RESEARCH PROPOSAL

SPATIAL DISTRIBUTION OF OBESITY, ITS PREDISPOSING FACTORS AND ASSOCIATED COMPLICATIONS AT THE DIMAMO POPULATION HEALTH RESEARCH CENTRE, LIMPOPO PROVINCE, SOUTH AFRICA.

BY

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DISSERTATION

Submitted in fulfillment of the requirements for the degree of

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University of Limpopo

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DECLARATION

I, Cairo Bruce Ntimana, hereby declare that the dissertation titled **SPATIAL DISTRIBUTION OF OBESITY, ITS PREDISPOSING FACTORS AND ASSOCIATED COMPLICATIONS AT THE DIMAMO POPULATION HEALTH RESEARCH CENTRE, LIMPOPO PROVINCE, SOUTH AFRICA,** hereby submitted to the University of Limpopo for the Degree of Master of Science in Medical Sciences (Chemical Pathology) has not been submitted by me or any other person for any degree at this or any other University, and that it is my own work in design and in execution, and that all material cited herein has been duly acknowledged.

Signature:  Date: 10-03-2023

DEDICATIONS

This research is dedicated to my parents, Lucky Ntimana and Nikiwe Mabilane, who raised me and have always been supportive and encouraging.

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Abstract

Introduction: Obesity is a physical condition resulting from excessive fat storage in the body. Globally at least 2.8 million people die due to being overweight and obesity. Changes in life habits and patterns, such as dietary behaviors, advances in technology, beliefs, sedentary life, and a decrease in physical activities, increases obesity and weight gain among men and women Obesity has also been associated with socioeconomic status. The prevalence of spatial distribution of obesity and overweight has been shown to be high in urban areas and wealthier regions of the country.

Purpose: To profile obesity in terms of spatial distribution, new classifications, measurements of predisposing factors, and associated complications at DIMAMO Population Health Research Centre (PHRC), Limpopo Province, South Africa.

Methodology: This was a cross-sectional, retrospective study. The present study used secondary data from the AWI-Gen phase 1 study. The present study analysed 791 participants (242 males and 459 females). Data were analysed using the Statistical Package for Social Sciences version 27.

Results: The present study's findings showed a high proportion of obesity (35.4%) and central obesity (59.9%). The proportion of healthy obese by high BMI in the total population was 22.9% and the proportion of healthy obese by high WC in the total population was 23.6%. Obesity correlated negatively with smoking, alcohol consumption, single, and divorced status, and also correlated positively associated with married status. Central obesity correlated negatively with smoking, and also correlated positively associated with married status, and being unemployed.

The prevalence of obesity and central obesity was significantly higher in cluster A and B as compared to other clusters. Spatial distribution of general obesity and central obesity correlated with gender, smoking alcohol, consumption and married status

Conclusion: The prevalence of obesity and central obesity were both high in the study population. Obesity and central obesity were more common in the North-eastern villages clusters compared to the Western and Southern clusters> The distribution of Obesity seems to be determined by gender, smoking alcohol, consumption and married status.

Key concepts: obesity, central obesity, VAT, SAT, and socio-demographic profiles.

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DEFINITION OF TERMS

All terms defined below will be used as they are unless otherwise stated.

Body Mass Index is a simple weight-for-height index that is often used to categorize underweight, overweight, and obesity in adults (Martinson et al., 2020). In the context of this study, BMI will refer to the body weight divided by the square height of an individual.

Physical activity is any body movement requiring energy expenditure (Thivel et al., 2018). Physical activity was defined as bodily motions that cause the residents of DIMAMO to expend energy.

Physical inactivity is defined as a lack of physical exercise (Thivel et al., 2018). In the context of this study Physical inactivity referred to lack of bodily motions that demand energy expenditure by the DIMAMO residents.

Profiling – An analysis representing the extent to which something exhibits varying characteristics (Shu, Wang & Liu, 2018). In this study profiling referred to establishing the risk factors related to the development of obesity, to establish proper intervention.

Obesity is defined as an excess of body fat with a body mass index (BMI) of more than 30 kg/m2 (Phillips, 2013).

Central obesity is a medical disorder in which body fat builds up to a particular extent and may negatively impact health, consequently shortening life expectancy and degrading health (Zhang et al., 2016).

Spatial distribution is the arrangement of a phenomenon across the earth's surface, and a graphical display of such an arrangement is an important tool in geographical and environmental statistics (Hermon, 2020). In this study, spatial distribution was used to determine geographically where the participants live and to determine which villages had a high concentration of obesity.

ABBREVIATIONS

% - Percent

<- less than

> - Greater than

µL- Microlitre

ACR- Albumin-to-creatinine ratio

AWI-GEN – Africa Wits-IN-DEPTH Partnership for Genomic Research

BMI- Body mass index

CV- Coefficient of variation

CT- Computed tomography

eGFR- Estimated glomerular filtration rate

GIS- Geographic information science

GPS- Global positioning system

HDL-C- High density lipoprotein cholesterol

HDSS- Health Demographic Surveillance Site

LDL-C- Low density lipoprotein cholesterol

IQR- Interquartile range

IHD- Ischemic heart disease

Kg/m^2- Kilogram per meter squared

PHRC- Population Health Research Centre

RAS- Renin–angiotensin system

SIR- Standardised incidence ratio

SNS- Sympathetic nervous system

SPSS- Statistical Package for Social Sciences

SAT- Subcutaneous adipose tissues

SSA- Sub-Saharan Africa

TC- Total cholesterol

TG- Triglycerides

TREC- Turfloop Research Ethics Committee

VAT- Visceral adipose tissues

WC- Waist circumference

WHO - World Health Organization

CHAPTER 1

1.1 INTRODUCTION

Obesity is defined as a physical condition resulting from excessive fat storage in the body (Kotsis et al., 2010; Phillips, 2013). It is diagnosed by measuring body mass index (BMI), which is weight in kilograms divided by the square of the height in meters. Individuals with a body mass index of ≥30 kg/m^2 are considered obese (Martinson et al., 2020; Brewer and Balen, 2010). Obesity is also diagnosed by measuring waist circumference, visceral adipose tissue, and subcutaneous adipose tissue.

Between 1980 and 2014, the worldwide prevalence of obesity more than doubled (Rutter, 2018). Approximately 2.8 million individuals worldwide have passed on due to being overweight and obesity (Chu et al., 2018). Overweight and obesity account for around 2.3 percent of disability-adjusted life years (Shekar and Popkin, 2020). It is estimated that more than half of adults aged 35—65 years living in Europe are either overweight or obese (Hruby and Hu, 2015; Visscher et al., 2006; Seidell and Rissanen, 2003). The prevalence of obesity is higher in women than in men and higher in urban as compared to rural areas (Turi et al., 2013). Geographic Information Science (GIS) is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems, with the help of spatial distribution and manipulating of the data on which the maps are based (Penney, Rainham, Dummer & Kirk, 2014). The prevalence of spatial distribution of obesity and overweight has shown to be high in cities and well-off sections of the country. This may be due to food availability and a sedentary lifestyle (Turi et al., 2013).

According to Central Statistical Agency (2011), the highest prevalence of obesity rate in South Africa was 27% when compared to other Sub-Saharan African countries, including Mauritania (23.3%), Swaziland (23.1%), and Gabon (21.5%). (NIPORT, 2007 & Macro International 2009). Statistics have reported the prevalence of obesity in South Africa to be high in women (30%), compared to men (7.5%) (Puoane et al., 2002). The prevalence of obesity in Dikgale village was also reported to be higher in females (27.8%) than in males (10.6%) (Maimela et al., 2016). The prevalence of central obesity was higher in females (49.8%) than in males (7.8%). According to Pou et al., (2009), the prevalence of subcutaneous abdominal obesity (measured as high subcutaneous adipose tissue) was reported to be 30% in women and 31% in men,

whilst the prevalence of visceral obesity was reported to be higher in women (44%) as compared to men (42%).

Obesity has been reported to have multifactorial etiology. Changes in life habits and patterns, such as food habits, technological advancements, attitudes, and sedentary behavior, and a decrease in lifestyle physical activities, increases the prevalence of obesity and weight accumulation among women and men (Mehrabani, 2018). Moreover, obesity has also been associated with socioeconomic status, where higher prevalence is seen in those with lower education and income, particularly among women (Kim et al., 2016; Philipsen et al., 2015).

Studies of the spatial distribution of obesity have produced similar findings they have reported the prevalence of obesity to be high in cities and well-off sections of the country (Turi et al., 2013; Greves Grow et al., 2010). However, some studies have found the prevalence of obesity to be high in rural areas compared to urban areas (Babu Rao and Junapudi, 2019).

Obesity can lead to many complications, including hypertension, type 2 diabetes mellitus, coronary heart disease, insulin resistance, cardiovascular disease, colon and breast cancer (Kinlen et al., 2018; Jamison and Weltbank, 2006; Bray, 2004). Excess caloric intake causes adipose tissue to accumulate in the body, and as the amount of adipose tissue increases, so does the release of proinflammatory cytokines (Unamuno et al., 2019). Increased inflammatory cytokine release can result in chronic low-grade inflammation. Chronic low-grade inflammation disrupts or blocks normal insulin signaling pathways, resulting in insulin resistance (Unamuno et al., 2019). An increase or expansion of lipids in the body can cause atherosclerosis, which causes the artery lining to harden, thicken, and stiffen, accumulating deposits of calcium, fatty lipids, and abnormal inflammatory cells to form a plaque, resulting in a blockage of blood supply to the heart and coronary heart disease (Unamuno et al., 2019).

1.2 PROBLEM STATEMENT

For proper management of any disease, profiling is essential in establishing the risk factors and the consequences associated with the development of the disease and selecting a proper intervention. The prevalence of general and visceral obesity among the rural black population in Limpopo Province has been shown to be high. However, no studies show the prevalence of both high visceral adipose tissues (VAT) and subcutaneous adipose tissues (SAT) among these populations. Furthermore, there are no epidemiological studies of obesity since the introduction of the healthy obese, unhealthy obese, and obese with normal waist and new measurements or determination of obesity such as VAT and SAT. According to our knowledge, no study has evaluated the spatial distribution of obesity in South Africa. The aim of the present study is thus to profile obesity in terms of spatial distribution, new classifications, measurements of predisposing factors, and associated complications at DIMAMO Health and Demographic surveillance site (HDSS), Limpopo Province, South Africa.

1.3 CONCEPTUAL FRAMEWORK

Obesity is a complex condition that results from the interaction between genetics and environment (Marks, 2015). There are a number of hypotheses about what causes obesity, including the Circle of Discontent theory, which connects weight increase, body dissatisfaction, negative affect, and overconsumption (Marks, 2015). This theory contends that people overeat as a result of cognitive and emotional factors. Some people may have a hereditary predisposition to obesity or extreme thinness (Marks, 2015).

The figure below illustrates the factors that lead to the development of obesity and indicates which diseases are more likely to result from obesity. Individual factors, environmental factors, social factors, and lifestyle or behavioural factors lead to obesity and the deposition of fats in the body. Increased or accumulation of lipids can lead to insulin resistance, type 2 diabetes mellitus, and cardiovascular diseases.

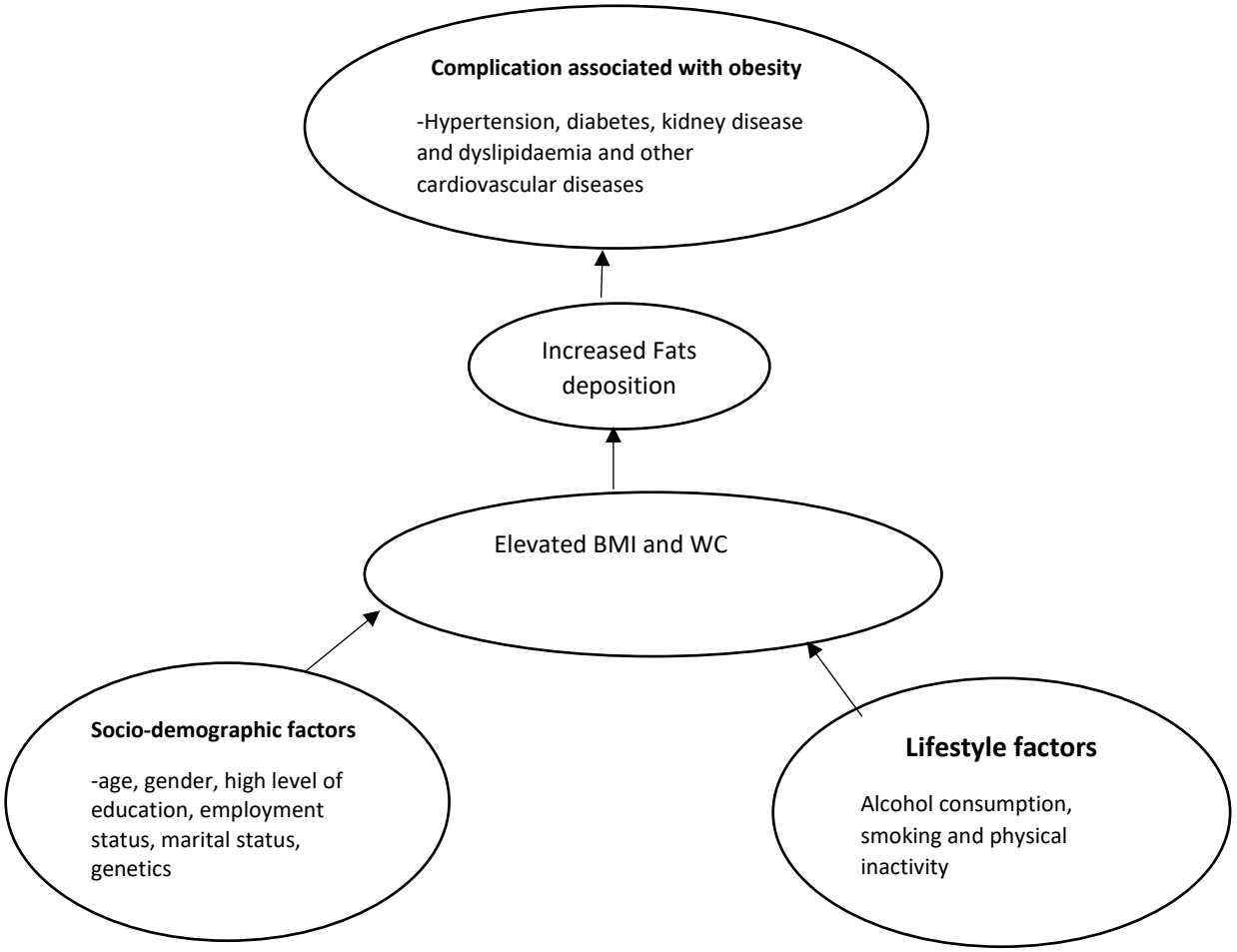

Figure 1. Shows factors that lead to obesity and how obesity leads to complications

1.4 Aim of the study

To determine spatial distribution of obesity and central obesity, associated complications and explore determinants of the distribution of obesity, at DIMAMO PHRC, Limpopo Province, South Africa.

1.5 Objectives of the study

1. To determine the prevalence of different types of obesity in the DIMAMO HDSS
2. To determine the socio-demographic determinants of obesity in the DIMAMO HDSS
3. To determine the complications of obesity in the DIMAMO HDSS
4. To determine spatial distribution of obesity in the DIMAMO HDSS
5. To determine the determinants of spatial distribution of obesity in the DIMAMO HDSS

1.6 Research question

- What is the spatial distribution of obesity types, and related determinants in DIMAMO HDSS, Limpopo Province, South Africa?

CHAPTER 2

2. LITERATURE REVIEW

This literature review consists of sections, namely, background information on obesity, prevalence, demographic factors and lifestyle associated with obesity, and lastly, the complications associated with obesity.

2.1 Background information on obesity

Obesity is defined as excessive fat accumulation in the body to the extent that it can negatively affect health (Schetz et al., 2019; Ulker and Yildiran, 2019). It is diagnosed by measuring the body mass index (BMI), which is weight in kilograms divided by the square of the height in meters. A person with a BMI greater or equal to 30 is generally considered obese (Mehrabani, 2018). Obesity can also be diagnosed by measuring the waist circumference; a measurement above ≥80 cm for women and ≥94 cm for men is considered centrally obese (Ahmad et al., 2016). This measurement is used to assess central or abdominal obesity (Ahmad et al., 2016; Parikh et al., 2007). Obesity can also be determined by the measurement of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) (Ng et al., 2012). Visceral adipose tissue, linked with the metabolic consequences of obesity, is usually characterised by measuring the VAT area at the L4-L5 vertebral interspace and is frequently measured using computed tomography (CT). The optimal cut-off values for the visceral fat area are reported to be 134.6 cm^2 and 91.1 cm for men and women, respectively (Lee et al., 2018).

According to Störchle et al., (2018), ultrasound provides the most accurate technique for thickness measurements of subcutaneous adipose tissue layers, the subcutaneous tissue thickness ranges from 1.65 mm to 14.65 mm in males, whereas it is from 3.30 mm to 18.20 mm in females. Metabolically healthy obesity refers to an obesity phenotype with no or little evidence of metabolic dysfunction, but with affected individuals having a BMI of ≥30 kg/m^2 (Magkos, 2019; Blüher, 2014). Lower liver fat content and visceral adipose tissue, greater insulin sensitivity and secretion, greater cardiorespiratory fitness, and a predominantly lower body fat deposition are key physiological traits of a metabolically healthy phenotype (Magkos, 2019; Blüher, 2014, 2012). Metabolically unhealthy obesity refers to individuals with a body mass index (BMI) of ≥30 kg/m^2 and showing symptoms associated with a risk of diabetes mellitus,

cardiovascular diseases, and malignancies (Jung et al., 2017). Individuals with a body mass index (BMI) of ≥30 kg/m^2 and a normal hip ratio, or waist circumference of 94cm and 80cm in men and women, respectively are considered obese with normal waist. Individuals with a body mass index (BMI) of ≥30 kg/m^2 and a waist circumference greater than 120 cm for men and 110 cm for women puts these individuals at extremely great danger for obesity-related health issues (Ahmad et al., 2016; Parikh et al., 2007).

2. 2 Prevalence of obesity

Obesity is one of the leading preventable causes of death worldwide, with increasing rates in adults and children (Babu Rao and Junapudi, 2019). Between 1980 and 2014, the worldwide prevalence of obesity more than doubled (Rutter, 2018). Approximately 2.8 million individuals worldwide have passed on due to being overweight and obesity (Chu et al., 2018). Obesity continues to be global health issue in both developed and developing countries. In low-income countries, obesity is generally more prevalent among middle-aged adults from wealthy and urban environments (especially women); whereas, in high-income countries, it affects both sexes and all ages, but its more prevalent among disadvantaged groups (Cois and Day, 2015; Seidell and Rissanen, 2003; Filozof et al., 2001; Anekwe et al., 2020; Nam et al., 2020; Jaacks et al., 2019; Seidell and Flegal, 1997).

According to Central Statistical Agency (2011), in sub-Saharan Africa (SSA), the prevalence of obesity differs widely from as low as 1% in Ethiopia to as high as 27% in South Africa. Apart from South Africa other countries in sub –Saharan Africa (SSA), only three reported a national obesity prevalence of over 20%, namely Mauritania (23.3%), Swaziland (23.1%), and Gabon (21.5%) (NIPORT, 2007 and Macro International 2009). In South Africa, the statistics have reported the prevalence of obesity in all women over the age of 15 years to be above 30%, which is more than three times higher than the prevalence in men 7.5% (Micklesfield et al., 2013; Puoane et al., 2002). The most affected population group was black women, with a prevalence of 31.8%, 22.7% in white women, 21.1% in Indian women, and 26.3% in women of mixed ancestry (Micklesfield et al., 2013). Sengwayo et al., (2012) indicated a higher prevalence of obesity in Limpopo Province about 40.8% of the population in Ga-Mothapo villages.

According to Maimela et al., (2016) the prevalence of obesity in Dikgale village was reported to be higher in females (27.8%) than in males (10.6%). Females ages 45-64 years had the highest prevalence of obesity in the age group (Maimela et al., 2016). The prevalence of obesity in females showed an increasing trend from 13.6% in the age group 15–25 years to 41.9% in the age group 55–64 years (Maimela et al., 2016). The prevalence of high waist circumference was found to be 34.6% of the total population, with females having a higher prevalence (49.8%) than males (7.8%) (Maimela et al., 2016). The prevalence of subcutaneous abdominal obesity (high SAT) was reported to be 30% in women and 31% in men, whilst the prevalence of visceral obesity was reported to be higher in women (44%) as compared to men (42%) (Maimela et al., 2016; Pou et al., 2009).

The geographic information system (GIS) has accelerated the use of mapping as an epidemiological tool by automating the production of disease maps and by enabling users to spatial referencing and manipulation of data on which maps are based (Wang and Xie, 2018; Worboys and Duckham, 2004). The global upward trend of overweight and obesity shows 58% (males) and 55% (females) of Nova Scotia communities have higher than expected rates of overweight and obesity (Penney et al., 2014). Communities in the provincial capital region had higher rates of obesity and overweight compared to rural areas. This indicates that the neighboring communities had similar rates (i.e., high spatial autocorrelation), the behavioral determinants of overweight and obesity also cluster (Penney et al., 2014).

Obesity and overweight in Uganda are reported to be high in urban areas and wealthier regions of the country (Turi et al., 2013). Being overweight and obese is associated with higher age, living in an urban area, and increased wealth. The Southwest region and the capital city of Kampala show the highest rates of obesity, with the rate of overweight reaching 40% (Turi et al., 2013). The Southwest has a high prevalence of overweight because of its relative political stability, a greater presence of tourism and nongovernmental organisations that provide economic support and supplemental nutrition, increased economic opportunities, higher rainfall and cash crop yields, and a subsequent higher level of food security (Turi et al., 2013). Furthermore, these factors have led to better education and higher wealth, which correlate with higher weight status in Uganda.

2.3 Factors associated with the development of obesity.

Being overweight increases with age, at least up until age 50-60 in men and women. Women have a generally higher prevalence of obesity compared to men, especially when older than 50 years of age (Chen et al., 2018; Seidell and Flegal, 1997). Ethnicity has been reported to be associated with the risk of obesity. The prevalence of obesity is 24.8% among Californian adults, with Whites (22.0%), Latinos (33.6%), and African Americans (36.1%) having a higher prevalence of obesity while Asians had a lower prevalence (9.8%) (Gong et al., 2021). Several studies reported the prevalence of obesity to be high in rural areas and compared to urban areas (Marques et al., 2018; Befort et al., 2012). The prevalence of obesity was higher in secondary schools than in tertiary institutions and a much higher rate of dropout students or people who are not educated at all (Dinsa et al., 2012). Individuals who are employed are less at risk of being obese than people who are not working (Dinsa et al., 2012).

2.4 Lifestyle associated with obesity.

Changes in life habits and patterns, such as dietary behaviors, advances in technology, beliefs, and sedentary life increase and decrease lifestyle physical activities, and increase obesity and weight gain among men and women (Mehrabani, 2018). Smoking has a significant effect on an individual's weight as smoking lowers body weight and cessation increases body weight (Wang et al., 2021; Yammine et al., 2021). Those who quit smoking gain an average of 4.4 kilograms for men and 5.0 kilograms for women over ten years. However, changing smoking rates have had little effect on the overall rates of obesity (Yammine et al., 2021).

Alcohol consumption is unclear in most populations; however, moderate alcohol consumption is sometimes associated with a higher body mass index (Traversy and Chaput, 2015) recorded the energy intake from alcohol when individuals had their highest intake. The risk of obesity was 70% higher in the heaviest drinking group compared to the lightest. These individuals had obtained ≥ 75% of their total daily energy intake from alcohol compared to the lightest group, which had < 24% of their daily energy intake from alcohol on their heaviest drinking day (Chung and Kim, 2020; Traversy and Chaput, 2015). Alcohol inhibits fat oxidation, further stating that frequent alcohol consumption could lead to fat accumulation and thus higher body fat in the

long term (Adams and Wijk, 2021; Traversy and Chaput, 2015). Alcohol consumption is directly associated with waist circumference and a higher risk of abdominal obesity in men, but not in women (Agnoli et al., 2018; Schröder et al., 2007). After controlling for energy under-reporting, which has slightly reduced these associations, it was observed that increasing alcohol consumption significantly increased the risk of exceeding recommended energy intakes in male participants (Agnoli et al., 2018).

Regular moderate physical activities such as walking, cycling, or participating in sports have significant benefits for health, and they are highly recommended for preventing and combating diseases of lifestyle (Alvarez-Pitti et al., 2020). Physical activity has been reported to be one of the significant treatments or preventative measures of obesity because it reduces body weight, improves cardiorespiratory fitness, reduces the circulation of lipids, decreases liver fat accumulation, reduces deposition of fats in adipose tissues, and increases lipolysis and lastly it maintains muscle mass and increases the uptake of glucose (Swift et al., 2018). little or no physical activity, diet, genetics, culture, and drinking alcohol, have been reported to be associated with the increased deposition of fats in the fatty tissues, which can result in increased levels of fats in the visceral adipose tissues and subcutaneous adipose tissues (Philipsen et al., 2015).

2.5 Complications associated with obesity.

Obesity and associated non-communicable diseases such as type 2 diabetes, hypertension, and ischaemic heart disease (IHD), which were previously thought to be a problem only in affluent countries (Jiang et al., 2016; Du et al., 2013; Kotsis et al., 2010), are now becoming more prevalent among all population groups in South Africa (Jiang et al., 2016). Obesity is a major risk determinant for high blood pressure, diabetes mellitus, and other morbidities that contribute to the development of kidney disease because it primarily increases tubular reabsorption, impairing pressure natriuresis and causing volume expansion via SNS and RAS activation (Jiang et al., 2016; Hall et al., 2014; Chen et al., 2013; Bray, 2004). Furthermore, obesity causes cardiovascular and renal diseases via a variety of mechanisms, including hypertension, hyperglycemia, inflammation, dyslipidemia, and atherosclerosis, all of which can coexist, especially in the presence of excess visceral fat (Jiang et al., 2016; Kotsis et al., 2010).

Obesity is a growing epidemic that threatens to overwhelm health-care resources by increasing the prevalence of diabetes mellitus, heart disease, high blood pressure, cancer, and chronic kidney disease (Kinlen et al., 2018; Jamison and Weltbank, 2006; Bray, 2004). As the obesity prevalence begins to rise, as does the burden of its associated co-morbidities. Non-communicable diseases and their risk factors, such as obesity, are now a major concern not only in urban areas but also in underdeveloped nations (Kinlen et al., 2018).

Excess caloric intake leads to the accumulation of adipose tissues in the body, and as the amount of adipose tissue increases it also increases the release of proinflammatory cytokines (Unamuno et al., 2019). Increased release of inflammatory cytokines can lead to the development of chronic low-grade inflammation. Prolonged chronic low-grade inflammation blocks or interferes with the normal insulin signaling pathways, leading to insulin resistance (Unamuno et al., 2019). An increase or expansion of lipids in the body can lead to atherosclerosis. This due to the artery's lining becoming hard, thick, stiff, and accumulating deposits of calcium, fatty lipids, and abnormal inflammatory cells to form a plaque. This results in the blockage of blood supply to the heart of which can result in coronary heart disease and cardiovascular disease (Unamuno et al., 2019; Eshtehardi et al., 2012).

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1 Research design

The proposed research was a cross-sectional, retrospective study. Cross-sectional is a study whereby data is collected once from the participants with no intervention (Caruana et al., 2015). The present study was cross-sectional as data collection will be performed once. A retrospective study uses existing data that have been recorded for reasons other than research (Caruana et al., 2015). The present study was retrospective since the data used secondary data. The study used AWI-gen phase 1 and the data was collected from 2014 to 2018. The researcher was employed as a research assistant for the AWI-gen project Phase 2 project, the researcher's duties were to assist with data collection, process of field sample meterialin the laboratory and degitizing of datasheets. (*See APPENDIX V*).

3.2 Study site

The DIMAMO Population Health Research Centre (PHRC), is situated approximately 40km from Polokwane, the headquarters of Limpopo Province, and slightly closer to the University of Limpopo Turfloop campus. The site is located between 29.65° and 29.85°E, and 23.65° and 23.90°S. The PHRC is located on a high plateau area (approximately 1250m above sea level) where communities typically consist of households clustered in villages, with access to local land for small-scale food production.

The figure below illustrates the South African map and where Limpopo province is situated and where the DIMAMO HDSS is located in the province and lastly the villages used in the present study.

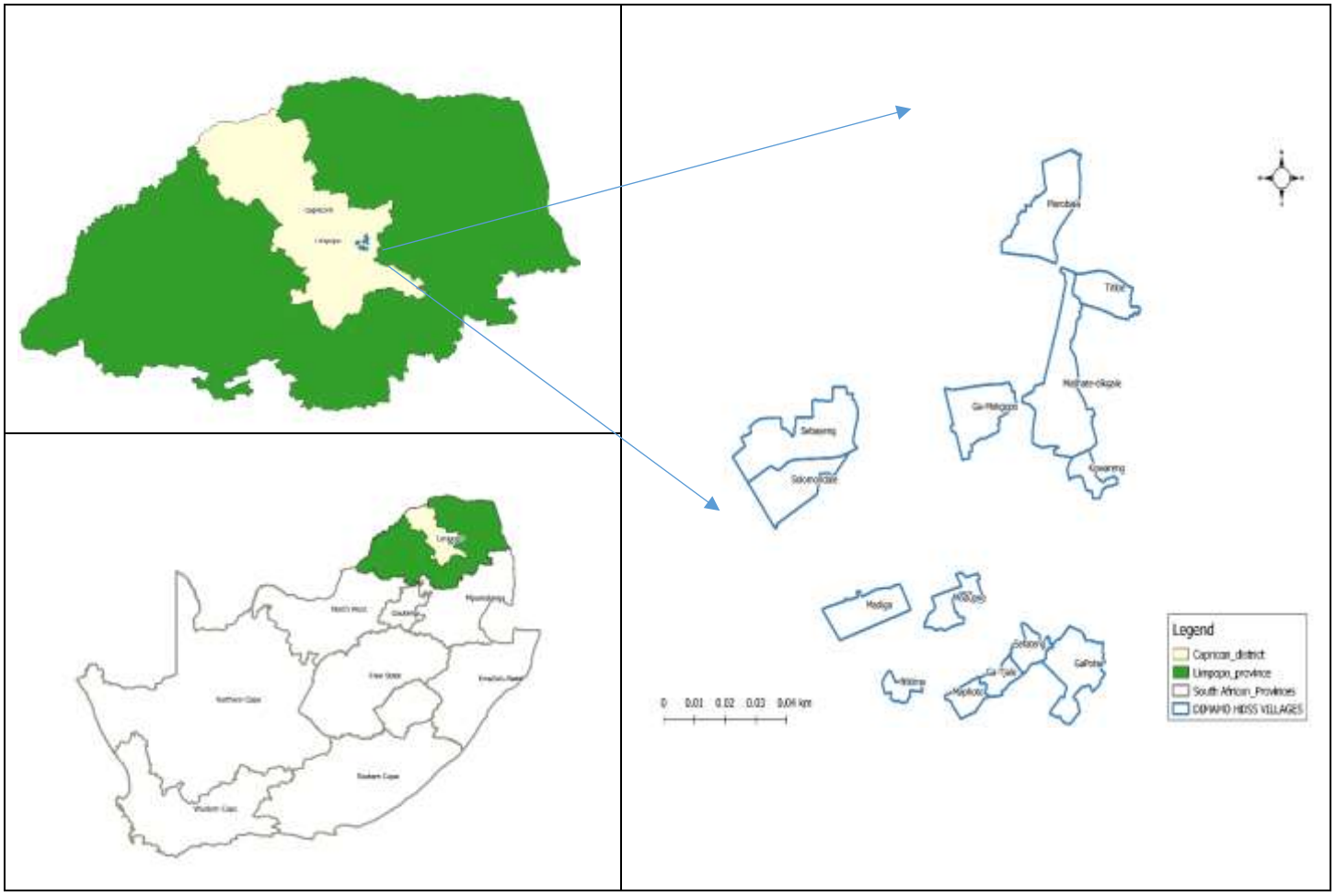

Figure 2: study site

3.3 Study population

The target area has an estimated population size of about 40000 (Alberts et al., 2015). The population comprised of participants who participated in the AWI-Gen1: genomic and environmental risk factors for cardio metabolic disease in Africans.

3.4 Sampling design

Participants were selected using convenient sampling. Convenient sampling refers to the inclusion of the participants as they availed themselves and satisfied the requirement (Asif, 2022). The selection of participants' data for the study was not random, participant's data was selected according to its availability.

3.5 Sample size

A survey research helps in collecting data that is representative of population. In a survey, a researcher uses information gathered from the survey to generalize findings from a drawn sample back to a population, within the limits of random error (Suresh &

Chandrashekara, 2015). The formula used by these authors in the article titled Determining sample size for research for proportion in survey type of studies

$$N = \frac{Z^2_{\alpha/2} * P * (1-p) * D}{E^2}$$

Where:

N= Total number of subjects

$Z_{\alpha/2}$ = represent type 1 error (1.96)

P= Prevalence of condition obesity (0.7). A study by Ringane and Choma, (2021), reported a higher prevalence of obesity 65% amongst rural black population in Limpopo province

D = is the design effect. D is the design effect reflects the sampling design used to in a survey type of study (Suresh & Chandrashekara, 2015). Sampling method be will convenience sampling hence D equals to 10

E = is the error of estimation (0.05)

N= $(1.96)^2(0.7)\ (1-0.7)\ (10)/(0.07)^2$

N=1 646

Since the study is retrospective we could not change the sample size of the original study which consisted of 1400 participants, however due to participants with incomplete record the present study consisted of 792 participants.

3.6. Inclusion criteria

All data of participants who participated in the AWI-Gen phase 1 project conducted in the DIMAMO PHRC.

3.7 Exclusion criteria

Participants with incomplete data needed for the present study were excluded.

3.8 Data collection

The present study was retrospective thus secondary data was used. The data of variables of interest were extracted from the database using an extraction tool.

(See APPENDIX I)

The data was collected using a structured questionnaire and laboratory analysis. The AWI-Gen questionnaire was designed using REDCap (Research Electronic Data Capture) and it consisted of both closed and open-ended questions was used to collect data. The questionnaire covered demographic factors, socioeconomic status, and lifestyle (Ali et al., 2018).

(*See APPENDIX* II)

3.9 Determination of prevalence of obesity and its subtypes

3.9.1 Anthropometric measurements

The body height was measured using a stadiometer manufactured by Omron Healthcare (INC, CHINA), whereby participants stepped onto the stadiometer with the back of the head, shoulder blades, buttocks, and heels touching the stadiometer with a small gap between the legs (10cm) and feet straight ahead. The head of the stadiometer was lowered so that the hair is pressed flat and the reading of the height was done from eye level and the height was recorded to the resolution of the stadiometer. weight was measured without shoes, heavy outer garments, and hair ornaments.

Before body weight could be measured, participants were told to remove heavy outer garments, take off their shoes and empty their pockets. The participants stepped and stood still in the Centre of the platform of the electronic scale or beam-balanced scale with a 10 cm gap between the heels, with the weight equally distributed on both legs. The weights were moved until the beam was balanced and the weight was recorded to the resolution of the scale. The participants' Body mass index (BMI) was calculated. BMI is an individual's weight in kilograms divided by the square of the height in meters.

Waist circumference measurements were made using a measuring tape (SECA, Hamburg, Germany), with the participants standing and arms slightly up. The researcher aligned the tape measure at the level of the belly button, and circle the whole way around the body and back to the starting point.

3.9.2 Measurements of visceral adipose tissue and subcutaneous adipose tissue

Visceral adipose tissue was measured as the distance in centimeters between the peritoneum and spine, when there was a clear space between the vertebra and the

aorta, using the LOGIQ-e ultrasound system (GE Healthcare, CT, USA) (Figure 1). Subcutaneous adipose tissue thickness was measured as the depth (cm) from the skin to the linea alba. Both measurements were made where the xiphoid line crosses the waistline (Figure 1). Visceral fat was measured using a 4C abdominal convex transducer placed longitudinally and subcutaneous fat with a 9L small parts linear transducer placed transversely.

The participants were asked to lie down on the provided bed. The gel was applied to the participants' lower abdomen to expose the peritoneum and spine. The probe was positioned in the midline at the level midway between the lower costal margin and the iliac crest. Xiphi-sternum and umbilicus were used as guides to accurate positioning. The spine was positioned horizontally and the vertebra was centrally in the image. Visceral adipose tissue measurements were taken only at baseline. A 3.5 MHz transducer was transversely positioned 1 cm above the umbilical scar on the abdominal midline without exerting any pressure over the abdomen. Visceral fat thickness attempted corresponding to the measurement in centimeters between the internal surface of the abdominal rectus muscle and the posterior aortic wall in the abdominal midline during expiration. Subcutaneous abdominal fat thickness was measured on the same location but on a transverse plane and was defined as the depth from the cutaneous boundary to the linea alba.

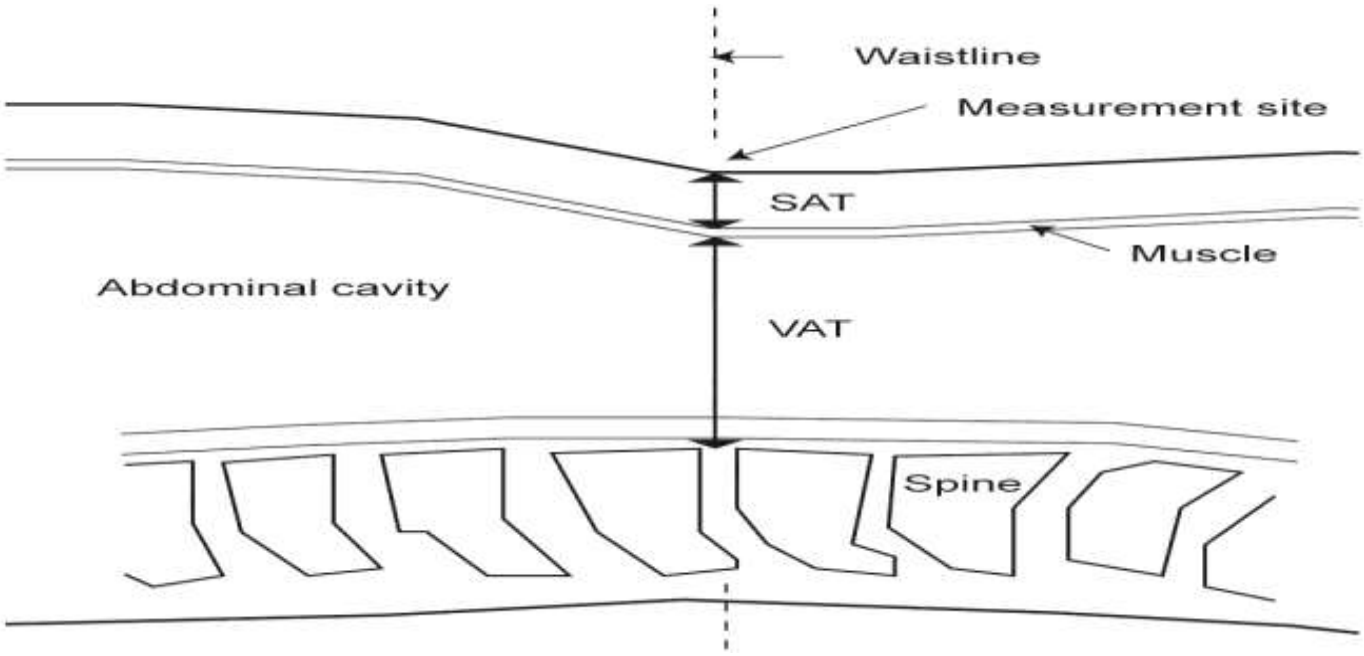

Figure 3: Measurement of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) with ultrasonography. Both measurements were performed where the xiphoid line crosses the waistline.

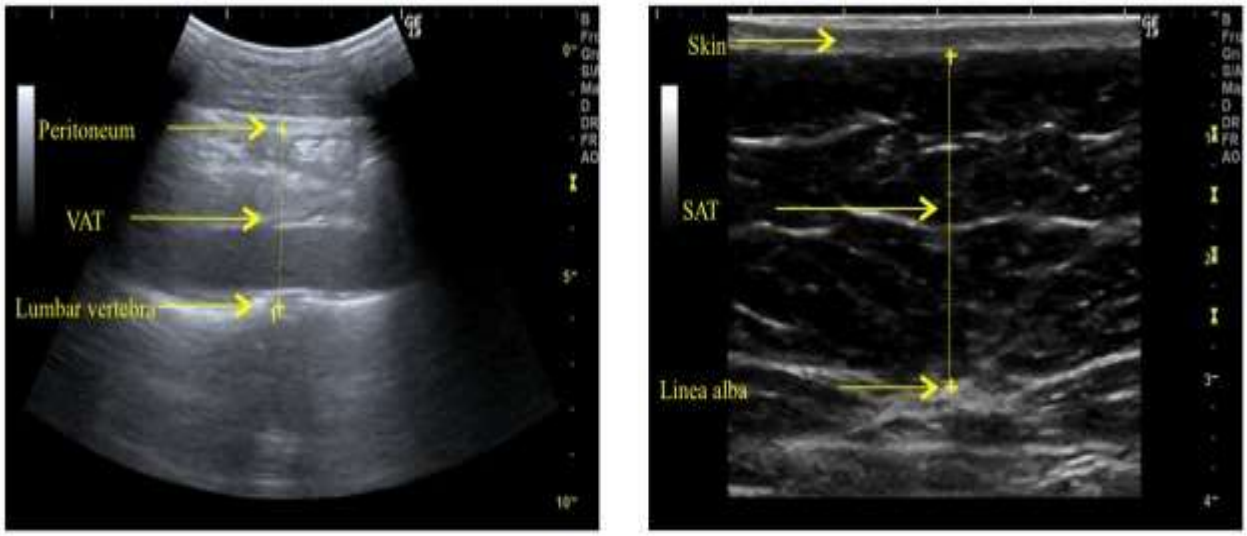

Figure 4: Ultrasound images of the visceral adipose tissue and SAT (Philipsen et al., 2015). The peritoneal and lumbar vertebra are indicated as well as the area in which VAT is measured. Skin and linea alba are indicated as well as the area in which SAT is measured.

3.10 Determination of determinants of obesity

Determinants of obesity were collected using an AWI-Gen questionnaire with both closed and open-ended questions. The variable included age, gender, highest level of education, marital status, employment status, smoking status, alcohol consumption status, diet with high carbohydrates, physical inactivity, frequent eating, genetics, social issues, and environmental factors.

3.11 Determination of complications of obesity

3.11.1 Measurement of blood pressure

The health care professional or qualified nurse wrapped an inflatable cuff around the participant's arm. Then inflates the cuff, which gently tightens on the participant's arm. The blood pressure was then measured using Omron blood pressure monitors (manufactured by Omron Healthcare CO. Japan). In a semi-automated blood pressure monitor, the inflation bulb was squeezed until the cuff inflates till the monitor

acknowledged the right amount of pressure. In fully automated monitors all the nurses had to do was to put on the cuff on participants and press start the button. The monitor will automatically handle the inflation and deflection of the cuff and display the blood pressure reading on the screen. Blood pleasure was measured while the participants were seated. Take multiple readings with five intervals between them until you get a consistent value because various factors like movement or talking can cause considerable fluctuation in the blood pressure values in each reading. Blood pressure within +/-3 mmHg or 2 percent and pulse within +/-5 percent of reading were considered.

3.11.2 Blood collection

Qualified nurses collected blood samples from the participants using yellow or green and grey blood collection tubes. Grey top blood collection tubes which contain sodium fluoride were used to collect plasma for glucose determination. Yellow top blood collection tubes were used to collect serum for the determination of serum lipids.

3.11.3 Laboratory analysis

The stored serum and plasma samples were analysed by the Chemical Pathology Laboratory, Department of Pathology and Medical Science, at the University of Limpopo.

3.11.3 Determination of total cholesterol (TC) levels

Serum TC was measured using an automated spectrophotometry method on an AU 480 auto-analyser supplied by Beckman Coulter, which was calibrated, using a standard reference material (system calibrator).

Method procedure: 24 µL of the reagent 1 and 0 µL of reagent 2 were mixed with 96 µL and 0 µL of diluent, respectively. The reaction mixture was amalgamated with 1.6 µL of the sample and incubated for 600 seconds at the wavelength 540 nm.

Principle and method performance of the method (Appendix III).

3.11.4 Determination of high-density lipoprotein cholesterol HDL-C

Serum HDL-C was measured using an automated spectrophotometry method on an AU 480 auto-analyser supplied by Beckman Coulter, which was calibrated, using a standard reference material (system calibrator).

Method procedure: 144 µL of the reagent 1 and 48 µL of reagent 2 were mixed with 0 µL and 0 µL of diluent, respectively. The reaction mixture was amalgamated with 1.6 µL of the sample and incubated for 700 seconds at 600 nm.

Principle and method performance of the method (Appendix III).

3.11.5 Determination of triglycerides (TG) levels

Serum TG was measured, using an automated spectrophotometry method on an AU 480 auto-analyser supplied by Beckman Coulter, which was calibrated, using a standard reference material (system calibrator).

Method procedure: 66 µL of the reagent 1 and 17 µL of reagent 2 were mixed with 57 µL and 10 µL of diluent, respectively. The reaction mixture was amalgamated with 1.6 µL of the sample and incubated for 800 seconds at the wavelength, 660 nm.

Principle and method performance of the method (Appendix III).

3.11.6 Calculation of low- density lipoprotein cholesterol (LDL-C) levels

The measurements of TC, HDL-C, and TG were used for the calculation of LDL-C by the Friedewald formula (Reiber et al., 2020).

- In mmol/L: LDL-C = (TC) - (HDL-C) - (TG/5)

The formula was not applicable at TG concentrations greater than 4.5 mmol/L.

3.11.7 Determination of blood glucose

Glucose was determined using an AU480 auto-analyser supplied by Beckman Coulter. Method performance: 40 µL of the reagent 1 and 20 µL of reagent 2 were mixed with 120 µL and 20 µL of diluent, respectively. The reaction mixture was amalgamated with 1.6 µL of the sample and incubated for 660 seconds at the wavelength 340 nm. Principle and method performance of the method (Appendix III).

3.11.8 Determination of eGFR and ACR

Morning urine sample was also collected and stored at −80°C. Urinary albumin concentration was measured with immunoturbidimetry and creatinine concentration was measured with Jaffe's kinetic method. The estimated glomerular filtration rate (eGFR) was calculated as 175× (Scr)−1.234 × (Age)−0.179 × (if female, × 0.79). The urinary albumin to creatinine ratio (ACR, mg/mmol) was calculated as urinary albumin divided by urinary creatinine.

3.12 Diagnosis

3.12.1 Diabetes mellitus diagnosis

The normal fasting blood glucose level was <5.6 mmol/L (Park et al., 2021). Participants with history of diabetes mellitus and having glucose levels of ≥7.0 were considered diabetic (Alam et al., 2021).

3.12.2 Obesity diagnosis

Individuals with a body mass index of ≥ 30 kg/m^2 were considered obese and those with a body mass index < 30 kg/m^2 were consider non obese (Mashinya et al., 2018; Mehrabani, 2018)

3.12.3 Normal waist circumference

The optimal cut-off values for WC 94 cm in men and 80 cm in women. Central obesity was defined as a waist circumference ≥80 cm for women and ≥94 cm for men(Ahmad et al., 2016)

3.12.4 Healthy obese diagnosis

Individuals with a MBI of over 30 kg/m^2 and a waist circumference ≥80 cm for women and ≥94 cm for mem, but they did not have high blood pleasure, diabetes mellitus, cardiovascular diseases and high cholesterol they were considered being metabolically healthy obese.

3.12.5 Normal cut-off values VAT and SAT

The optimal cut-off values for VAT are 6.5cm and 5.0cm for men and women, respectively (Lee et al., 2018).The subcutaneous adipose tissue cut of value was1.82cm in males, whereas 1.46cm in females (Störchle et al., 2018).

3.12.6 Hypertension diagnosis

Normal adult blood pressure is defined as a systolic pressure of less than 120mmHg and diastolic less than 80mmHg (Jose et al., 2019). Individuals with the history of hypertension or blood pressure that is either >140 systolic mmHg or >90 diastolic mmHg i.e. defined as 140/90 mmHg or above were considered to be hypertensive (Jose et al., 2019).

3.12.7 Dyslipidemia diagnosis

Normal cut-off values for serum lipid was total TC level <5.00 mmol/L, TG level <1.7 mmol/L, LDL-C level <3.0 mmol/L, and HDL-C >1.0mmol/l for men and >1.3mmol/l for women (Klug et al., 2018, 2015). The optimal cut-off values for lipid ratios was TC/HDL-C <5.3 mmol/l, TG/HDL-C <4.70 mmol/l for men and <3.7 mmol/l for women (Hadaegh et al., 2010). Individuals with at least serum total increased TC,TG,LDL-C and reduced HDL-C and increased levels of TG/HDL-C , TC/HDL-C and LDL-C/HDL-C were considered to be having dyslipidaemia in the present study (Magwai et al., 2022).

3.12.8 Diagnosis of Chronic kidney disease

The optimal value for eGFR was 60 mL/min/1.73m2 and for ACR was 30mg/mol. Choric kidney disease was defined as a decreased eGFR mL/min/1.73m2 and/or ACR ≥ 30 mg/mmol (Fabian et al., 2022).

3.13 Data analysis

3.13.1 Statistical analysis

Data was analyzed statistically using Statistical Package for Social Sciences (SPSS) version 27.0 software. The distribution of variables was determined. Continuous variables, which were normally distributed, were expressed as the mean ± standard deviation, and continuous variables that were not normally distributed were expressed as the median, interquartile range (IQR) and were transformed using log form to

change it to a normal distribution before applying the inferential statistical tests. All categorical characteristics of the participants were expressed as percentage while continuous characteristics of the participants were expressed as mean ± 2SD. A comparison of proportions was performed using Chi-Square whilst a comparison of means was performed using an unpaired student -t-test. Bivariate correlation and, partial correlation, were used to describe the association between obesity and its determinants, and also do determine the complications associated with obesity. Logistic regression was used to determine the association between obesity and its determinants and also to determine the complication that are associated with obesity. Logistic regression with the backward condition was used to determine the determinants of obesity per cluster. In the regression model, either obesity or central obesity was the dependent variable, and the covariates included were socio-demographic variables (age, sex, educational status, employment status, and marital status status), and lifestyle variables (smoking, and alcohol use). These covariates were reported to be determinants of obesity in literature. The p- value of 0.05 or less was considered significant.

3.14 Determination of Spatial distribution of obesity

The spatial analysis was limited to stratifying the prevalence of obesity by clusters. Spatial distribution of obesity/central obesity was done by comparing the distribution of risk factors across each clusters and correlation between risk factors and obesity/central obesity.

The present study was conducted in the DIMAMO HDSS where data on participants' residential addresses or households, work, birth history, fertility preferences, breastfeeding, and vaccinations have been collected. The participant's residential address and geographical position were extracted from the HDSS database.

Spatial data was collected using a global positioning system (GPS). The GPS data collection was done with a dedicated GPS unit, which communicates with a constellation of satellites to measure the position of the GPS unit on the earth's surface. Geocoding is the key method in generating spatial information for public health data. Geocoding refers to the process of converting addresses into geographical coordinates, which can be stored in a GIS database and mapped. It

allows researchers to add spatial locational information to observations in a health database using existing fields that have already been collected.

The acquired spatial data of participants was analyzed using Quantum GIS version 3.6, which is a software used to capture, store, manipulate and analyses geographically referenced data. The spatial analysis involved visualization of percentages of prevalence of obesity and central obesity using natural breaks classification method. The method was used to for visualize data specific classifications derived from the prevalence of obesity and central obesity.

3.15 Reliability and validity

3.15.1 Reliability

Reliability is the extent to which any measurement, test, or measuring procedure produces the same results in repeated trials (Hopkins et al., 2019). A questionnaire is considered reliable if it produces persistent results, and it must be accurate and precise (Hopkins et al., 2019). To ensure the reliability and validity of the questionnaire, a pilot study was conducted among 15 participants from previous AWI-Gen projects (Ali et al., 2018).

Laboratory methods are considered reliable if they can produce the same results when the method is repeated. Reliability was determined by checking the inter-assay and intra-assay co-efficient of variations of each method.

Intra- assay means the method will be used to determine the concentration of the same sample several times in one run and calculate the co-efficient variation.

Inter-assay means the method will be used to determine the concentration of the same sample several times in more than one run and calculate co-efficient variation.

Co-efficient variation was calculated by using the equation:

- CV= (SD/mean)*100
- The method is considered reliable if the CV equals to or below 5%

3.15.2 Validity

Validation of Demographic lifestyle and Anthropometric measurements

The demographic and lifestyle data and measurement of the anthropometric data and ultrasound measurements were manually entered into a Redcap database on a "Mac Mini" computer installed at each of the centers. Before transferring the data to the AWI-Gen collaborative center, data clerks at each center verified the accuracy of 10% of all entries by comparing the paper form to the electronic version, looking for outliers and missing data in accordance with their own internal data management and quality control processes. (Ali et al., 2018).

Validation of laboratory methods

Validity is defined as the extent to which any measuring instrument measures what it is intended to measure (Hopkins et al., 2019). All laboratory tests, were conducted and captured at University of Witwatersrand. As I was with other data, laboratory data was also subjected to internal data management and quality control processes where outliers and missing data were identified and corrected. Accuracy was ensured by using quality control samples in all laboratory methods.

3.16 Bias

Bias is described as a systematic failure that develops in the design, conduct, or analysis of the study resulting in an inaccurate measure of association (Wang and Cheng, 2020).

(i) Methodological bias was avoided by using validated data collection tools or laboratory methods.

(ii) Sampling bias was not avoided since the primary study (i.e., the AWI-Gen phase 1 project used convenience sampling)

(iii) Statistical bias was avoided by calculating sample size and using appropriate statistical tests.

3.17 Ethical considerations

3.17.1 Approval

The research proposal was submitted to the Turfloop Research Ethics Committee (TREC) at the University of Limpopo for approval (TREC/264/2021:PG).

3.17.2 Consent

The study used secondary data, and there is no need to get consent from the participants. However, participants in the previous study were made aware that enrolment in the AWI-Gen study was purely voluntary and they were granted an opportunity to ask questions. The aim, objectives, and procedures including the collection of blood samples, were clearly explained to participants. The participants who volunteered to participate were then given consent forms to sign.

SEE APPENDIX IV

3.17.3 Confidentiality and anonymity

Confidentiality refers to not discussing information provided by an individual with others, while anonymity means presenting research findings in ways that ensure individuals cannot be identified (Hokama et al., 2021). Anonymity was ensured by using research identifiers, and the names of the participants were deleted. In terms of the National Health Act No 61 Section 14, all information concerning a study participant, including information relating to their health status, treatment or stay in any health establishment is confidential. The researcher ensured confidentiality by withholding the clinical and laboratory information obtained through the study from other researchers or relatives/ friends of the participants under study.

3.17.4 Harm

Harm did not apply in the study since the study used secondary data.

CHAPTER 4: RESULTS

This section presents results in line with the research objectives. It includes characteristics of participants by gender, the prevalence of obesity, central obesity and their possible determinants, comparison of socio-demographic profiles between participants who are obese and non-obese. In addition, a comparison between the socio-demographic profiles of participants with central obesity and those without central obesity. Correlation between BMI status and socio-demographic factors, a correlation between waist circumference and socio-demographic factors, classification of obesity based on the new category (healthy obese non- healthy obese), and lastly the spatial distribution of obesity in the DIMAMO HDSS.

Table 4.1 summarizes the characteristics of participants by gender. The present study consisted of 791 participants (459 women and 242 men). The table of characteristics will help to outline the status of possible demographic, anthropometric, and biochemical confounders.

TABLE 4.1. Characteristics of participants by gender

SOCIO-DEMOGRAPHIC STATUS				
	Total (n)	Women	Men	P value
N (n)%	791	69.4 %(549)	30.6 %(242)	
Age(years)	52.47 ± 8.24	52.48±8.06	54.45 ± 8.64	0.952
MARITAL STATUS				
Single %(n)	20.9% (165)	20.6% (113)	21.5% (52)	0.421
Married%(n)	46.8% (370)	47.5%(261)	45.0%(109)	0.284
Divorced%(n)	2.9% (23)	2.2% (12)	4.5%(11)	0.059
Widowed %(n)	16.9% (134)	20.4% (112)	9.1% (22)	<0.001
HIGHEST LEVEL OF EDUCATION				

No formal education%(n)	9.2%(73)	10.2%(56)	7.0%(17)	0.096
Primary%(n)	35.3%(279)	35.0%(192)	36.0%(87)	0.433
Secondary%(n)	52.9% (418)	52.9% (290)	52.9% (128)	0.528
Tertiary%(n)	2.5% (20)	1.8%(10)	4.1(10)	0.053
EMPLOYMENT STATUS				
Unemployed %(n)	68.7%(542)	49.2% (388)	19.5% (154)	0.05
Lifestyle factors				
Smoking%(n)	21.3% (149)	2.9% (14)	76.1% (134)	<0.001
Alcohol consumption %(n)	33.7% (215)	16.5% (76)	78.5% (139)	<0.001
ANTHROPOMETRIC MEASUREMENTS AND BIOCHEMICAL MEASUREMENTS				
BMI (kg/m^2)	28.01± 8.24	30.81± 8.05	21.67±4.08	<0.001
Obesity %(n)	35.4% (280)	49.5% (272)	3.3% (8)	<0.001
Healthy obese by BMI%(n)	22.9%(65)	23.2%(64)	12.5%(1)	<0.001
Waist circumference (cm)	90.12± 16.07	94.36± 15.89	80.60± 11.83	<0.001
Central obesity %(n)	59.9% (474)	79.6% (437)	15.3% (37)	<0.001
Healthy obese by waist circumference%(n)	23.6%(112)	26.1%(114)	21.6%%(8)	<0.001

Subcutaneous adipose tissue (cm)	1.8 ± 1.07	2.21 ± 1.01	0.9 ± 0.52	<0.001
High SAT%(n)	56.2%(441)	77.7%(424)	7.1%%(17)	<0.001
Healthy obese by High SAT%(n)	27.2% (120)	27.1% (115)	29.4% (5)	<0.001
Visceral adipose tissue (cm)	6.56± 2.17	6.78 ± 2.23	6.04 ± 1.96	<0.001
High VAT%(n)	61.8%(484)	73.3%(399)	35.6%(85)	<0.001
Healthy obese by High VAT%(n)	26.7%(129)	25.3%(101)	32.9%(28)	0.016

The mean age of the total population was 52.47 ± 8.24, there was no significant difference in mean age between women and men. The prevalence of divorced participants in the population was 2.9% and significantly more men were divorced (4.5% vs 2.2%, p=0.05), as compared to women. The prevalence of participants with deceased partners in the population was 16.9%. Significantly more women were widowed (20.4% vs 9.1%, p=<0.001) as compared to men. There was no significant difference in single and married participants between females and males

The proportion of unemployment in the population was 68.7%, and significantly more women were unemployed (49.2% vs 19.5%, p=0.05), as compared to men. The proportion of alcohol consumption in the population was 33.7%, and significantly more men were alcohol consumers as compared to women (78.5% vs 16.5%, p=<0.001). The proportion of smoking in the population was 21.3%, and significantly more men were smokers as compared to women (76.1% vs 2.9%, p=<0.001).

The mean BMI of the total population was 28.01±8.24. BMI was significantly higher in women (30.81±8.05) as compared to men (21.67±4.08, p=<0.001). The proportion of obesity in the total population was 35.4%, and significantly more women were obese (49.5% vs 3.3%, p=<0.001), as compared to men. The proportion of healthy obese by BMI in the total population was 22.9%, and significantly more women were healthy obese (23.2% vs 12.5%, p=<0.001) as compared to men.

The mean waist circumference in the total population was 90.12±16.07, waist circumference was significantly higher in women (94.36±15.89) as compared to men (80.60±11.83, p=<0.001). The proportion of central obesity in the total population was 59.9%, and significantly more women were centrally obese (79.6% vs 15.3%, p=<0.001), as compared to men. The proportion of healthy obese by waist circumference in the total population was 23.6%, and significantly more women were healthy obese (26.1% vs 21.6, p=<0.001) as compared to men

In the total population, the subcutaneous adipose fat mean was 1.8±1.07. The subcutaneous fat mean was significantly higher in women (2.21±1.01, p=<0.001) than in men (0.9±0.52, p=<0.001). The proportion of high SAT in the total population was 56.2% and significantly more women had high SAT (77.7% vs 7.1%, p=<0.001) as compared to men. The proportion of healthy obese by high SAT in the total population was 27.2%, and significantly more men were healthy obese (29.4 vs 27.1%, p=<0.001) as compared to women.

In the total population, the visceral adipose fat mean was 6.56±2.17. The visceral fat mean was significantly higher in women (6.78±2.23, p=<0.001) than in men (6.04±1.96, p=<0.001). The proportion of high VAT in the total population was 61.8% and significantly more women had high VAT (73.3% vs 35.6%, p=<0.001) as compared to men. The proportion of healthy obese by high VAT in the total population was 26.7%, and significantly more men were healthy obese (32.9 vs 23.2%, p=<0.001) as compared to women.

The reason for comparing is that since the study aimed to determine the spatial distribution of obesity, there is a need to compare obese and non-obese to determine which sociodemographic profiles are associated with obesity which may explain determinants of the spatial distribution of obesity

Table 4.2.1: The comparison of socio-demographic with obese and obese among people residing in DIMAMO HDSS.

Characteristics		Non obese %(N)	Obese %(N)	P value
Gender	Men	96.7 %(234)	3.3% (8)	<0.001
	Women	50.5%(277)	49.5% (272)	

Type of marital status	Single	70.3%(116)	29.7%(49)	0.099
	Married	42.7 %218)	54.3%(152)	0.002
	Divorced	87.0%(20)	13.0%(3)	0.026
	Widowed	59.0%(79)	41.0%(55)	0.138
Highest level of education	No formal education	67.1%(49)	32.9%(24)	0.701
	Primary	64.9%(181)	35.1%(98)	0.938
	Secondary	63.9%(267)	36.1%(151)	0.710
	Tertiary	65.0%(13)	35.0%(7)	1.000
Unemployed		65.1%(353)	34.9% (189)	0.688
Alcohol consumption		84.2%(181)	15.8%(34)	<0.001
Smoking		95.3%(142)	4.7%(7)	<0.001

The prevalence of general obesity among women was higher as compared to men (49.5% vs 3.3%, p=<0.001).There were significantly more married participants who were obese compared to non-obese (54.3%vs 42.7%, p=0.002). The proportion of divorced participants was significantly lower in obese as compared to non-obese (13.0% vs 87.0, p=0.026). Moreover, the proportion of alcohol consumption was significantly lower in obese than non-obese participants (15.8% vs 84.2%, p=<0.001). The proportion of smoking was also significantly lower in obese than non-obese (4.7% vs 95.3%, <0.001).

Bivariate correlation and regression analysis were performed to confirm if the association of single status, married status, divorced status, alcohol status, smoking status, and BMI observed in table 4.2.1 are true associations.

Table 4.2.2: Bivariate correlation between BMI and socio-demographic factors

		BMI	
Variables		Correlation	P value
	Single	-0.093	0.009

Type of marital status	Married	0.164	<0.001
	Divorced	-0.101	0.004
	Widowed	0.042	0.240
Highest level of education	No formal education	-0.025	0.484
	Primary	-0.026	0.462
	Secondary	0.040	0.266
	Tertiary	0.000	0.999
Unemployed		-0.001	0.968
Villages by clusters	Cluster A	-0.045	0.211
	Cluster B	-0.065	0.069
	Cluster C	0.066	0.062
	Cluster D	0.045	0.203
Smoking		-0.458	<0.001
Alcohol consumption		-0.326	<0.001

Single and divorced status correlated negatively and significantly with obesity. Married status correlated positively (r=0.164) and significantly with obesity (p=<0.001). Unemployed status correlated negatively but not significantly with obesity. Smoking and alcohol consumption correlated negatively and significantly with obesity.

Since bivariate correlation does not control for known confounders, i.e. age and gender. A partial correlation analysis was used to determine if the association between single status, married status, divorced status, alcohol status, and smoking status with BMI obtained in table 4.2.1 And table 4.2.2 are not confounded by age and gender.

Table 4.2.3: Partial correlation between BMI and socio-demographic factors

		BMI	
Variables		Correlation	P value
	Single	-0.118	0.002

Type of marital status	Married	0.172	<0.001
	Divorced	-0.092	0.016
	Widowed	-0.017	0.647
Highest level of education	No formal education	-0.055	0.120
	Primary	-0.017	0.631
	Secondary	0.038	0.228
	Tertiary	0.038	0.228
Unemployed		0.055	0.151
Villages by clusters	Cluster A	-0.006	0.870
	Cluster B	-0.063	0.045
	Cluster C	0.045	0.203
	Cluster D	0.025	0.480
Smoking		-0.142	<0.001
Alcohol consumption		-0.093	0.015

Single and divorced status correlated negatively and significantly with obesity even after controlling for age and gender. The married status also correlated positively (r=0.172) and significantly with obesity (p=<0.001) after controlling for the confounder's age and gender, the same was also observed for smoking and alcohol consumption. Cluster B correlated negatively and significantly with obesity.

Binary logistic regression was used to determines the association between obesity and its determinants.

Table 4.2.4: Binary logistic regression of general obesity with sociodemographic factors and place residence.

Characteristics		OR	P value
Gender	Men	1	-

	Women	42.47	<0.001
Marital status	Single	1	-
		1.184	0.671
	Married	1	-
		0.519	0.069
	Divorced	1	-
		2.185	0.299
	Widowed	1	-
		0.734	0.458
Highest level of education	No formal education	1	-
		1.931	0.381
	Primary	1	-
		1.564	0.519
	Secondary	1	-
		1.499	0.552
	Tertiary	1	-
		1.020	0.967
Unemployed		1	-
		1.582	0.036
Villages By Clusters	Cluster A	1	-
		1.157	0.030
	Cluster B	1	-
		1.652	0.015
	Cluster C	1	-
		0.978	0.922
	Cluster D	1	-
		1.334	0.136
Smoking		1	-
		0.548	<0.001
Alcohol consumption		1	-

	0.205	<0.001

Women were 42.47 times more likely to be obese. Unemployed status were 1.582 times more likely to be obese. Smoking status were 0.548 less likely to be obese and alcohol status were 0.205 less like to be obese.

Since central obesity is more related to metabolic diseases as compared to general obesity then, the present study compares the socio-demographic profiles of participants with central obesity and those without central obesity. To determine which socio-demographic profile have the highest proportion participants with central obesity. Since the aim of the present study was to profile obesity in terms of new classifications, the distribution of central obesity among participants was done.

Table 4.3.1: Comparison between socio-demographic profiles of participants with central obesity and those without central obesity.

Characteristics		Without central obesity %(n)	With central obesity %(n)	P value
Gender	Women	20.4%(112)	79.6%(437)	<0.001
	Men	84.7%(205)	15.3%(37)	
Types of marital status	Single	49.7%(82)	50.3%(83)	0.006
	Married	31.4%(116)	68.6%(254)	<0.001
	Divorced	65.2%(15)	34.8%(8)	0.017
	Widowed	31.3%(42)	68.7%(92)	0.026
Highest level of education	No formal education	38.4%(28)	61.6%(45)	0.803
	Primary	40.5%(113)	59.5%(166)	0.880
	Secondary	40.2%(168)	59.8%(250)	1.000
	Tertiary	40.0%(8)	60.0%(12)	1.000
Unemployed		40%(217)	60.0%(325)	1.000
Smoking		87.2%(130)	12.8%(19)	<0.001

Alcohol consumption	66.0%(142)	34.0%(73)	<0.001

The prevalence of central obesity among women was higher as compared to men (79.6% vs 15.3%, p=<0.001).The proportion of single, married, and widowed participants was higher in those with central obesity compared to those without central obesity. The proportion of divorced participants was significantly higher in those without central obesity than in those with central obesity (65.2% vs 34.8%, p=0.017). The proportion of alcohol consumption was significantly higher in participants without central obesity than in central obesity (66.0% vs 34.0%, p=<0.001), and the proportion of smoking were also significantly higher in participants without central obesity than obese central obesity (87.2% vs 34.0%, p=<0.001).

Bivariate correlation and regression analysis was done to confirm if the association of single status, married status, divorced status, alcohol status, and smoking status, and waist circumference observed in table 4.3.1 are true associations.

Table 4.3.2: Bivariate correlation between waist circumference and socio-demographic factors

		Waist circumference	
		Correlation	P value
Type of marital status	Single	-0.130	<0.001
	Married	0.208	<0.001
	Divorced	-0.075	0.036
	Widowed	0.027	0.446
Highest level of education	No formal education	-0.005	0.880
	Primary	0.001	0.980
	Secondary	-0.006	0.857
	Tertiary	0.028	0.440
Unemployed		-0.035	0.322
Villages	Cluster A	-0.033	0.356

by clusters	Cluster B	-0.085	0.017
	Cluster C	0.053	0.138
	Cluster D	0.067	0.060
Smoking		-0.403	<0.001
Alcohol consumption		-0.256	<0.001

Single and divorced status correlated negatively and significantly with central obesity. Married status correlated positively (r=0.028) and significantly with central obesity. Cluster B correlated negative correlated negatively (r=-0.085) and significantly with central obesity (p=0.017).

Smokers correlated negatively(r=-0.403) and significantly with central obesity (p=<0.001). Alcohol consumers correlated negatively (r=-0.256) and significantly with central obesity (p=<0.001).

Since bivariate correlation does not control for known confounders, i.e., age and gender. A partial correlation analysis was used to determine if age and gender are not confounding results of the bivariate correlation.

Table 4:3:3: partial correlation between Waist circumference and socio-demographic factors

		Waist circumference	
Variables		Correlation	P value
Type of marital status	Single	-0.128	<0.001
	Married	0.218	<0.001
	Divorced	-0.058	0.102
	Widowed	-0.050	0.158
Highest level of education	No formal education	-0.042	0.235
	Primary	-0.024	0.507
	Secondary	0.027	0.458
	Tertiary	0.067	0.05

Unemployment		0.010	0.778
Villages by clusters	Cluster A	-0.026	0.512
	Cluster B	-0.061	0.124
	Cluster C	0.046	0.252
	Cluster D	0.045	0.255
Smoking		-0.174	<0.001
Alcohol consumption		-0.057	0.170

Single status correlated negatively (r=-0.128) and significantly with central obesity (p=<0.001) even after controlling for age and gender. The married status also correlated positively (r=0.172) and significantly with obesity (p=<0.001) after controlling for the confounder's age and gender, the same was also observed for smoking. Tertiary status correlated positively (r=0.067) and significantly with central obesity (p=0.05).

Binary logistic regression was used to determines the association between central obesity and its determinants.

Table 4.3.4: Binary logistic regression of central obesity and socio-demographic factors.

		OR	P value
Gender	Men	1	-
	Women	32.82	<0.001
Types of Marital status	Single	1	-
		0.889	0.768
	Married	1	-
		3.189	0.002
	Divorced	1	-
		0.760	0.692
	Widowed	1	-
		1.537	0.315

Highest level of education	No formal education	1	-
		0.814	0.694
	Primary	1	-
		0.955	0.923
	secondary	1	-
		0.941	0.897
	Tertiary	1	-
		1.023	0.961
Unemployed		1	-
		2.148	0.005
Villages by clusters	Cluster A	1	-
		1.593	0.022
	Cluster B	1	-
		1.893	0.002
	Cluster C	1	-
		1.201	0.372
	Cluster D	1	-
		1.535	0.109
Smoking		1	-
		0.154	<0.001
Alcohol consumption		1	-
		1.220	0.568

Women were 32.82 time more likely to have central obesity. Married status were 3.189 times more likely to have central obesity. Unemployed status were 2.148 times more likely to have central obesity. Smoking were 0.154 times less likely to have central obesity.

Villages in cluster A were 1.593 times more likely to have central obesity and those in cluster B were 1.893 times more likely to be centrally obese.

Binary logistic regression of central obesity and sociodemographic statuses

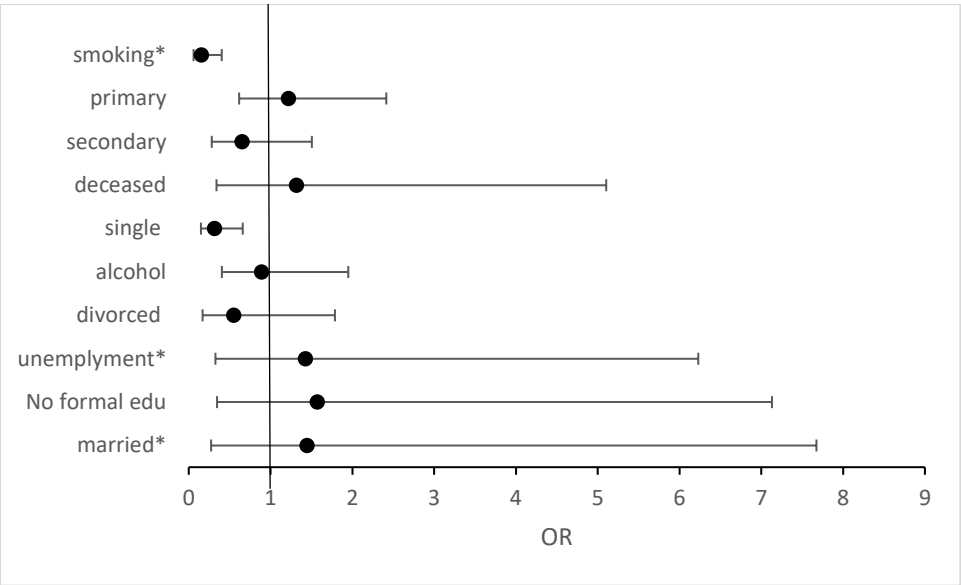

Figure 5: Forest Plot illustrating the binary logistic regression of central obesity and socio-demographic factors. Normal=1, OR>1=Positive relationship, OR<1=Negative relationship.

The present study compares the complication between obese participants and non-obese participants. To establish the possible complications that are associated with obesity.

Table 4.4: Comparison of complications between obese and non-obese

Characteristics	Non-obese %(n)	Obese %(n)	P value
Diabetes mellitus	5.7%(29)	7.5%(21)	0.359
Hypertension	25.0%(128)	35.4%(99)	0.002
High ACR cat	21.3%(43)	25.7%(28)	0.398
Low egrcat	4.9%(25)	3.2%(9)	0.359
Kidney disease	11.9%(61)	13.2%(37)	0.652
LDL-C/HDL-C ratio	32.3%(159)	55.1%%(145)	<0.001
TC/HDL-C ratio	8.9%(45)	14.5%(40)	0.022
TG/HDL-C ratio	1.6%%(8)	0.7%%(2)	0.508

The proportion of hypertension was significantly higher in participants with obesity than in those without obesity (35.4% vs 25.0%, p=0.002). The proportion of high LDH-

C/HDL-C ratio was significantly higher in obesity participants than those without obesity (55.1% vs 32.3%, p=<0.001). Moreover, the proportion of high TC/HDL-C ratio was significantly higher in obesity as compared to non-obesity (14.5% vs 8.9%, p=0.010). The was no significant difference between non-obese and obese in terms of TG/HDL-C ratio.

Bivariate correlation was done to determine if any association exists between BMI and complications. To establish the possible complications that are associated with obesity.

Table 4.5: Bivariate correlation between BMI and complications

Variables	Correlation	P value
Diabetes mellitus	0.048	0.183
Glucose	0.075	0.037
Hypertension	0.126	<0.001
High ACR cat	0.080	0.157
Low egrcat	0.024	0.494
Kidney disease	0.073	0.039
LDL-C/HDL-C ratio	0.238	<0.001
TC/HDL-C ratio	0.063	0.079
TG/HDL-C ratio	-0.025	0.478

Glucose correlated positively (r=0.075) and significantly with obesity (p=0.037). kidney disease correlated positively (r=0.0073) and significantly with obesity(p=0.039). Hypertension correlated positively (r=0.126) and significantly with obesity (p=<0.001). High LDL-C/HDL-C ratio correlated positively (r=0.238) and significantly with obesity (p=<0.0-01).

Since bivariate correlation does not control for known confounders, i.e., age and gender. A partial correlation analysis was used to determine if age and gender are not confounding results of the bivariate correlation.

Table 4.6: Partial correlation between BMI and complications

Variables	Correlation	P value
Diabetes mellitus	0.093	0.108
Glucose	0.109	0.060
Hypertension	0.111	0.002
High ACRcat	0.089	0.126
Low egrcat	-0.055	0.3380
Kidney disease	0.071	0.221
LDL-C/HDL-C ratio	0.226	<0.001
TC/HDL-C ratio	0.063	0.086
TG/HDL-C ratio	0.024	0.511

High LDL-C/HDL-C ratio correlated positively and significantly with obesity even after controlling for age and gender. Diabetes mellitus, glucose, hypertension, High ACRcat, and kidney disease correlated positively and not significantly with obesity. Hypertension and low egrcat correlated negatively and not significantly with obesity.

Binary logistic regression was used to determines the association between obesity and its associated complications.

Table 4.7: Binary logistic regression between BMI and complications

Variables	OR	P value
Diabetes mellitus	1	-
	0.943	0.928
Glucose	1	-
	1.089	0.417
Hypertension	1	-
	3.409	0.017
High ACRcat	1	-

	0.729	0.321
Low egrcat	1	-
	2.531	0.182
Kidney disease	1	-
	0.999	0.621
LDL-C/HDL-C ratio	1	-
	0.129	0.060
TC/HDL-C ratio	1	-
	6.229	0.270
TG/HDL-C ratio	1	-
	63.67	1.000

Hypertensive participants were 3.409 times more likely to be obese.

Since central obesity is more related to metabolic diseases as compared to general obesity then, the present study compares the complication between participants with central obesity and those without central obesity. To determine which complications have the highest proportion of central obesity.

Table 4.8: Comparison of complications between central obese and non-central obese

Characteristics	Non-central-obese %(N)	Central obese %(N)	P value
Diabetes mellitus	2.8%(9)	8.6%(41)	0.001
Hypertension	19.9%(63)	34.6%(164)	<0.001
High ACR cat	18.2%(22)	25.8%(49)	0.129
Low egrcat	2.5%(8)	5.5%(26)	0.049
Kidney disease	8.2%(26)	15.2%(72)	0.004
LDL-C/HDL-C ratio	27.5%(84)	49.8%(220)	<0.001
TC/HDL-C ratio	7.3%(23)	13.2%(62)	0.010

TG/HDL-C ratio	0.9%(3)	1.5%%(7)	0.748

The proportion of diabetes mellitus was significantly higher in participants with central obesity than without obese central obesity (8.6% vs 2.8%, p=<0.001). The proportion of hypertension was significantly higher in participants with central obesity than in those without central obesity (34.6% vs 19.9%, p=0.001). The proportion of low egrcat was significantly higher in central obesity as compared to non-central obesity (5.5% vs 2.5%, p=0.049), and also the proportion of kidney disease was significantly higher in participants with central obesity as compared to those without central obesity (15.2% vs 8.2%, p=0.004). The proportion of high LDH-C/HDL-C ratio was significantly higher in central obese participants than those in non-central obesity (49.8% vs 27.5%, p=<0.001). Moreover, the proportion of high TC/HDL-C ratio was significantly higher in central obesity as compared to non-central obesity (13.2% vs 7.3%, p=0.010).

Bivariate correlation was done to determine if any association exists between waist circumference and complications. To establish the possible complications that are associated with obesity.

Table 4.9: Bivariate correlation between waist circumference and complications

Variables	Correlation	P value
Diabetes mellitus	0.127	<0.001
Glucose	0.157	<0.001
Hypertension	0.179	<0.001
High ACRcat	0.162	0.004
Low egrcat	0.055	0.124
Kidney disease	0.133	<0.001
LDL-C/HDL-C ratio	0.271	<0.001
TC/HDL-C ratio	0.110	0.002
TG/HDL-C ratio	0.024	0.499

Diabetes mellitus, glucose, hypertension high ACRcat, and kidney disease correlated positively and significantly with central obesity. High LDL-C/HDL-C ratio and TC/HDL-C ratio correlated positive and significantly with central obesity.

Since bivariate correlation does not control for known confounders, i.e., age and gender. A partial correlation analysis was used to determine if age and gender are not confounding results of the bivariate correlation

Table 4.10: Partial correlation between waist circumference and complications

Variables	Correlation	P value
Diabetes mellitus	0.110	0.002
Glucose	0.201	<0.001
Hypertension	0.153	<0.001
High ACRcat	0.169	0.003
Low egrcat	-0.018	0.761
Kidney disease	0.151	0.009
LDL-C/HDL-C ratio	0.255	<0.001
TC/HDL-C ratio	0.102	0.005
TG/HDL-C ratio	0.074	0.044

Diabetes mellitus, glucose, hypertension high ACRcat, kidney disease high LDL-C/HDL-C ratio, and TC/HDL-C ratio correlated positively and significantly with central obesity even after controlling for age and gender. High TG/HDL-C ratio correlated positively (r=0.074) and significantly with central obesity (p=0.044).

Binary logistic regression was used to determine the association between obesity and its associated complications.

Table 4.11: Binary logistic regression between waist circumference and complications

Variables	OR	P value

Diabetes mellitus	1	-
	4.081	0.001
Glucose	1	-
	1.323	0.004
Hypertension	1	-
	4.810	0.024
High ACRcat	1	-
	7.404	0.204
Low egrcat	1	-
	4.770	0.163
Kidney disease	1	-
	11.93	0.758
LDL-C/HDL-C ratio	1	-
	0.290	0.040
TG/HDL-C ratio	1	-
	1.916	0.572
TC/HDL-C ratio	1	-
	0.076	0.146

Participants with central obesity were 4.081 times more likely to have diabetes mellitus Participants with elevated glucose were 1.323 times more likely to be centrally obese. Participants with central obesity were 4.810 times more likely to have high blood pressure. Participants with central obesity had a 0.290 lower likelihood of having an elevated LDL-C/HDL-C ratio.

Spatial distribution of obesity

The map below bellows illustrates the spatial distribution of obesity to indicate which cluster or villages have the highest prevalence of obesity. The reason why these villages are presented as clusters is that some villages had a lower number of

participants and it was a bit problematic doing some statical analysis, then it was decided that the villages that are close to each other be unified and regarded as one.

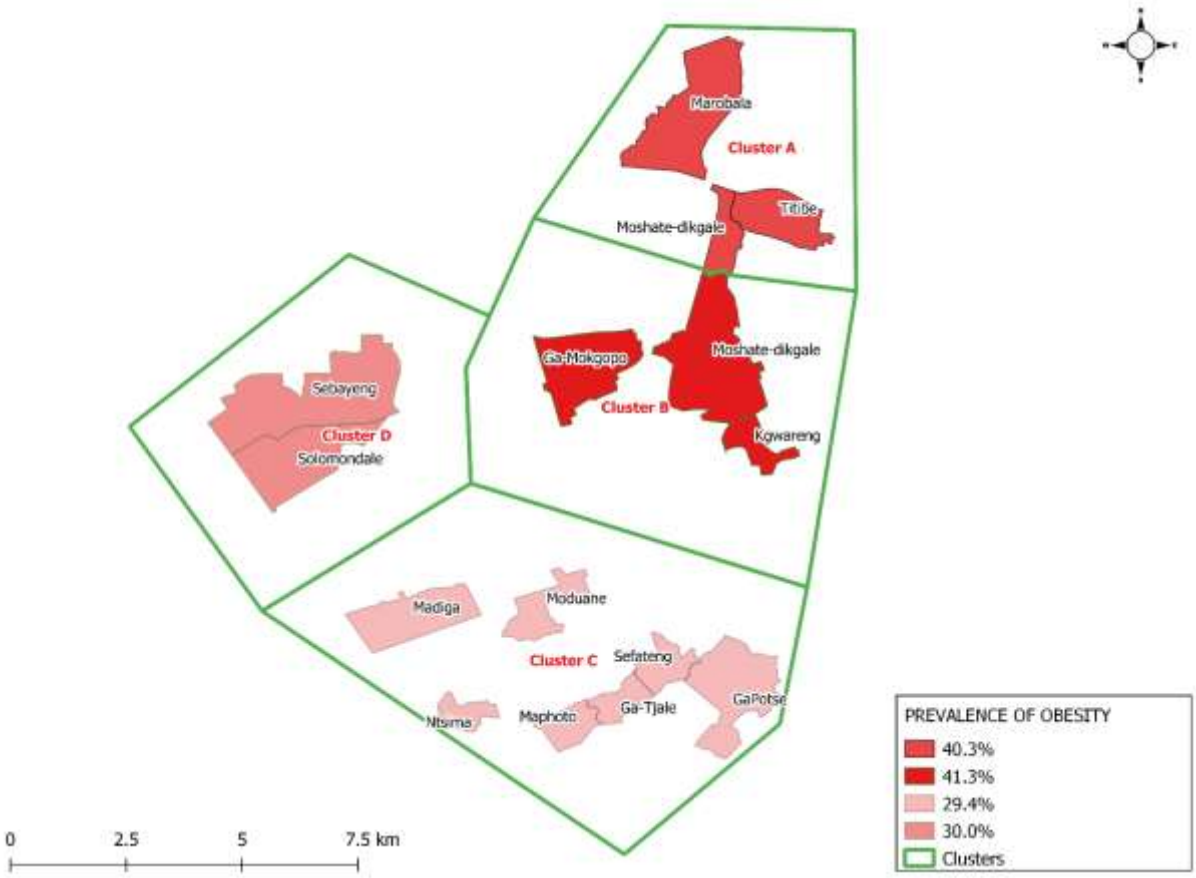

Figure 6: The proportion of obesity by clusters of people residing at DIMAMO HDSS

Obesity was more clustered in the north-eastern clusters compared to the west and south clusters. The proportion of people with obesity was significantly higher in cluster B compared to cluster A (p=0.005), cluster C (p=0.019), and cluster D (p=0.018). There was no significant difference between cluster A and C, cluster A and D, and cluster D and C.

The map bellows illustrates the spatial distribution of central obesity to indicate which cluster nor villages have the highest prevalence of central obesity.

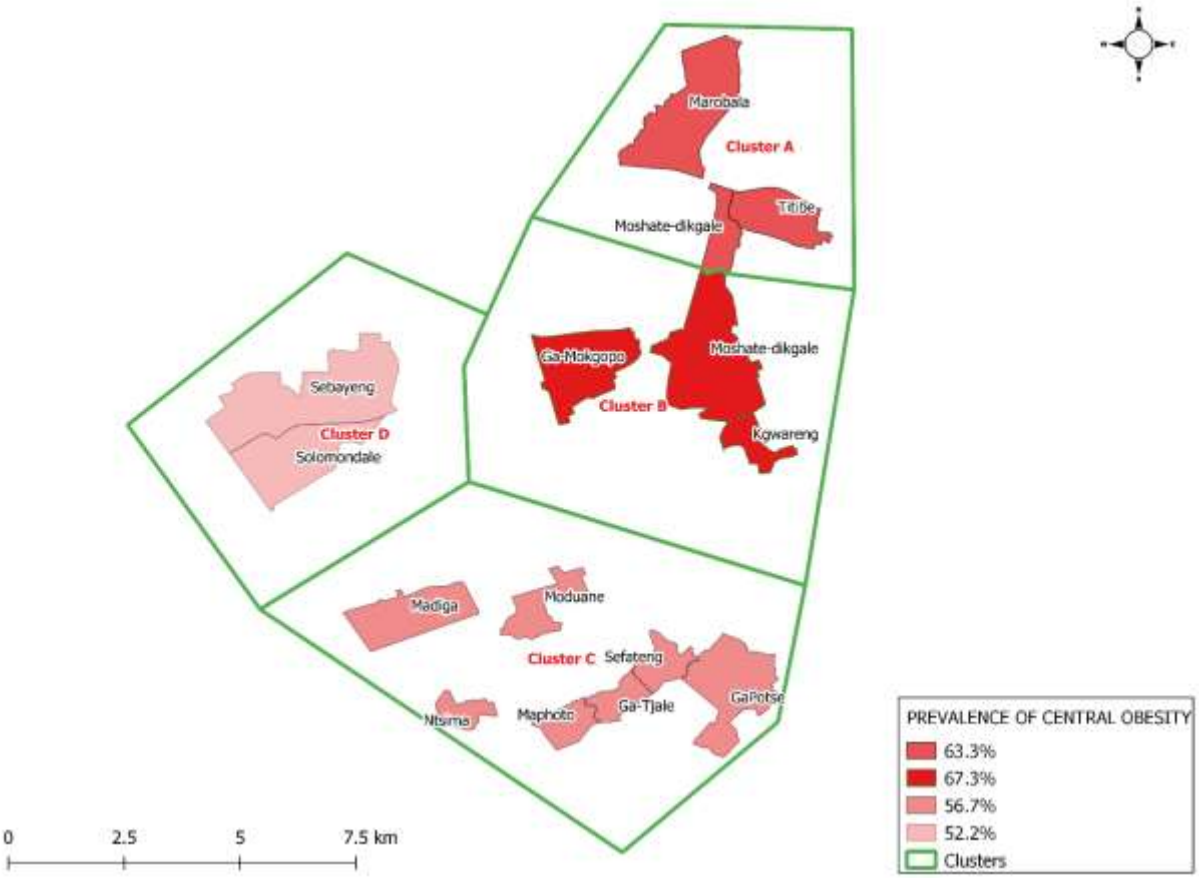

Figure 7: The proportion of participants with central obesity by cluster of people residing at DIMAMO HDSS.

Central Obesity was also more clustered in the north-eastern village clusters compared to the west and south clusters. The proportion of participants with central obesity was significantly higher in cluster B as compared to cluster A (p=0.004), cluster C (p=0.036), and cluster D (p=0.002). The proportion of people with central obesity was significantly higher in cluster A as compared to cluster D (p=0.030). There was no significant difference between cluster A and C and cluster D and C.

Table 4.12.1. shows the determinants of obesity and central obesity.

Table 4.12.1: Sociodemographic factors by village clusters

		Cluster A	Cluster B	Cluster C	Cluster D
N		196	208	180	207
Age		52.11±8.145	52.77±8.15	52.99±8.34	52.06±8.67
Obesity (%)		40.3%	41.3%	29.4%	30.0%
Healthy obese by high BMI (%)		21.52%	26.74%	18.87%	24.19%
Central obesity (%)		66.3%	67.7%	56.7%	52.2%
Healthy obese by high WC		25%	25.71%	27.45%	25%
Gender W (%)		75.5% #$	71.2%	65.0%	65.7%
Marital status	Single	17.9%(35)	19.7%(41)	21.7%(39)	24.2%(50)
	Married	51.5%(101)$	47.1%(98)	48.9%(88)	40.1%(83)
	Divorced	3.1%(6)	3.8%(8)	2.8%(5)	1.9%(4)
	Widowed	16.3%(32)	19.2%(40)	17.2%(31)	15.0%(31)
Highest level of education	No formal education	7.1%(14)	6.8%(14)	11.1%(20)	12.1%(25)
	Primary	34.7%(68)	36.2%(75)	37.8%(68)	32.9%(68)
	secondary	54.1%(106)	54.1%(112)	50.0%(90)	53.1%(110)
	Tertiary	4.1%(8)	2.9%(6)	1.1%(2)	1.9%(4)
Unemployment		33.7%(66)	30.8%(64)	27.2%(49)	33.2%(68)
Alcohol consumption		27.6%(43) $	32.0%(57)	33.6%(47)	41.5%(68)
Smoking		16.5%(29) $¥	19.3%(36)	21.2%(33)	28.5%(51)

Footnote: * significance difference between cluster A and B, # significance difference between cluster A and C, $ significant difference between Cluster A and D, ¥ significant difference between cluster B and D, € significant difference between cluster B and C, £ significant difference between cluster D and C.

The was no significant difference in healthy obese (healthy obese by High BMI and healthy obese by high WC) in all the clusters. The proportion of women was significantly higher in cluster A, as compared to cluster C (p=0.031) and cluster D (p=0.038). There was no significant difference between cluster A and B, cluster B and C, and cluster C and D.

The proportion of married status was significantly high in cluster A as compared to cluster D (p=0.005). The was no significant difference in married status between cluster A and B, cluster A and C, cluster B and C and cluster C and D. In terms of educational level, the was no significant difference in educational level (No formal education, primary, secondary, and tertiary) in all the clusters.

The proportion of alcohol consumption was significantly high in cluster D as compared to cluster A (p=0.027). There was no significant difference in alcohol consumption between cluster A and B, Cluster A and C, cluster B and C, and cluster B and D.

Cluster D had a higher proportion of smokers as compared to A (p=0.016). The proportion of smokers was significantly higher in cluster D as compared to cluster B (p=0.04). There was no significant difference in smoking status between cluster A and B, cluster A and C, and cluster B and C.

Bivariate correlation was done to determine if any association exists between BMI and socio-demographic status/determinates (i.e. Type of marital status, highest level of education, employment status, smoking, and alcohol consumption) per cluster.

Table 4.12.2: Bivariate correlation between Sociodemographic factors and BMI by village clusters

		BMI							
		Cluster A		Cluster B		Cluster C		Cluster D	
Variables		correlation	P value	correlation	P value	Correlation	P value	Correlation	P value
Type of marital status	Single	-0.128	0.073	-0.095	0.173	-0.126	0.092	-0.017	0.806
	Married	0.166	0.020	0.071	0.306	0.267	<0.001	0.150	0.031
	Divorced	-0.092	0.201	-0.093	0.181	-0.114	0.128	-0.131	0.060
	Widowed	0.098	0.173	0.064	0.358	-0.067	0.368	0.058	0.404
Highest level of	No formal	-0.005	0.942	-0.051	0.462	-0.016	0.835	-0.003	0.967

educati on	educati on								
	Primary	-0.013	0.855	-0.007	0.920	-0.021	0.782	-0.064	0.362
	Second ary	0.035	0.595	0.028	0.686	0.041	0.582	0.041	0.558
	Tertiary	-0.054	0.421	0.013	0.851	-0.055	0.467	0.075	0.280
Unemployed		0.072	0.316	-0.076	0.276	-0.027	0.723	0.013	0.853
Smoking		-0.451	<0.00 1	-0.528	<0.00 1	-0.384	<0.00 1	-0.445	<0.001
Alcohol consumption		-0.338	<0.00 1	-0.438	<0.00 1	-0.242	0.004	-.0385	<0.001

In cluster A, C, and D, married status correlated positively and significantly with obesity. Smoking and alcohol consumption correlated negatively and significantly with obesity across all the clusters.

Since bivariate correlation does not control for known confounders i.e., age and gender. A partial correlation analysis was used to determine if age and gender are not confounding results of the bivariate correlation.

Table 4.12.3: Partial correlation between Sociodemographic factors and BMI by village clusters, adjusted for age and gender.

		BMI							
		Cluster A		Cluster B		Cluster C		Cluster D	
Variables		correla tion	P value	correlati on	P value	Correlat ion	P value	Correlat ion	P value
	Single	-0.123	0.139	-0.101	0.201	-0.131	0.141	-0.141	0.087

Type of marital status	Married	0.233	0.005	0.094	0.223	0.235	0.008	0.244	0.003
	Divorced	-0.183	0.027	0.028	0.728	-.127	0.153	-0.157	0.056
	Widowed	-0.003	0.968	-0.045	0.616	-0.051	0.570	-0.040	0.625
Highest level of education	No formal education	-0.057	0.498	-0.161	0.040	0.037	0.675	0.003	0.972
	Primary	-0.031	0.968	0.091	0.247	0.089	0.318	-0.134	0.105
	Secondary	0.099	0.238	-0.040	0.616	-0.101	0.258	0.087	0.293
	tertiary	-0.088	0.290	0.088	0.265	-0.034	0.701	0.119	0.150
Unemployed		0.111	0.186	0.012	0.876	0.077	0.391	0.067	0.419
Smoking		-0.119	0.155	-0.183	0.020	-0.80	0.369	-0.200	0.015
Alcohol consumption		-0.034	0.682	-0.089	0.260	0.038	0.66	-0.167	0.043

In cluster A, C, and D married status correlated positively and significantly with obesity, even after controlling for age and gender. In cluster B and D, smoking correlated negatively and significantly with obesity, even after controlling for age and gender. In addition, alcohol consumption correlated negatively and significantly with obesity (p=0.043) in cluster D, even after controlling for age and gender.

Binary logistic regression was used to determine the association between general obesity and its determinants.

Table 4.12.4: Binary logistic regression between Sociodemographic factors and BMI by village clusters

	General obesity			
	Cluster A	Cluster B	Cluster C	Cluster D

Variables		OR	P value	OR	P value	OR	P value	OR	P value
Type of marital status	Single	1	-	1	-	1	-	1	-
		0.439	0.309	3.715	0.110	1.015	0.977	1.397	0.275
	Married	1	-	1	-	1	-	1	-
		0.141	0.007	1.936	0.366	0.416	0.030	0.471	0.275
	Divorced	1	-	1	-	1	-	1	-
		1.278	0.854	0.673	0.798	3.757	1.00	20.45	0.999
	Widowed	1	-	1	-	1	-	1	-
		0.245	0.081	2.703	0.202	0.000	0.999	0.846	0.831
Highest level of education	No formal education	1	-	1	-	1	-	1	-
		0.220	0.209	16.25	0.078	0.163	1.000	0.786	0.737
	primary	1	-	1	-	1	-	1	-
		0.323	0.249	4.441	0.295	0.103	1.000	1.972	0.208
	Secondary	1	-	1	-	1	-	1	-
		0.301	0.217	4.159	0.312	0.163	1.000	1.096	0.764
	tertiary	1	-	1	-	1	-	1	-
		2.076	0.998	0.271	0.284	1.1520	1.000	0.000	0.997
Unemployed		1	-	1	-	1	-	1	-
		1.1461	0.346	1.583	0.246	2.027	0.238	1.207	0.697
Smoking		1	-	1	-	1	-	1	-
		0.000	0.998	0.068	0.001	0.104	0.003	0.091	<0.001
Alcohol consumption		1	-	1	-	1	-	1	-
		0.468	0.181	0.644	0.396	0.392	0.029	0.205	<0.001

Married participants were 0.141 less likely to be obese in cluster A. In cluster C, married participants were 0.416 less likely to be obese. Smokers in cluster B, C, and D were less likely to have obesity. In addition, alcohol consumers were 0.205 less likely to have obesity in cluster D.

Bivariate correlation was done to determine if any association exists between waist circumference and socio-demographic status/determinates (i.e. Type of marital status, highest level of education, employment status, smoking, and alcohol consumption). To establish possible determinants of central obesity by clusters.

Table 4.12.5: Bivariate correlation between Sociodemographic factors and WC by village clusters

		Waist circumference							
		Cluster A		Cluster B		Cluster C		Cluster D	
Variables		Correlation	P value	correlation	P value	Correlation	P value	Correlation	P value
Type of marital status	Single	-0.148	0.039	-0.142	0.041	-0.166	0.026	-0.058	0.408
	Married	0.223	0.002	0.112	0.108	0.306	<0.001	0.188	0.007
	Divorced	-0.043	0.551	-0.068	0.329	-0.106	0.157	-0.114	0.102
	Widowed	0.051	0.481	0.019	0.073	-0.059	0.428	0.082	0.238
Highest level of education	No formal education	0.012	0.872	-0.038	0.585	-0.032	0.665	0.060	0.392
	primary	-0.007	0.925	0.018	0.800	0.003	0.970	-0.014	0.843
	Secondary	0.019	0.794	-0.018	0.801	0.022	7.&67	-0.057	0.418
	tertiary	-0.046	0.520	0.059	0.401	-0.022	0.771	0.111	0.112
Unemployed		0.035	0.642	-0.112	0.106	-0.081	0.278	0.004	0.956

Smoking status	-0.350	<0.001	-0.461	<0.001	-0.379	<0.001	-0.407	<0.001
Drinking status	-0.236	0.003	-0.339	<0.001	-0.184	0.030	-0.347	<0.001

In cluster A, C and D, married participants correlated positively and significantly with central obesity. In cluster A, B, and C, single participants correlated negatively and significantly with central obesity. Smoking and alcohol consumption correlated negatively and significantly with central obesity across all the clusters.

Since bivariate correlation does not control for known confounders, i.e. age and gender. A partial correlation analysis was used to determine if age and gender are not confounding results of the bi-variate correlation.

Table 4.12. 6: Partial correlation between Sociodemographic factors and WC by village clusters, adjusted for age and gender.

		Waist circumference							
		Cluster A		Cluster B		Cluster C		Cluster D	
Variables		Correlation	P value	Correlation	P value	Correlation	P value	Correlation	P value
Type of marital status	Single	-0.290	0.361	-0.122	0.123	-0.164	0.064	-0.134	0.105
	Married	0.265	0.405	0.113	0.152	0.258	0.003	0.254	0.002
	Divorced	0.091	0.778	0.026	0.740	-0.121	0.173	-0.153	0.064
	Widowed	-0.037	0.909	-0.090	0.256	-0.049	0.582	0.015	0.860
Highest level of education	No formal education	0.091	0.778	-0.145	0.065	0.040	0.654	0.061	0.461
	primary	0.485	0.110	0.074	0.351	0.011	0.900	-0.115	0.163

	Secondary	-0.531	0.076	-0.051	0.518	-0.032	0.720	0.013	0.878
	tertiary	-0.016	0.824	0.140	0.075	-0.007	0.939	0.165	0.046
Unemployed		0.552	0.063	0.012	0.887	0.026	0.774	0.088	0.290
Smoking status		-0.095	0.769	-0.196	0.012	-0.107	0.231	-0.247	0.002
Drinking status		0.260	0.415	-0.055	0.490	0.085	0.341	-0.205	0.012

Married status correlated positively and significantly with central obesity in cluster C and D, even after controlling for age and gender. Smoker and alcohol consumers correlated negatively and significantly with central obesity in cluster D, even after controlling for age and gender.

Participants with tertiary as their highest level of education correlated positively and significantly with central obesity in cluster D. In addition, smokers correlated negatively and significantly with central obesity in cluster B.

Binary logistic regression was used to determine the association between central obesity and its determinants.

Table 4.12.7: Binary logistic regression between Sociodemographic factors and WC by village clusters.

		Central obesity							
		Cluster A		Cluster B		Cluster C		Cluster D	
Variables		OR	P value	OR	P value	OR	P value	OR	P value
Type of marital status	Single	1	-	1	-	1	-	1	-
		0.536	0.451	2.939	0.297	0.439	0.490	1.329	0.682
	Married	1	-	1	-	1	-	1	-
		0.141	0.010	2.556	0.312	0.096	0.046	0.188	0.022
	Divorced	1	-	1	-	1	-	1	-
		1.410	0.773	3.448	0.418	0.307	0.439	0.176	0.411
	Widowed	1	-	1	-	1	-	1	-
		0.307	0.162	1.962	0.498	0.163	0.152	0.538	0.413

Highest level of education	No formal education	1	-	1	-	1	-	1	-
		0.072	0.072	6.197	0.282	0.000	1.000	1.978	0.662
	Primary	1	-	1	-	1	-	1	-
		0.198	0.126	7.328	0.152	0.000	1.000	2.401	0.503
	Secondary	1	-	1	-	1	-	1	-
		0.211	0.125	4.453	0.277	1.006	0.984	1.336	0.821
	Tertiary	1	-	1	-	1	-	1	-
		2.463	0.303	1.023	0.980	1.316	0.848	0.802	0.52
Unemployed		1	-	1	-	1	-	1	-
		0.919	0.873	2.882	0.095	2.089	0.170	3.021	0.054
Smoking status		1	-	1	-	1	-	1	-
		0.039	<0.001	0.009	<0.001	0.084	0.002	0.014	<0.001
Drinking status		1	-	1	-	1	-	1	-
		0.177	<0.001	1.295	0.757	0.797	0.729	0.173	<0.001

Married participants in cluster A, C, and D were less likely to be centrally obese. Smokers were less likely to be centrally obese across all clusters.

Alcohol consumers in cluster A were 0.177 less likely to have central obesity. Moreover, in cluster D alcohol consumers were 0.173 less likely to have central obesity.

The tables bellow shows the determinants of general and central obesity by Clusters

Table 5.1: Backward Binary logistic regression between Sociodemographic factors and general obesity by village cluster A.

Variable		P value	OR	95% C.I
Step8	Gender(women)	0.020	2.171	(1.133-4.161)
	Alcohol consumption	0.073	0.594	(0.336-1.051)
	Smoking status	0.012	0.123	(0.064-0.715)

	Married status	0.033	1.554	(1.035-2.331)

In cluster A backward binary logistic regression showed a negative relationship between smoking status and a positive relationship between women, and married status with obesity.

Table 5.2: Backward Binary logistic regression between Sociodemographic factors and general obesity by village cluster B.

Variable		P value	OR	95% C.I
Step6	Gender(women)	0.045	2.135	(1.017-4.485)
	Alcohol consumption	0.081	0.592	(0.328-1.066)
	Smoking status	0.002	0.273	(0.094-0.602)
	Married status	0.676	1.125	(0.647-1.955)
	Divorced status	0.165	0.225	(0.027-1.846)

In cluster B the backward binary logistic regression showed a negative relationship between smoking status and a positive association between women and obesity.

Table 5.3: Backward Binary logistic regression between Sociodemographic factors and general obesity by village cluster C.

Variable		P value	OR	95% C.I
Step9	Smoking status	0.070	0.105	(0.009-1.199)
	Married status	0.030	2.365	(1.087-5.147)

In cluster C, binary logistic regression with a backward condition showed a positive relationship between married status and obesity.

Table 5.4: Backward Binary logistic regression between Sociodemographic factors and general obesity by village cluster D.

Variable	P value	OR	95% C.I

Step9	Smoking status	0.020	0.113	(0.081-0.712)

In cluster D, binary logistic regression with a backward condition showed a negative relationship between smoking status and obesity.

Table 5.5: Backward Binary logistic regression between Sociodemographic factors and central obesity by village cluster A.

Variable		P value	OR	95% C.I
Step7	No formal education	0.072	6.043	(0.849-43.027)
	Smoking status	0.001	0.486	(0.125-1.889)
	Married status	0.002	4.257	(1.708-10.735)
	Gender(women)	0.001	3.583	(1.665-7.712)

In cluster A binary logistic regression with a backward condition showed a negative relationship between smoking status, and positive relationship between women, and married status, with central obesity.

Table 5.6: Backward Binary logistic regression between Sociodemographic factors and central obesity by village cluster B.

Variable		P value	OR	95% C.I
Step10	Smoking status	0.049	0.250	(0.063-0.993)
	Gender(women)	0.022	5.692	(1.291-11.65)

In cluster B binary logistic regression with a backward condition showed a negative relationship between smoking status, and a positive relationship between women with central obesity

Table 5.7: Backward Binary logistic regression between Sociodemographic factors and central obesity by village cluster C.

Variable	P value	OR	95% C.I

Step9	Smoking status	0.108	0.370	(0.110-1.243)
	Married status	0.002	3.539	(1.582-7.919)

In cluster C binary logistic regression with a backward condition showed a positive relationship between married status and central obesity

Table 5.8: Backward Binary logistic regression between Sociodemographic factors and central obesity by village cluster D.

Variable		P value	OR	95% C.I
Step9	Smoking status	0.001	0.113	(0.032-0.402)
	Married status	0.037	3.749	(1.083-12.979)

In cluster D binary logistic regression with a backward condition showed a negative relationship between smoking status, married status and central obesity

Chapter 5: DISCUSSION

This chapter will discuss the findings of the present study about the spatial distribution of obesity, its predisposing factors, and associated complications together with information and literature from previous studies.

5.1 Socio-demographic profile, anthropometric measurements, and biochemical measurements characteristics for both gender.

The present study consisted of more women (69.4%) as compared to mem (30.6%). The reason for this may be because women are more likely to seek and use healthcare, have better health knowledge, adhere to medical programs, and ensure the health of others as well as their own (Osamor and Grady, 2016; Wald et al., 2007). Another reason for this difference may be the fact that the majority of the men are either day workers in the area settings or have official jobs in urban areas, and hence are not able to partake throughout the day (Van Zyl et al., 2012).

The mean age for the study was 52.07± 8.24, there was no significant difference in mean age between women and men. Mashinya et al., (2018), reported similar findings. In the present study, there was no significant difference in single and married participants between women and men. Mashinya et al., (2018), reported similar findings. Significantly, more females than males were divorced, and significantly, more women than men had deceased partners. However, the findings of the present study are not in agreement Mashinya et al., (2018), who reported no significant difference in divorced and participants with deceased partners between men and women, the inconsistences between the present study and Mashinya et al., (2018) may be due to the difference in sample size. The proportion of the unemployment rate in the population was 68.7%. Significantly, more women were unemployed as compared to men. The findings of the present study are in agreement with Mashinya et al., (2018), who reported a higher unemployment rate in women as compared to men. Culturally men should provide for their families as the main breadwinner of the family (Bobrova et al., 2010).

The present study reported a proportion of alcohol consumption of 33.7% and men had a significantly higher proportion of alcohol consumption than women. These findings are in agreement with Maimela, et al., (2016), who also reported that

significantly more men were alcohol consumers as compared to women. The findings of this study are similar to those of big community-based surveys conducted in other countries of Sub-Saharan Africa. In Nigeria, 32.7% of men and 5.3% of women reported past-year alcohol use (Gureje et al., 2007). While in Tanzania, the rate of alcohol use was significantly higher in men at 38.5% as compared to women at 23.7% (Mbatia et al., 2009). Recent longitudinal research with younger children indicated that a stronger association between parental alcohol use and children's intentions to drink in boys than in girls over time, implying that boys may be more directly influenced by parental drinking than girls (Mafa et al., 2019; Schulte et al., 2009). Cultural norms dictate a double standard for the monitoring and punishment of deviance for girls and boys, this discrepancy between genders serves as a protective factor against risk-taking for female adolescents whereas boys have more freedom to interact with peers that teach and reinforce alcohol use (Mafa et al., 2019; Bobrova et al., 2010; Schulte et al., 2009). The main reason why men drink more than women, is that traditionally the role of a woman is to be mother and keeper of house and family (Bobrova et al., 2010). The findings of the present study reported the proportion of smoking to be 21.3% and significantly, more men were smokers compared to women. Maimela et al., (2016), reported similar findings, reported the current smokers were significantly higher in men (29.2%) as compared to women (4.5%). Cultural norms detect that when a man smokes, it is just a health issue but when women smoke, it is considered a taboo (Tehrani et al., 2022; Başar et al., 2021).

Obesity

Increased BMI values, as well as a rise in overweight and obesity among black South Africans, have been reported in South African studies (Maimela et al., 2016; Sengwayo et al., 2012). In the present study the mean BMI was found to be in the overweight range (28.01 ± 8.24), corroborating previous findings in Limpopo Province (Magwai et al., 2022; Sengwayo et al., 2012) that excess weight, among other health concerns, exists in black South Africans. The present study reported the mean BMI to be significantly higher in women as compared to men. The findings of the present study are in agreement with Mashinya, et al., (2018).

The increased BMI in women, may be attributed to hormonal (i.e. estrogen) imbalances largely affecting women, particularly older women (Moraba and Mabusela,

2014). When estrogen levels are high enough, it can inhibit lipid synthesis in adipocytes, assisting in the regulation of energy expenditure and food consumption. (Moraba and Mabusela, 2014). Its deficiency, which is more common in older people, enhances fat deposition in adipose tissue, resulting in obesity. (Mashaba et al., 2022; Moraba and Mabusela, 2014). Another reason for an increase in obesity in women may be the socio-cultural barrier to practicing physical activities perceived by women is that they have home commitments, like taking care of the children and house duties, and negative attitudes by family members towards women practicing exercise/sport (Musaiger, 2011)

Obesity is on the rise around the world, contributing significantly to the rising burden of non-communicable diseases (Cois and Day, 2015). This rising trend is notably affecting South Africa, and cross-sectional evidence supports socioeconomic and behavioral characteristics as plausible drivers. Socioeconomic status (married, unemployed, and the highest level of education), excessive dietary energy consumption, little or no physical activity, and lifestyle (smoking, and alcohol consumption), have been reported to be associated with obesity (Kim et al., 2016; Cois and Day, 2015; Philipsen et al., 2015). South African, statistics have reported the prevalence of obesity to be 30%, which is three times higher than the prevalence of men 7.5% (Micklesfield et al., 2013).

Sengwayo et al., (2013), reported a higher prevalence the obesity in Limpopo Province of about 40.8% of the population in Ga-Mathapo villages. A study by Maimela et al. (2016), reported the prevalence of obesity to be higher in women (27.8%) than in men (10.6%) in Dikgale villages. Similarly, Mashinya et al., (2018), also reported similar results. In agreement with these studies, the present study reported the Proportion of obesity to be at 35% and significantly more women were obese as compared to men.

Central obesity

The waist circumference mean in the population was 90.12±16.07, and women had a significantly higher mean waist circumference than men. Gaziano et al., (2017), in their study of Cardio-metabolic risk in a population of older adults with multiple co-morbidities in rural South Africa, reported similar findings. One possible explanation for high WC in women is that most women available for the study were older and poor, forcing them to eat high-carbohydrate foods like pap (Mashinya et al., 2018). One of

the major risk factors for cardio-metabolic diseases is central obesity. However, there is little research on the socio-demographic and lifestyle factors that influence waist circumference (WC) change over time (Arabshahi, 2014).

Another possible reason for high waist circumference in women may be that most women in the area have more challenges engaging in physical activities as compared to men. The main socio-cultural barrier to practicing physical activities perceived by women is that they have home commitments, like taking care of the children and house duties, and negative attitudes by family members towards women practicing exercise/sport (Musaiger, 2011). One of the major risk factors for cardio-metabolic diseases is central obesity. However, there is little research on the socio-demographic and lifestyle factors that influence waist circumference (WC) change over time (Arabshahi, 2014).

The present study found a higher proportion of central obesity (59.9 %), in the study population with significantly more women than men having central obesity. The current study's findings are consistent with those of Liu et al., (2017), who found that the proportion of central obesity was significantly higher in older adults in both men and women. In addition, the proportion of central obesity was significantly lower among men than among women (Lv et al., 2015).

The proportion of high SAT in the total population was 56.2% and significantly more women had high SAT as compared to men. In agreement with the present study Kong et al., (2022), reported similar findings. The proportion of high VAT in the total population was 61.8% and significantly more women had high VAT as compared to men. In contrast a study by several studies reported the proportion of high VAT to be significantly higher in men as compared to women (Kong et al., 2022; Rolle-Kampczyk et al., 2020; Shuster et al., 2012). The inconsistences between the present study and the other studies may be due to the difference in sample size.

Metabolic Healthy obese

The proportion of healthy obese by high BMI in the total population was 22.9%, with significantly more women than men having a higher proportion of healthy obese. In agreement with the present study Blüher, (2014), reported the proportion of metabolic healthy obese to be high in women as compared to men. Similarly, metabolically healthy obesity was observed in 9.2% of obese men and in 16.4% of obese women

(Blüher, 2012). The proportion of healthy obese by high waist circumference in the total population was 23.6%, with significantly more women than men having a higher proportion of healthy obese. In agreement with the present study, Appleton et al., (2013), reported similar findings. Sex appears to be a significant predictor of the healthy obese sub phenotype, as healthy obesity is significantly more prevalent in postmenopausal women (Blüher, 2014, 2012). This may be due to hormonal imbalance which can inhibit lipid synthesis in adipocytes, assisting in the regulation of energy expenditure and food consumption (Moraba and Mabusela, 2014).

5.2 Association of obesity and central obesity with sociodemographic profiles.

5.2.1 Association between obesity and central obesity with marital status

Obesity with marital status

In the present study, most of the obese participants were married whilst most of the non-obese were single or divorced participants. Bivariate correlation analysis showed, single and divorced participants correlated negatively and significantly with obesity, and married participants correlated positively with obesity which was in agreement with results on comparing obese and non-obese participants. These correlations remain the same even after partial correlation analysis where age and gender were controlled for. In other words, single and divorced participants were less likely to be obese and married participants were more likely to be obese.

Central obesity and marital status

In the present study, participants with central obesity were significantly more likely to be single, married, or widowed than participants without central obesity. Liu et al., (2017), reported similar findings. Bivariate correlation analysis showed, single and divorced participants correlated negatively and significantly with central obesity, and married participants correlated positively with central obesity. These correlations remain the same even after partial correlation analysis where age and gender were controlled. Moreover, binary logistic regression confirmed the positive relationship between married participants and central obesity. In agreement with the present study, several studies have indicated that married adults had a higher rate of general obesity and central obesity than other marital status groups combined, and never-married

people had a lower central obesity rate than married people (Mashinya et al., 2018; Liu et al., 2017; Memish et al., 2014; Bakir et al., 2017).

In the present study married individuals were more likely to be obese and centrally obese as compared to other marital status, this association may be explained by the fact that psychosocial factors, such as social isolation, may cause qualitative and quantitative changes in the amount of food consumed through loss of appetite, refusal to eat, or lack of motivation to prepare food, reducing the amount of energy consumed and, as a result, increasing the risk of having a poor nutritional status (Elovainio et al., 2017; Davidson et al., 2009).

5.2.2 Association between obesity and central obesity with smoking

Obesity with smoking

In the present study, the proportion of smoking was significantly lower in obese participants as compared to non-obese participants. The findings of the present study are in agreement with Dare et al., (2015), who reported the proportion of smoking to be high in non-obese participants than in obese participants. Bivariate correlation and partial correlation showed a negative association between smoking and obesity. In agreement with the findings of the present study, a cross-sectional study reported that smokers were less likely to be obese than never-smokers (Dare et al., 2015). In addition, Mashinya et al., (2018) also reported a negative association between BMI and smoking.

Central obesity with smoking

In the present study, the proportion of smoking was significantly high in participants without central obesity than in central obesity. Bivariate correlation analysis revealed that smokers were negatively and significantly associated with obesity in the current study. The correlation remained unchanged even after controlling for age and gender in a partial correlation analysis. In addition, binary logistic regression confirmed the negative relationship between smokers and central obesity. In agreement with the present study several studies reported a negative association between smoking and central obesity (Gasperin et al., 2014; Audrain-Mcgovern and Benowitz, 2011; Al-Riyami and Afifi, 2003). However, a cross-sectional study by Kim et al., (2016), reported a positive association between smoking and central obesity. Similarly, Lv et

al., (2015), reported a positive association between smoking and central obesity. The inconsistencies between these studies may be that the present study used a lower sample size.

Similarly, a study by Mackay et al., (2013), on the Impact of smoking and smoking cessation on overweight and obesity", reported that smoking is associated with the lowering of weight whilst smoking cessation is associated with the increase of body weight. The mechanism by which smoking leads to reduced body weight and waist circumference is complex and involves multiple neurochemical pathways. Most of the effects of smoking on body weight are mediated by nicotine inhaled from cigarette smoke (Chao et al., 2019; Audrain-Mcgovern and Benowitz, 2011; Benowitz, 2010).

Nicotine increases the levels of various neurotransmitters, such as catecholamines, dopamine, and serotonin in the brain, which in turn suppresses appetite and consequently reduces food intake (Seoane-Collazo et al., 2021; Fowler and Kenny, 2014; Audrain-Mcgovern and Benowitz, 2011). It is theoretically possible, however not yet confirmed that nicotine has a negative effect on eating, since is a drug that imitates the action of the neurotransmitter acetylcholine and can easily penetrate the blood-brain barrier (Fowler and Kenny, 2014; Mackay et al., 2013).

5.2.3 Association between obesity and central obesity with alcohol consumption

In the present study, significantly more participants that are non-obese were alcohol consumers compared to obese participants. Dare et al., (2015) reported similar findings. Alcohol consumption is common worldwide, and alcohol energy (7 kcal/g) can contribute to weight gain if not compensated for (Traversy and Chaput, 2015).

Bivariate correlation analysis showed that alcohol consumption was negatively and significantly associated with obesity in the present study. The correlation remained unchanged even after controlling for age and gender in a partial correlation analysis. In addition, binary logistic regression confirmed the negative relationship between alcohol consumption and obesity even further. These results are in agreement with other studies, which have reported a negative association between alcohol consumption and obesity (Otang-Mbeng et al., 2017; Traversy and Chaput, 2015; Arabshahi, 2014). Moreover, Mashinya, et al., (2018), reported a negative relationship between alcohol consumption and BMI.

The mechanism in which alcohol consumption leads to reduced BMI is complex and not completely understood. Several mechanisms of how alcohol consumption leads to reduced weight have been postulated. Firstly, alcohol is reported to disrupt the mechanism that regulates appetite and thus food intake, causing appetite to decrease (Holstein-Rathlou and Gillum, 2019; Ivezaj et al., 2019; Broberger, 2005). Secondly, alcohol is reported to harm the cell lining of the stomach and intestine thus reduces digestion and absorption (Gathuci, 2020; Setlalentoa et al., 2010). Lastly, alcohol inhibits the breakdown of nutrients into useful amino acids by decreasing the secretion of the necessary digestive enzymes, resulting in decreased nutrient absorption and weight loss (Gathuci, 2020; Setlalentoa et al., 2010). There was no association between central obesity and alcohol consumption in the present study.

5.2.4 Association between obesity and central obesity with unemployment

In the present study there was no association between unemployment and obesity. However, binary logistic regression showed that unemployed participants were 2.148 times more likely to have central obesity. In agreement with the present study, several studies reported unemployment to be associated with increased waist circumference (Pan et al., 2020; Herber et al., 2019; Bakir et al., 2017; Sarlio-Lähteenkorva et al., 2006). Unemployed individuals might not be able to afford nutritious food because of financial restrictions (Herber et al., 2019). The health of a person may be impacted by unhealthy or poor eating. One has an emotional emptiness in their lives while they are unemployed. One frequently eats junk food and food rich in carbohydrates to fill boredom, which causes obesity (Herber et al., 2019).

5.3 Obesity and central obesity with associated complications

5.3.1 Obesity with hypertension

In the present study, the proportion of hypertension was significantly higher in obese participants than in non-obese. Bivariate correlation analysis revealed that hypertension was positively and significantly associated with obesity. The correlation remained unchanged even after controlling for age and gender in a partial correlation analysis. In addition, binary logistic regression confirmed the positive relationship between hypertension and obesity even further. A study by Jiang et al., (2016), reported similar findings. In agreement with the present study, Mollan et al., (2021)

reported a positive relationship between obesity and hypertension. Maimela, et al., (2016), found obesity to be associated with hypertension.

5.3.2 Central obesity with hypertension

In the present study, the proportion of hypertension was significantly higher in central obesity participants than in non-central obesity. Bivariate correlation analysis revealed that hypertension was positively and significantly associated with central obesity in the current study. The correlation remained unchanged even after controlling for age and gender in a partial correlation analysis. In addition, binary logistic regression confirmed the positive relationship between hypertension and central obesity even further. Jiang et al., (2016), reported similar findings.

The mechanisms through which general or central obesity directly causes hypertension are still an area of research. One postulated mechanism is, that an increase in the amount of intra-abdominal and intra-vascular fat, and sodium retention leading to an increase in renal reabsorption, and the renin-angiotensin system, are considered to have important functions in the pathogenesis of obesity-related hypertension (Du et al., 2013; Yiannikouris et al., 2012). Activation of the sympathetic nervous system has been considered to have an important function in the pathogenesis of obesity-related hypertension (Jiang et al., 2016; Kotsis et al., 2010). During the early phases of obesity, primary sodium retention exists as a result of the increase in renal tubular reabsorption.

Extracellular-fluid volume is expanded and the kidney-fluid apparatus is restored to a hypertensive level, consistent with a model of hypertension because of volume overload (Jiang et al., 2016; Kotsis et al., 2010). Plasma renin activity, angiotensinogen, angiotensin II and aldosterone values display significant increases during obesity. Insulin resistance and inflammation may promote an altered profile of vascular function and consequently hypertension (Du et al., 2013; Yiannikouris et al., 2012; Kotsis et al., 2010). In addition, plasma aldosterone has been reported to be high especially in visceral obesity participants (Mende and Einhorn, 2022). An increase in increase aldosterone can lead to vasocontraction and ultimately leads to hypertension (Kućmierz et al., 2021; Simoes e Silva et al., 2021), it can raise rise blood pressure in obese people by acting on mineralocorticoid receptors found in various

tissues such as the kidney, vasculature, and brain (Parasiliti-Caprino et al., 2022; Gorini et al., 2019)

5.3.3 Obesity and diabetes mellitus

In the present study, there was no difference in the proportion of diabetes mellitus between non-obesity and obesity. In the present study, partial correlation analysis revealed that diabetes mellitus participants were negatively and not significantly associated with obesity. The correlation remained insignificant even after controlling for age and gender in a partial correlation analysis. Binary logistics further confirmed that there is no relationship between obesity and diabetes mellitus. In contrast with the present study, Dai and Jiang, (2019), reported a positive association between obesity and diabetes mellitus. The inconsistencies between the present study and Dai and Jiang study may be that the other study focused on mitochondrial dysfunction which is reported to be the key regulator in the pathophysiology of obesity and diabetes mellitus. Furthermore, mutations in certain mitochondrial genes have been shown to be the primary causes of these metabolic diseases (Geto et al., 2020).

5.3.4 Central obesity with diabetes mellitus

In the present study, the proportion of diabetes mellitus was significantly higher in central obesity as compared to non-central obesity Bivariate correlation analysis in the current study found a positive and significant association between diabetes mellitus and obesity. Even after controlling for age and gender in partial correlation analysis, the association did not change. Additionally, binary logistic regression supported the association between diabetes mellitus and obesity even further after adjusting for known and unknowable variables. The findings of the present study are in agreement with Jiang et al., (2016). Excess caloric intake leads to the accumulation of adipose tissues in the body, and as the amount of adipose tissue increases it also increases the release of proinflammatory cytokines. Increased release of inflammatory cytokines can lead to the development of chronic low-grade inflammation (Unamuno et al., 2019). Prolonged chronic low-grade inflammation blocks or interferes with the normal insulin signaling pathways, leading to insulin resistance and thus the development of diabetes mellitus (Unamuno et al., 2019).

5.3.5 Obesity and chronic kidney diseases

Partial correlation analysis showed that kidney disease was positively and not significantly associated with obesity in the present study. In addition, binary logistic regression confirmed that there is no relationship between kidney disease and obesity. There was no association between high ARC, egrcat, and obesity. A study by Hall et al., (2014), reported a positive association between obesity and kidney disease as compared to the current study. The reason for this insistence may be that perhaps hypertension in the population may not be that severe. Collins et al., (2012), reported hypertension to account for 75% of end-stage renal disease and in most cases, hypertension will be a result of gained weight.

5.3.6 Central obesity with chronic kidney disease

In the present study, the proportion of kidney disease was significantly higher in central obese participants than in non-central obese. In the present study, bivariate correlation and partial correlation showed a positive association between high ACR and central obesity the findings of the present study are in agreement with Du et al., (2013), who reported, central obesity is positively associated with an increased urinary ACR. In addition, a study by Qin et al., (2021), reported similar findings, participants with central obesity, had a higher risk of elevated urinary ACR. Bivariate correlation and partial correlation showed a positive association between high kidney disease and central obesity. In agreement with the present study, Silva Junior et al., (2017), reported central obesity to be a major cause of abnormal kidney disease. Increased visceral adiposity may result in access to renal sodium reabsorption, impaired renal-pressure natriuretic, and expansion of extracellular fluid volume, all of which raise arterial blood pressure (Hall et al., 2010). In addition, elevated blood pressure coupled with renal vasodilation and glomerular hyperfiltration, SNS and RAAS activation, inflammation, and metabolic derangements eventually causes renal injury (Hall et al., 2014)

5.3.7 Obesity and Dyslipidemia

In the present study, the proportion of high LDL-C/HDL-C ratio and TC/HDL-C ratio was significantly higher in obese participants than in non-obese. Bivariate correlation analysis revealed that a high LDL-C/HDL-C ratio correlated positively and significantly with obesity. The correlation remained unchanged even after controlling for age and

gender in a partial correlation analysis. The findings of the present study are in agreement with Nadeem et al., (2021), who reported increased body weight to be associated with a high LDL-C/HDL-C lipid ratio.

5.3.8 Central obesity and Dyslipidemia

In the present study, the proportion of high LDL-C/HDL-C ratio, and TC/HDL-C ratio was significantly higher in central obese participants than in non-central obese. Bivariate correlation analysis revealed that high LDL-C/HDL-C ratio, and TC/HDL-C ratio were positively and significantly associated with central obesity in the current study. The correlation remained unchanged even after controlling for age and gender in a partial correlation analysis. In agreement with the present study (Rysz, 2014), reported a positive association between central obesity and LDL-C/DHL-C ratio. (Goh and Hart, 2018; Reddy and Nambiar, 2018), reported, that central obesity is significantly associated with higher levels of TC/HDL-C ratios. This suggests that waist circumference plays an important role in classifying the risk of lipid deposition in adipose tissue (Nadeem et al., 2021).

Obesity has a negative effect on HDL metabolism because it increases chylomicron and VLDL remnants and impairs lipolysis (Tall et al., 2022; Klop et al., 2013). Increased LDL-C and total cholesterol lipoprotein levels result in increased CETP activity, which exchanges HDL cholesterolesters for VLDL and LDL TG (Klop et al., 2013). Furthermore, hepatic lipase lipolyzes these TC-rich HDL, producing small HDL with a lower affinity for apo A-I, resulting in apo A-I detachment from HDL. This will eventually result in lower HDL-C levels, a decrease in circulating HDL particles, impaired reversed cholesterol transport, and an increase in LDL-C and total cholesterol levels in the blood (Klop et al., 2013).

5.4 Spatial distribution

The DIMAMO HDSS consisted of 12 villages, but due to the low numbers of participants in other villages, clusters were created to better explain and show how obesity is distributed in the HDSS. The reason why these villages are presented in clusters is that some villages had a lower number of participants and it was a bit problematic doing some statistical analyses, then it was decided that the villages that are close to each other be assimilated and regarded as one.

5.4.1 Spatial distribution of obesity and central obesity

The study consisted of 791 participants, cluster A had 196 participants, cluster B with 208, cluster C with 180, and cluster D with 207 participants. Cluster B and A had the highest prevalence of both general obesity and central obesity this may be due to that these clusters had the highest number of participants as compared to other clusters and less number of smokers and alcohol consumers. Most studies have reported the waist circumference to be significantly higher in women as compared to men (Bhagwat et al., 2018; Streng et al., 2018; Gaziano et al., 2017), hence cluster B and A has the highest prevalence of central obesity due to the number of women within these clusters. Moreover, most of these participants were women. In addition, looking at the analysis of the present study obesity and central was more prevalent in women as compared to men. Another reason may be these clusters had the highest prevalence of married participants. Married adults had a higher rate of overweight or obesity than other marital status groups combined, and never married people had a lower obesity rate than married people (Memish et al., 2014).

5.5 Determinants of distribution of obesity

5.5.1 Gender as a determinant of the distribution obesity and central obesity

The proportion of women was significantly higher in cluster A, as compared to cluster C and cluster D. Binary logistic regression showed a positive association between women and both general and central obesity. In agreement with the present study, several studies have indicated that women are more likely to develop both general obesity and central obesity (Mashaba et al., 2022; Monakali et al., 2019; Bhagwat et al., 2018; Mashinya et al., 2018; Streng et al., 2018; Gaziano et al., 2017; Moraba and Mabusela, 2014; Ali and Crowther, 2010).

5.5.2 Marital status as a determinant of the distribution obesity and central obesity

In cluster A and D, married participants correlated positively and significantly with obesity in bivariate correlation. These correlations remain the same even after partial correlation analysis where age and gender were controlled. In other words, married participants were more likely to be obese. The findings of the present study are in agreement with Mashinya et al., (2018) who reported a positive association between

BMI and being married. Similarly, in cluster A, C, and D, bivariate and partial correlation analysis showed married participants correlated positively and significantly with central obesity. Moreover, binary logistic regression confirmed the positive relationship between married status and central obesity. In agreement with the present study, several studies have indicated that married adults had a higher rate of central obesity than other marital status groups combined, and never-married people had a lower central obesity rate than married people (Liu et al., 2017; Memish et al., 2014)

5.5.3 Smoking as a determinant of the distribution obesity and central obesity

In the present study, bivariate correlation and logistic regression showed a negative association between smoking and obesity in cluster B, C, and D. In agreement with the findings of the present study, a cross-sectional study reported that smokers were less likely to be obese than never smokers (Dare et al., 2015). In addition, Mashinya et al., (2018) also reported a negative association between BMI and smoking.

Bivariate correlation analysis showed that smokers were negatively and significantly associated with central obesity in all the clusters. Binary logistic regression confirmed the negative relationship between smokers and central obesity. In agreement with the present study Gasperin et al., (2014), reported a negative association between smoking and central obesity.

5.5.4 Alcohol consumption as a determinant of the distribution obesity and central obesity

Bivariate correlation analysis showed that alcohol consumption was negatively and significantly associated with obesity in cluster D. The correlation remained unchanged even after controlling for age and gender in a partial correlation analysis. In addition, binary logistic regression confirmed the negative relationship between alcohol consumption and obesity even further. These results are in agreement with other studies, which have reported a negative association between alcohol consumption and obesity (Otang-Mbeng et al., 2017; Traversy and Chaput, 2015; Arabshahi, 2014). Moreover, Mashinya et al., (2018), reported a negative relationship between alcohol consumption and BMI.

Similarly, bivariate correlation analysis showed that alcohol consumption was negatively and significantly associated with central obesity in cluster A and D. The

correlation remained unchanged even after controlling for age and gender in a partial correlation analysis in cluster D. In addition, binary logistic regression confirmed the negative relationship between alcohol consumption and central obesity even further in both cluster A and D. In agreement with the present study Traversy and Chaput, (2015) reported similar findings.

5.6 Conclusion

The present study's findings showed a high proportion of obesity and central obesity in the DIMAMO HDSS. The proportion of healthy obese by high BMI in the total population was 22.9% and the proportion of healthy obese by high WC in the total population was 23.6%.

Both Obesity and central obesity were more common in the Northeastern part of the DIMAMO HDSS compared to the Eastern and Northern village clusters. The significant determinants of obesity and central obesity were gender, marital status, alcohol consumption and smoking. These determinants also showed to be critical in determining how obesity is distributed in the DIMAMO HDSS. Obese participants were more likely to be hypertensive, and centrally obese participants were more likely to be diabetic, hypertensive, and have chronic kidney disease.

5.7 Limitations

Due to the following limitations, the current study's findings should be interpreted with caution. The results of the study cannot be generalized to the entire population of Limpopo Province or the larger community outside of this group due to the use of convenient sampling method. This could have resulted in either under or over-estimation of the prevalence of the obesity. The sample size may be too small for a detailed spatial epidemiological analysis the present study. The use of retrospective data has prevented the researcher to get an appropriate denominator in each cluster when calculating prevalence per cluster. However, the present study provides a baseline platform that necessitate the need for similar studies as such epidemiological studies can help the health professionals to know which geographical areas should be targeted when establishing appropriate interventions such as obesity awareness campaigns.

5.8 Recommendations

We recommend that similar studies be conducted, whereby a random sampling of participants used, and with a significant sample size, to determine the spatial distribution of obesity of the Limpopo province by villages instead of clusters.

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7. APPENDICES

Appendix I: DATA EXTRACTION TOOL

Id	
DEMOGRAPHIC STATUS	
Age	
Gender	
Physical home address	
Date of birth	
Country	
Race	
Suburbs or rural area	
SOCIO ECONOMIC STATUS	
School	
Marital status	
Working	
LIFESTYLE	
Physical activity	
Sedentary life	
Advanced technology	
Beliefs	
SUBSTANCES USE	
Alcohol	
Smoking	

LABORATORY MEASUREMENTS AND ANALYSIS	
Weight	
Height	
Blood for lipids analysis	
GENERAL HEALTH	
Problem weight or obesity	
Hypertension	
High cholesterol	
Diabetes Meletus	

Appendix II

AWI-Gen H3Africa Questionnaire

Genomic and Environmental Risk Factors for Cardiometabolic Disease Africans

AWI-Gen Study Number: |__|__|__|__||__|	**Unique Site Identifier: |__|__|__|__||__|__|__|**

BARCODE STICKER
Please stick the barcode sticker here

1. GENERAL INFORMATION (Ditlabakelo ka kakaretšo)		
1.1	Data collection date (Letšatši la kgoboketšo ya tshedimošo)	**| d | d | | m | m | m | | y | y | y | y |**
1.2	Interviewer code (Nomoro ya mmotšiši)	_____

1.3	Start time (Nako ya go thoma)	**| h | h |:| m | m | am / pm** ***[please circle appropriate time of day]*** ***[laetša nako ya letšatši ka ntikodiko]***

2. DEMOGRAPHIC INFORMATION				
2.1	First Name (Leina)			
2.2	Last Name (Sefane)			
2.3	Date of birth known? ***[If no, skip to Q.2.5]*** (A o tseba letšatši la gago la matswalo? ***[ge o sa le tsebe fetela go Q.25]***)	Yes/Eng	No/Aowa	
2.4	Date of Birth ***[eg. 27 SEP 1957]*** (Letšatši la matswalo)	**| d | d | | m | m | m | | y | y | y | y |**		
2.5	Approximate year of birth (Kakanyo ya ngwaga wa pelego)	**| 1 | 5 | | J | U | N| | y | y | y | y |**		
2.6	Gender (Bong)	Female (Mosadi)	Male (Monna)	***[please tick the appropriate box]***

				[thaletša lepokisi la maleba]
2.7	Country (Naga)	South Africa (Afrika Borwa)		

PHENOTYPIC COLLECTION DATA

3. PREGNANCY (Go ima) **[If male, please skip to the next section - Marital Status]** **[Ga e ba ke monna, fetela go tša nyalo]**			
3.1	Are you pregnant? (A o mmeleng?)	Yes/Eng	No/Aowa

4. SUBSTANCE USE (Tšhomišo ya ditagi)

4.1. Alcohol use (Tšhomišo ya dinotagi				
4.1.1	Do you drink alcohol? (A o nwa dinotagi?)	***[If no, skip to Q.9.3]*** ***[Ga ebake aowa fetela go Q 9.3]***	Yes/Eng	No/ Aowa
4.1.2	Over the past 30 days, on how many days did you drink one or more alcoholic beverages?		**|__|__|** days/matšatši	

	(Matšatšing a masometharo ao a fitilego, ke matšatši a ma kae moo o nwelego dinotagi?)	
4.1.3	On the days that you drank alcoholic beverages, what was the average number of alcoholic beverages you had each day? (Go matšatši ao o nweleng dinotagi, ke dino tše kae tšeo o di nwelego letšatšing le tee?)	|__|__|
4.1.4	What type of alcoholic beverage do you usually drink? (Ke mohuta o fe wa dinotagi oo o dulang o o nwa?)	Beer Wine Spirits Home brew Other (Specify/letša)_____

5. GENERAL HEALTH (Tša maphelo)

Please indicate if you have or had, any of the following illnesses

(Laetša ge mmago ana le, a ile a ba le malwetsi ao a latelago)

[Please tick the appropriate boxes]

[Thaletša ka lepokising la maleba]

5.1	Weight problem/obesity (Bothata bja boima)	Yes/Eng	No/Aowa	Not sure/ Ga ke na bonnete	Refuse to answer/ O gana o araba

5.2	High blood pressure (Madi ama kgolo)	Yes/Eng	No/Aowa	Not sure/ Ga ke na bonnete	Refuse to answer/ O gana o araba
5.3	Heart problems (Bothata bja pelo)	Yes/Eng	No/Aowa	Not sure/ Ga ke na bonnete	Refuse to answer/ O gana o araba
5.4	High cholesterol (a lot of fat in your blood) (Makhura a mantši mading)	Yes/Eng	No/Aowa	Not sure/ Ga ke na bonnete	Refuse to answer/ O gana o araba

6. INFECTION HISTORY (Histori ya malwetši a phetetšo)

[Please tick the appropriate boxes]

[Thaletša ka lepokising la maleba]

6.1. HIV					
6.1.1	Have you been tested for HIV? ***[If no, skip to Q.11.1.4]*** (A o ile wa dira diteko tša HIV?) ***[Ga eba ke aowa, fetela go Q 11.1.4]***	Yes/Eng	No/Aowa		Refuse to answer/ O gana o araba
6.1.2	Are you HIV positive? (A ekaba o na le HIV?)	Yes/Eng	No/Aowa	Don't know/Ga a tsebe	Refuse to answer/

					O gana o araba
6.1.3	Do you use medication for it? (A o šomiša dihlare go okobatša HIV?)	Yes/Eng		No/Aowa	
6.1.4	Do you agree to have your blood sample tested for HIV? (O ka dumela gore madi a gago a dirwe diteko tša HIV?)	Yes/Eng		No/Aowa	

7. Time at completion of questionnaire **| h | h |:| m | m | am / pm /**

APPENDIX III

a) Principle, method performance and quality assurance of biochemical measurements

Determination of TC

Principle:

$$\text{Cholesterol esters} + 2H_2O \xrightarrow{\text{CHE}} 2\text{Cholesterol} + 2\text{ Fatty acids}$$

$$2\text{Cholesterol} + 2O_2 \xrightarrow{\text{CHO}} 2\text{Cholesterol} - 3 - \text{one} + 2H_2O$$

$$2H_2O_2 + 4 - \text{Aminoantipyrine} + \text{Phenol} \xrightarrow{\text{POD}} \text{Quinoneimine} + 4\ H_2O$$

The cholesterol reagent utilises an enzymatic method to measure cholesterol in human serum and plasma. In this procedure cholesterol esters in a sample are hydrolysed by cholesterol esterase (CHE). The free cholesterol produced is oxidised by cholesterol oxidase (CHO) to cholestene-3-one with the simultaneous production of hydrogen peroxide (H_2O_2), which oxidatively couples with 4-aminoantipyrine and phenol in the presence of peroxidase (POD) to yield a chromophore.

The red quinoneimine dye formed can be measured spectrophotometrically at 540/600 nm as an increase in absorbance.

Method performance:

- The CV for the method within run is 1.6%.
- Sensitivity equals 1 mg/dL.
- The method is not interfered by ascorbate, icterus, haemolysis and lipemia.

Quality assurance:

- SeraChem 1 and 2 were used for quality assurance.

b) Determination of HDL-C

Principle:

$$\text{LDL, VLDL and chylomicrons} \xrightarrow{\text{Anti} - \text{human} - \beta - \text{lipoprotein antibody}} \text{Antigen} - \text{Antibody complexes}$$

$$\text{HDL} - \text{cholesterol} + \text{H}_2\text{O} + \text{O}_2 \xrightarrow{\text{CHE and CHO}} \text{Cholest} - 4 - \text{en} - 3 - \text{one} + \text{Fatty acids} + \text{H}_2\text{O}_2$$

$$\text{H}_2\text{O}_2 + 4 - \text{AA} + \text{F} - \text{DAOS} \xrightarrow{\text{POD}} \text{Blue dye}^+ + \text{F}^- + 2\text{H}_2\text{O}$$

Anti-human-β-lipoprotein antibody in R1 binds to lipoproteins other than HDL (LDL, VLDL and chylomicrons). The antigen-antibody complexes formed block enzyme reactions when R2 is added. HDL-cholesterol is quantified by the presence of an enzyme chromogen system.

Method performance:

- The CV for the method within run is 1.7%.
- The method is not interfered by bilirubin, lipids and haemoglobin.

Quality assurance:

- SeraChem 1 and 2 were used for quality assurance.

c) Determination of TG

Principle:

$$\text{Triglycerides} + 3\,H_2O \xrightarrow{\text{Lipase}} \text{Glycerol} + \text{Fatty acids}$$

$$\text{Glycerol} + \text{ATP} \xrightarrow{GK,\,Mg^{2+}} \text{Glycerol} - 3 - \text{phosphate} + \text{ADP}$$

$$\text{Glycerol} - 3 - \text{phosphate} + O_2 \xrightarrow{\text{GPO}} \text{Dihydroxyacetone phosphate} + H_2O_2$$

$$H_2O_2 + 4 - \text{AAP} + \text{MADB} \xrightarrow{\text{POD}} \text{Blue Dye} + OH^- + 3\,H_2O$$

This Triglyceride procedure is based on a series of coupled enzymatic reactions. The triglycerides in the sample are hydrolysed by a combination of microbial lipases to give glycerol kinase (GK) to produce glycerol-3-phosphate. The glycerol-3-phosphate is oxidised by molecular oxygen in the presence of GPO (glycerol phosphate oxidase) to produce hydrogen peroxide (H_2O_2) and dihydroxyacetone phosphate. The formed H_2O_2 reacts with 4-aminophenazone and N,N-bis(4-sulfobutyl)-3,5-dimethylaniline, disodium salt (MADB) in the presence of peroxidase (POD) to produce a chromophore, which is read at 660/800nm. The increase in the absorbance at 660/800nm is proportional to the triglyceride content of the sample.

Method performance:

- The method is not subject to interference by lipaemia, haemoglobin and bilirubin.

Quality assurance:

- SeraChem control 1 and 2 were used for quality assurance.

d) Determination of glucose

Glucose was determined, using AU480 auto-analyser supplied by Beckman Coulter.

Principle:

$$\text{Glucose} + \text{ATP} \xrightarrow{\text{HK, Mg}^{2+}} \text{Glucose} - 6 - \text{phosphate} + \text{ADP}$$

$$\text{Glucose} - 6 - \text{phosphate} + \text{NAD}^{+} \xrightarrow{\text{G6P} - \text{DH}} \text{Gluconate} - 6 - \text{P} + \text{NADH} + \text{H}^{+}$$

Glucose is phosphorylated by hexokinase (HK) in the presence of adenosine triphosphate (ATP) and magnesium ions to produce gluacose-6-phosphate and adenosine diphosphate (ADP). Glucose-6-phosphate dehydrogenase (G6P-DH) specifically oxidises glucose-6-phosphate to gluconate-6- phosphate with the concurrent reduction of NAD^{+} to NADH. The increase in absorbance at 340 nm is proportional to the glucose concentration in the sample.

Method performance:

- According to the manufacturer, the coefficient of variance within run is 2.2 %. The analytical sensitivity of the method is 0.0 mmol/L and there is no interference from lipemia up to sample absorbance of 6.8/cm at 660 nm (12.4 mmol/L). No interference up to 0.300 mmol/L haemoglobin). No interference up to 137 umol/L bilirubin.

Quality assurance

- Serachem control level 1 and 2.

e) Determination of CRP

CRP was measured, using AU480 auto-analyser supplied by Beckman Coulter.

Principle:

When a sample is mixed with R1 buffer and R2 latex suspension, CRP reacts specifically with anti-human CRP antibodies coated on the latex particles to yield insoluble

aggregates. The absorbance of these aggregates is proportional to the CRP concentration in the sample.

Method performance

- According to the manufacturer the CV of this method is 3.12%, analytical sensitivity is 0.10 mg/L (0.010 mg/dL). There is no interference by bilirubin, lipids and haemoglobin.

Quality Assurance

- Serology Control level 1, 2 and 3 were used for quality assurance.

APPENDIX IV: CONSENT FORM

Statement by Researcher

I have fully explained to the participant the aim, objectives and procedures of the study, including collection of a blood sample. I have answered to the best of my ability any questions that have arisen regarding the study and the procedures.

Signed by researcher :……

Date :…….

Statement by the participant

I have been fully informed as to aim, objectives and procedures to be followed and understood them. In signing this form, I agree to this research and understand that I am free to refuse or withdraw this consent regarding my participation in the study, at any time.

Signed :…….

Date :…….

Witness :…….

Appendix V: appointment latter

University of Limpopo
Human Resources Department
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 2129, Fax: (015) 268 2289, Email: Ingrid.fourie@ul.ac.za

15 April 2021

M CB Ntimana
PO Box 1407
Hluvukani
1363

Dear Mr Ntimana

OFFER OF APPOINTMENT AS RESEARCH ASSISTANT: FACULTY OF HEALTH SCIENCES

We have pleasure in confirming your **THREE (3)**-month temporary appointment at the University of Limpopo as follows:

Designation	:	Research Assistant
Department / Faculty	:	Faculty of Health Sciences. AWIGen Phase 2 Project
Effective date of appointment	:	08 March 2021
Expiry date of appointment	:	30 June 2021
Pre-tax Monthly Package	:	
Total Salary for duration of contract	:	
Guaranteed total annual package	:	
Cost Centre	:	311

Whereas all the necessary precautions have been taken to ensure the accuracy of the information on this letter, should any errors be detected later on, they shall be rectified accordingly.

Finding solutions for Africa

Kindly let us have your formal acceptance within 10 (ten) days of receipt for the attention of **Ms Ingrid Fourie.**

Yours sincerely

MR JK MOLOTO
Chief Human Resources Officer

19/04/2021
DATE

PROF RJ SINGH
DVC: Research, Innovation and Partnerships

19/04/2021
DATE

PROF NM MOKGALONG
Vice-Chancellor and Principal

19/04/2021
DATE

APPENDIX VI: TREC CERTIFICATE

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3935, Fax: (015) 268 2306, Email: anastasia.ngobe@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **09 November 2021**

PROJECT NUMBER: **TREC/264/2021: PG**

PROJECT:

Title:	Spatial Distribution of Obesity, Its Predisposing Factors and Associated Complications at the DIMAMO Population Health Research Centre, Limpopo Province, South Africa
Researcher:	CB Ntimana
Supervisor:	Mr SSR Choma
Co-Supervisor/s:	Dr ML Masemola-Maphutha
School:	Health Care Sciences
Degree:	Master of Science in Medical Science

PROF P MASOKO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) **This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**

ii) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**

iii) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

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