigh right now.

**Questions 48 to 72 will assess the barriers that have kept you from maintaining the weight you lost the very first time you enrolled in the Nutriline weight loss program.**

48. Is eating out a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
49. Is being at a party a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier

50. Is being on a trip a barrier that makes it hard for you to stick to a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
51. Is depression a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
52. Is stress a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
53. Is injury to self or family a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
54. Is lack of support from family a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
55. Is lack of support or pressure from friends a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
56. Is the fact that your food pattern differs from that of your family members keeping you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
57. Is a frequent feeling of hunger when on a weight management diet a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
58. Is your preference for junk foods whenever they are available and your inability to resist them a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
59. Whenever sweets, chocolates, candies, ice-cream, cakes, biscuits are available you are unable to follow a healthy eating plan thus unable to keep your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
60. Healthy foods are not delicious and this is a barrier that keeps you from following a healthy eating plan completely thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
61. Healthy eating is too expensive and this is a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
62. Healthy eating is too time consuming and this is a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
63. A healthy eating is too boring and this is a barrier that keeps you from following a healthy eating plan thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier

64. Exercise is too time consuming and this is a barrier preventing you from being physically active and thus keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
65. Feeling too tired to exercise is a barrier that keeps you from being physically active thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
66. Not having anyone to exercise with is a barrier that keeps you from being physically active thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
67. Lack of a place to do physical activity, exercise or sport is a barrier that keeps you from being physically active thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
68. Foot or other body pain is a barrier that keeps you from being physically active thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
69. Heavy body weight is a barrier that keeps you from being physically active thus preventing you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
70. Lack of interest in being physically active or exercising regularly is a barrier that keeps you from keeping your weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
71. Managing my weight is very difficult and this is a barrier preventing me from keeping my weight? 1. Not applicable 2. Not a barrier 3. Somewhat a barrier 4. A very important barrier
72. What is the one thing that makes it hardest for you to maintain your weight?
73. What is the number of weight loss attempts you made after your **first** program with NWLP?

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Baseline weight (Kg): Current weight (Kg): Height (m): Baseline BMI: Current BMI: Total weight loss from baseline to end of treatment (kg/%):
Total weight loss from baseline to now (kg/%): Total weight regain (kg/%):
NWLP chosen program duration: Actual duration of stay on NWLP (Weeks):
Length of time post NWLP: Attendance frequency: <50% OR ≥ 50%
Desired weight goal at the start of NWLP:

## Appendix B: Ethical approval certificate

**NOGUCHI MEMORIAL INSTITUTE FOR MEDICAL RESEARCH**
*Established 1979A Constituent of the College of Health Sciences*

**University of Ghana**

**INSTITUTIONAL REVIEW BOARD**

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My Ref. No: DF.22
Your Ref. No:

3rd July, 2019

**ETHICAL CLEARANCE**

**FEDERALWIDE ASSURANCE FWA 00001824** **IRB 00001276**

**NMIMR-IRB CPN 004/16-17 *amend. 2019*** **IORG 0000908**

On 3rd July, 2019 the Noguchi Memorial Institute for Medical Research (NMIMR) Institutional Review Board (IRB) at a full board meeting conducted continuing review and amended your protocol titled:

**TITLE OF PROTOCOL** : **Prevalence, perceived barriers, predictors and associated biomarkers of weight loss maintenance success among previous participants of a commercial weight loss program in Accra Ghana**

**PRINCIPAL INVESTIGATOR** : **Prof. Matilda Steiner-Asiedu**

**CO-P. INVESTIGATORS** : **Prof. Christina Nti, Dr. Jonathan Adjimani, Dr. Fredrick Vuvor & Sandra Ayisi Addo, MSc**

Please note that a final review report must be submitted to the Board at the completion of the study. Your research records may be audited at any time during or after the implementation.

Any modification of this research project must be submitted to the IRB for review and approval prior to implementation.

Please report all serious adverse events related to this study to NMIMR-IRB within seven days verbally and fourteen days in writing.

This certificate is valid till 2nd July, 2020. You are to submit annual reports for continuing review.

Signature of Chair: .......................................................
Mrs. Chris Dadzie
**(NMIMR – IRB, Chair)**

**Appendix C: consent form**

**NMIMR-IRB consent form**

**Title:** Prevalence, perceived barriers, predictors and associated biomarkers of weight loss maintenance success among previous participants of a commercial weight loss programme in Accra, Ghana.

**Principal Investigator**: Professor Matilda Steiner-Asiedu

**Address**: Dean, School of Biological Sciences, College of Basic and Applied Sciences, University of Ghana. Telephone: 0541260704 Email: tillysteiner@gmail.com

**General Information about Research**

This will be a research involving participants who completed the Nutriline Weight Loss Programme (NWLP) at least six months before the survey start date. This study seeks to evaluate the NWLP programme and understand your health behaviours before, during and after enrolment in the NWLP. This study will involve NWLP participants who: have baseline Body Mass Index greater than 25 at the time of enrolment into NWLP, are able to walk for exercise, and are medically fit (self- report) and are willing to participate in the study. Data to be collected will include demographics, socio-economic, measurement of your body weight, health status, lifestyle factors (dietary, exercise and weight management practices and behaviours), weight management challenges and biochemical data. Participants will spend an hour to complete a questionnaire and an additional one hour if you are selected for blood draw. In all questionnaire completion and blood draw will be done only once during the study period.

**Possible Risks and Discomforts**

You will complete a questionnaire, your body weight will be measured, and a sample of blood equivalent in volume to a teaspoon of blood will be drawn by a competent trained person from a registered laboratory to measure some biochemical parameters. None of these procedures are dangerous to your health.

**Possible Benefits**

This is the first time that a formal research is being done in Ghana to follow up on previous participants of a weight loss programme to evaluate their progress and to gain insights to improve the outcomes of the programme. By participating in the study you will be contributing towards a great cause in the understanding of the health behaviours of people previously on a weight loss programme and the use of such information in developing long term weight loss programme guidelines for the country. All these assessment together with the biochemical investigation will be carried out free of charge. Any person identified to have an abnormal biochemical data will be given dietary counselling for the management of the condition and referred to the nearest hospital/clinic for physician attention.

Additional costs: There will be no additional costs to you

Compensation: There will not be any compensation for participating in this study

**Confidentiality**

The privacy and confidentiality of the information you give us will be ensured. Codes will be used in place of names for all completed questionnaires and blood test results. Completed questionnaires and blood test results will be kept in a safe which will only be accessible to the research team. All questionnaires and printed blood test results will be destroyed after keeping for 5 years by shredding. All the findings of the study will be treated with utmost confidentiality and all reports made from the study will represent only in terms of the entire group. No name will be mentioned in any report.

**Voluntary Participation and Right to Leave the Research**

Your participation in the study is completely voluntary. You can decide to end your participation in the study right now and you will not be affected in anyway. If at any point in time/space during the study you decide not to participate further, you are at liberty to do so immediately without any further discussion and it will have no consequences whatsoever. If you agree to participate, you can refuse to answer any of the questions that we ask

**Notification of Significant New Findings**

We will inform you about any relevant findings after analysing the data we collect or inform you about some information you need to know. We will however reveal any information about you on demand. In addition anything we notice about you that needs immediate attention will be communicated to you.

**Contacts for Additional Information**

If you have any questions about the study or about your participation the first person to contact is Sandra Ayisi Addo, Tel: 020 812 4004, followed by Prof. Matilda Steiner-Asiedu, Tel: 0541260704, Prof. Christina Nti, Tel: 02444615310, Dr. Jonathan Adjimani, Tel: 0244799941, Dr. Fredrick Vuvor, Tel: 0244608344.

**Your rights as a Participant**

The proposal and other supporting documents have been reviewed and approved by the department of Nutrition and Food Science. The school of Biological Sciences has approved the topic and research area.

This research has also been reviewed and approved by the Institutional Review Board of Noguchi Memorial Institute for Medical Research (NMIMR-IRB). If you have any questions about your rights as a research participant you can contact the IRB Office between the hours of 8am-5pm through the landline 0302916438 or email address: nirb@noguchi.mimcom.org

**VOLUNTEER AGREEMENT**

The above document describing the benefits, risks and procedures for the research title (Prevalence, perceived barriers, predictors and associated biomarkers of weight loss maintenance success among previous participants of a commercial weight loss programme in Accra, Ghana) has been read and explained to me. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree to participate as a volunteer.

__________________________ __________________________________________

Date Name and signature or thumbprint of volunteer

**If volunteers cannot read the form themselves, a witness must sign here:**

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

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Date Name and signature of witness

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

-------------------------------- -----------------------------------------------------

Date Name Signature of Person Who Obtained Consent

**Appendix D: Individual barrier items for healthy eating related barriers subjected to CatPCA (n =230)**

| Individual barrier items | Median item score [IQR] |
|---|---|
| Eating out | 2.00 [2.00-4.00] |
| Being at a party | 2.00 [2.00-3.00] |
| Being on a trip | 3.00 [2.00-4.00] |
| Depression | 2.00 [1.00-3.00] |
| Stress | 3.00 [2.00-4.00] |
| Injury to self or family | 2.00 [2.00-3.00] |
| Lack of family support | 2.00 [2.00-3.00] |
| Lack of support or pressure from friends | 2.00 [2.00-2.00] |
| Differing food pattern from that of the family | 2.00 [2.00-3.00] |
| Preference for junk foods whenever they are available | 2.00 [2.00-3.00] |
| Inability to follow plan whenever sweets, chocolates, candies, ice-cream, cakes, biscuits are available | 2.50 [2.00-3.00] |
| Healthy foods are not delicious | 2.00 [2.00-3.00] |
| Healthy eating is too expensive | 2.00 [2.00-3.00] |
| Healthy eating is too time consuming | 2.00 [2.00-4.00] |
| Healthy eating is too boring | 2.00 [2.00-3.00] |

**Appendix E: Physical activity related barrier items subjected to CatPCA (n=230)**

| Individual barrier items | Median item score [IQR] |
|---|---|
| Exercise is too time consuming | 2.00 [2.00-3.00] |
| Feeling too tired to exercise | 3.00 [2.00-3.00] |
| Not having anyone to exercise with | 2.00 [2.00-4.00] |
| Lack of a place to do physical activity | 2.00 [2.00-2.00] |
| Foot or other body pain | 2.00 [2.00-3.00] |
| Heavy body weight | 2.00 [2.00-2.00] |
| Lack of interest in being physically active | 2.00 [2.00-2.00] |

**Appendix F: Barrier items not subjected to CatPCA (n=230)**

| Individual barrier items | Median item score [IQR] |
| --- | --- |
| Frequent feeling of hunger when on a weight management diet | 2.00 [2.00-4.00] |
| Perceived difficulty in managing weight | 3.00 [2.00-4.00] |