TYPE 2 DIABETES PREVALENCE AND ITS ASSOCIATED RISK FACTORS AMONG ADULTS ATTENDING THE OUTPATIENT DEPARTMENTS IN A MANZINI TERTIARY HOSPITAL, SWAZILAND

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PREFACE

This thesis is submitted to the University of KwaZulu Natal, College of Health Sciences in fulfilment of the requirements for the degree of Doctor of Philosophy, under the supervision of Doctor Boikhutso Tlou.

DECLARATION 1

I **MOJEED AKOREDE GBADAMOSI** declare that:

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List of publications arising from the thesis and contribution statements:

(i) Gbadamosi MA, Tlou B. Prevalence of abnormal glucose metabolism among adults attending Outpatient department at a tertiary referral hospital in Swaziland: a cross-sectional study. *BMC Public Health*. (2020) 20:392. https://doi.org/10.1186/s12889-020-08489-9

Contribution: Mojeed Gbadamosi reviewed the literature, made substantial contributions to the conception and design, and drafted the manuscript. Boikhutso Tlou participated in the design of the study and the drafting of the manuscript. Both authors read and approved the final manuscript.

(ii) Gbadamosi MA, Tlou B. Modifiable risk factors associated with abnormal glucose metabolism and hypertension among outpatients in Manzini, Swaziland: a cross-sectional study. *BMC Public Health*. (2020) 20:665. https://doi.org/10.1186/s12889-020-08816-0

Contribution: Mojeed Gbadamosi reviewed the literature, made substantial contributions to the conception and design, and drafted the manuscript. Boikhutso Tlou participated in the design of the study and the drafting of the manuscript. Both authors read and approved the final manuscript.

(iii) Gbadamosi MA, Tlou B. Overweight, obesity, and associated factors: a cross-sectional study of adult outpatients at a Swazi Hospital. This manuscript has been submitted to JEMDSA. Under Review.

Contribution: Mojeed Gbadamosi reviewed the literature, made substantial contributions to the conception and design, and drafted the manuscript. Boikhutso Tlou participated in the design of the study and the drafting of the manuscript. Both authors read and approved the final manuscript.

(iv) Gbadamosi MA, Tlou B. Comparative analysis of anthropometric indices of obesity as predictors of T2DM prediabetes and hypertension in Swazi adults: a cross-sectional study. This manuscript has been submitted to BMC Nutrition. Under Review.

Contribution: Mojeed Gbadamosi reviewed the literature, made substantial contributions to the conception and design, and drafted the manuscript. Boikhutso Tlou participated in the design of the study and the drafting of the manuscript. Both authors read and approved the final manuscript.

DEDICATION

This work is dedicated to the Almighty God who gave me the privilege, strength, and wisdom to pursue this degree, to my wife, who supported and encouraged me throughout the period of the study, and to my children for their encouragement and understanding.

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LIST OF ABBREVIATIONS

BMI	Body Mass Index
BP	Blood Pressure
CVD	Cardiovascular Disease
NCD	Non-communicable Diseases
SES	Socio-economic Status
SSA	Sub-Saharan Africa
T2DM	Type 2 Diabetes Mellitus
WC	Waist Circumference
WHO	World Health Organisation
WHR	Waist-to-hip ratio

ABSTRACT

Background: The prevalence of type 2 diabetes is rising worldwide, with a rapid increase in sub-Saharan Africa. Diabetes prevalence in sub-Sahara Africa is expected to increase by 143% by 2045. Nevertheless, there is a scarcity of epidemiological data on the prevalence of type 2 diabetes mellitus (T2DM) and its associated risk factors in Swaziland. Therefore, this study aimed to determine the prevalence of T2DM and analyse the influence of environmental and lifestyle factors on developing type 2 diabetes among patients in a tertiary hospital in Manzini, Swaziland.

Methods: A cross-sectional study (Paper I-IV) was conducted among 385 (197 [51.2%] men and 188 [48.8%] women) randomly selected adult outpatients 18 years and older in a tertiary referral hospital in Manzini, Swaziland. Paper I estimated the prevalence of type 2 diabetes mellitus and prediabetes. Diabetes was defined as a fasting blood glucose (FBG) $\geqslant$ 7.0 mmol/L (126 mg/dL) and pre-diabetes was defined as an FBG of 6.1–6.9 mmol/L (110–125 mg/dL) and an FBG < 7.0 mmol/L (< 126 mg/dL), respectively for impaired fasting glucose (IFG) and impaired glucose tolerance (IGT). Paper II determined the dietary and lifestyle factors associated with T2DM, prediabetes, and hypertension among these adult outpatients. In Paper III, the prevalence of overweight and obesity was estimated while the factors associated with these conditions among adult outpatients were determined. Paper IV then evaluated the ability of standard anthropometric measures (body mass index [BMI], waist circumference [WC], waist-to-hip ratio [WHR]) to predict T2DM and hypertension risk in Swazi adults and to estimate their optimal cut-off levels. Data analysis was done using SPSS version 26, and the level of statistical significance was set at $\alpha < 0.05$.

Results: The crude prevalence of type 2 diabetes mellitus and pre-diabetes was 7.3% (95% CI 4.9–10.3) and 6.5% (95% CI 4.2–9.4) respectively, with clear gender differences. The overall age-adjusted prevalence rates of type 2 diabetes mellitus and pre-diabetes were 3.9% and 3.8%. Among the diabetic group, 10.7% had known T2DM, whereas 89.3% were newly diagnosed during the study. Advancing age, gender, raised blood pressure, abnormal body mass index, and wealth index were significant risk factors for T2DM or pre-diabetes (Paper I). The overall prevalence of hypertension was 48.3%, while the prevalence of stage 1 and 2 hypertension was 29.4% and 19%, respectively. In the multivariate analyses, consumption of vegetables (p <0.0001; β -3.05; AOR 0.05; 95% CI 0.02-0.15]), fruits (p <0.0001; β -2.12; AOR 0.12; 95% CI 0.04-0.38), sweet drinks (p=0.042; β 1.16; AOR 3.19; 95% CI 1.04-4.75), and salty processed foods (p=0.005; β 1.95; AOR 7.01; 95% CI 1.77-5.72) remained significantly associated with T2DM. Smoking (p=0.002; β 2.19; AOR 8.90; 95% CI 2.27-34.82), consumption of fruits (p=0.014; β 1.35; AOR 0.26; 95% CI 0.09-0.76), vegetables (p<0.0001; β -3.04; AOR 0.05; 95% CI 0.02-0.15), and sweet drinks (p=0.043; β 1.25; AOR 3.48; 95% CI 1.08-11.65) were independently associated with pre-diabetes, while the consumption of vegetables (p=0.002; β -0.86; AOR 0.42; 95% CI 0.24-0.75) and salty processed foods (p=0.003; β 0.74; AOR 2.10; 95% CI 1.32-3.34) were the factors independently associated with hypertension (Paper II). The overall prevalence of general obesity was 19.5% (women 33.5% vs men 6.1%), while the prevalence of central obesity was 27.3% by WC (women 26.1% vs men 28.4%) and 23.1% by WHR (women 23.1% vs men 22.9%). Prevalence rates of overweight were 26.5%, 15.3%, and 12.7% according to BMI (women 33.5% vs men 19.8%), WC (women 16.0% vs men 14.7%), and WHR (women 14.4% vs men 11.2%), respectively. The prevalence of overweight and obesity increased with advancing age in both genders (Paper III). Among men with diabetes or pre-diabetes (abnormal glucose metabolism [AGM]), WC significantly yielded the highest area under the ROC curve (AUC) (AUC=0.708; 95% CI 0.60-0.82; p=0.002) than either WHR (AUC=0.663; 95% CI 0.54-0.79; p=0.017) or BMI (AUC=0.646; 95% CI 0.52-

0.78; *p*=0.032). Among women with diabetes/prediabetes, WC was slightly higher (AUC=0.582; 95% CI 0.48-0.69; *p*=0.139) than BMI (AUC=0.570; 95% CI 0.48-0.67; *p*=0.209) or WHR (AUC=0.563; 95% CI 0.45-0.68; *p*=0.254). Waist-to-hip ratio (WHR) and WC was significantly higher (AUC=0.764; 95% CI 0.68-0.85; p<0.0001 and 0.704; 95% CI 0.59-0.82; p=0.002) among men with raised systolic blood pressure (SBP) than BMI (AUC=0.628; 95% CI 0.51-0.75; *p*=0.051). Among women with raised SBP, the performance of WC (AUC=0.774; 95% CI 0.68-0.87; *p*<0.0001) was better than that of BMI (AUC=0.736; 95% CI 0.64-0.83; *p*<0.001) or WHR (AUC=0.679; 95% CI 0.56-0.80; *p*=0.002). The optimum cut-off values of all three anthropometric indices to discriminate T2DM/prediabetes risk estimated for males and females in this study were BMI (23.35 vs 25.45 kg/m²), WC (81.50 vs 79.0 cm) and WHR (0.85 vs 0.82). The optimal cut-off points for all three indices to discriminate hypertension risk in men and women respectively were 22.8 and 28.95 kg/m² for BMI, 78.50 and 89.5 cm for WC, and 0.86 for WHR. (Paper IV).

Conclusions: The high prevalence of T2DM, hypertension, and obesity in this setting is concerning. In a resource-limited setting such as Swaziland, this condition could have devastating effects unless urgent measures are taken to address the growing epidemic of T2DM and other chronic diseases. Additional studies are required to confirm the prevalence of T2DM and hypertension (HTN) in this hospital and other Swaziland areas. Modifiable risk factors play an essential role in the rising prevalence of T2DM, HTN, and obesity in the present study. Notably, the influence of westernisation is apparent among this population. Cost-effective and culturally acceptable interventions are needed to promote healthy lifestyles among this population and the general Swazi population. This study shows the critical role of central obesity in the risk of T2DM in a sub-Saharan Africa (SSA) population. Overall, WC exhibited a better ability to identify raised fasting blood glucose and HTN than WHR or BMI. Therefore, WC should be used, in addition to BMI, as a screening tool in this setting and other clinical settings in Swaziland and SSA, mainly when the WC is 81.50 cm for men and 79.0 cm for women, regardless of BMI.

Keywords: Abnormal glucose metabolism, Adult, Body mass index, Central obesity, Diabetes, Hypertension, Non-communicable diseases, Overweight, Outpatient, Prevalence, Risk factors, Waist circumference.

CHAPTER ONE

INTRODUCTION

This chapter provides an overview of diabetes mellitus, its global and African prevalence, as well as the risk factors for type 2 diabetes (T2DM). This chapter is critical for laying a solid basis for the rest of the study.

1. Background and Context of the Study

1.1. Rising burden of non-communicable diseases in sub-Saharan Africa

In both rich and developing countries, the rising burden of non-communicable diseases (NCDs) is a major public health problem. Non-communicable diseases (NCDs) are the primary cause of death worldwide, accounting for 71% of the 57 million deaths in 2016 (1). Cardiovascular diseases, type 2 diabetes mellitus (T2DM), chronic respiratory diseases, and cancer together accounted for 78.8% of all NCD fatalities globally (1). Disturbingly, in 2016, low and middle-income countries (LMICs) accounted for 78% of all NCD mortality (2). Moreover, the frequency of NCDs is expected to continue to rise in sub-Saharan Africa (SSA), resulting in at least nine million deaths each year in people under sixty years of age (3). A WHO publication anticipates that deaths from NCDs in SSA will surpass those from communicable diseases (4).

According to a recent review of the 2017 Global Burden of Diseases (GBD) survey (5), the burden of NCDs in SSA is increasing. In SSA, all-age disability-adjusted life-years (DALYs) related to NCDs increased by 67% from 90.6 million in 1990 to 151.3 million in 2017. In 2017, cardiovascular diseases (CVDs) were the region's second major source of NCD burden, accounting for 15.1% (22.9 million) of the total NCD burden (5). In 2017, cardiovascular diseases (CVDs) were the region's second major source of NCD burden, accounting for 15.1% (22.9 million) of the total NCD burden (5). The prevalence (age-standardised) of NCDs is increasing, particularly in southern Africa (5). By 2025, diabetes and other non-communicable diseases such as heart disease are predicted to outnumber communicable diseases in associated mortality and morbidity across Africa (6). Diabetes constituted a major contributor to the NCD illness burden in SSA; between 1990 and 2017, and the total DALYs attributable to diabetes grew by 126.4% (5). Furthermore, NCD-related DALYs rates were greater in Swaziland (and three other countries) than in countries with similar Socio-demographic Indexes (SDI) (5).

Non-communicable diseases are caused mainly by behavioural risk factors that are inextricably linked to economic transition, rapid urbanisation, and Western lifestyles: cigarette use, harmful alcohol use, unhealthy diet, and insufficient physical activity (3). Individuals' behaviour changes because of these transitions and some are increasingly adopting Western diets in place of their traditional food. As a result,

total energy consumption is higher, while energy utilisation is lower (7). These risk factors are measurable in the field and can be targeted for intervention. Therefore, identifying and quantifying risk factors is critical for reducing the burden of NCDs and developing cost-effective interventions to prevent NCDs.

1.2. Epidemiology and aetiology of T2DM

Diabetes mellitus (DM) is a group of metabolic disorders marked by a chronic hyperglycaemic state caused by insulin secretion, insulin action, or both (8). Diabetes is a major public health concern in industrialised and developing countries worldwide (9). Type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM), gestational diabetes mellitus (GDM), and other specific forms (10) are the four types of diabetes, each with its own aetiology. T2DM accounts for 90% of all diabetes cases (11).

In 2014, the disease afflicted an estimated 422 million people (1 in 11 people) worldwide (9). According to the NCD Risk Factor Collaboration (11), this figure will rise to 700 million by 2025, and the World Health Organisation (WHO) (3) anticipates that T2DM will become the 7th major cause of death globally by 2030. Between 1980 and 2014, the global prevalence of diabetes (age-standardised) nearly doubled, going from 4.7% to 8.5% in the adult population (11). Most diabetes patients (80%) live in LMICs, and these countries are expected to experience the greatest increase in diabetes cases over the next half-decade (11). People aged 40 to 60 years (i.e. working age) are the most affected in developing countries, compared to those older than 60 years in rich countries (12). The rise in T2DM prevalence in developing countries is closely linked to the adoption of a Western lifestyle, which has resulted in significant changes in the quality and quantity of food consumed and decreased physical activity (13, 14).

In Africa, 19 million persons were living with T2DM in 2019, and this number is expected to rise to 47 million by 2045, indicating a 143% increase from 2019 (1). According to the IDF Diabetes Atlas 2019 (1), Africa's age-standardised prevalence of T2DM was 4.7% (the lowest worldwide). Furthermore, Werfailli et al. (15) found a higher prevalence of T2DM based on the oral glucose tolerance test (OGTT) (23.9%; 95% CI 17.7 – 30.7) compared to studies that used fasting blood glucose (FBG) to diagnose T2DM (10.9%; 95% CI 8.9 – 13.0, $p<0.0001$) in a systematic review involving 16 086 individuals from different countries in SSA. The prevalence of diabetes was considerably greater in non-stepwise approach to surveillance (STEPS) surveys than in STEPS surveys (17.9%; 95% CI 13.6 – 20.9 vs 9.6; 95% CI 6.6 – 13.0; $p=0.003$) (15). Glezeva et al. (16) published a review that emphasised the rising diabetes burden in SSA. According to the study, the prevalence of T2DM in the population ranged from 2.7% in Zambia to 17.9% in Senegal. The study's findings also reveal that the prevalence of T2DM differed by gender, ranging from 3.2% to 14.0% in men and 2.7% to 21.8% in women.

Non-communicable diseases accounted for 37% of all fatalities in Swaziland in 2016, up by 54.2% from 2014. (2). According to the WHO (2), the Swazis have a higher rate of cardiovascular disease, T2DM, cancer, and chronic obstructive pulmonary disease (COPDs). In Swaziland, however, the exact prevalence of T2DM and prediabetes is unknown. According to the International Diabetes Federation (IDF) 2011 report, the prevalence of diabetes was 2.36%, based on a similar country's statistics (17). However, the WHO (2) estimates the prevalence of diabetes to be 6.0%, with apparent gender disparity in the prevalence of diabetes; 8.2% (females), and 5.0% (males). Type 2 diabetes mellitus was the third most common case reported to outpatient departments in Swaziland in 2016 (18). In 2016, T2DM was the primary cause of in-patient admissions, followed by hypertension, which accounted for 15 and 11% of in-patient admissions respectively (18). Type 2 diabetes mellitus was also the second major cause of NCD fatalities in Swaziland in 2016 (18). Disturbingly, the mortality attributable to T2DM has been increasing steadily since 2014, rising from 47 deaths in 2014 to 109 deaths in 2016 (18).

In Swaziland, there is minimal published epidemiological research on T2DM prevalence. According to the Ministry of Health's 2014 WHO STEPS survey (19), the prevalence of impaired fasting glycemia (IFG) was high, at 9.8% (95% CI 8.2–11.4). Similarly, 14.2% (95% Cl 10.8–17.7) of the survey respondents had high blood sugar or were taking diabetes medication. The prevalence of T2DM was 0.7% in a study (20) done among HIV-infected patients at Good Sheppard Hospital in the Lubombo region of Swaziland, with prediabetes being documented in 10% of the study participants. Rabkin et al. (21) did a study in Swaziland to determine if cardiovascular disease risk factor (CVDRF) screening could be done at an HIV clinic. According to the study's findings, 5% of HIV-infected patients aged 40 and older had diabetes. This study, however, did not offer the age-adjusted prevalence of T2DM and excluded patients aged 18 to 39 years.

Estimates of T2DM in Swaziland are patchy, and more studies are needed to understand the prevalence of T2DM in Swaziland for the optimum allocation of resources to reduce its burden. Without current epidemiologic data, it will be difficult to justify investment in measures aimed at tackling the growing burden of T2DM in Swaziland.

1.3 Pathophysiology of T2DM

Type 2 diabetes mellitus is a complex disease caused by a mix of genetic factors linked to decreased insulin production and insulin resistance and environmental factors such as obesity, poor food, and lack of physical activity (22, 23). Type 2 diabetes mellitus susceptibility is determined by a combination of intrinsic factors that affect the pancreatic beta cells' insulin-producing capacity, cellular insulin sensitivity, the amount of glucose derived from the gut (food digestion) and liver, and the extent to which glycogen is degraded (glycogenolysis) (22). Thus, T2DM is caused by a relative shortfall in insulin action, with the primary cause

being a defect in exogenous insulin synthesis, insulin signalling, and glucose over-availability (8). Plasma glucose concentrations are kept within a restricted range under normal physiological conditions, despite significant changes in supply and demand, through a carefully regulated and dynamic relationship between tissue sensitivity to insulin (particularly in the liver) and insulin production (24). These pathways fail in type 2 diabetes, resulting in two major pathological defects: decreased insulin production due to pancreatic β-cell malfunction and impaired insulin action due to insulin resistance (25, 26). It has been established that T2DM is caused by gene-environment interactions (13, 26-29), with environmental factors (such as physical inactivity, poor diet, and obesity) assigned greater weight because diabetes rates were increasing in populations with relatively stable gene pools (30).

1.4 Diagnosis of Prediabetes and T2DM

An oral glucose tolerance test (OGTT), fasting plasma glucose (FPG), or glycated haemoglobin (HbA1C) test can all be used to detect type 2 diabetes and prediabetes (intermediate hyperglycaemia). The World Health Organisation (WHO) and the American Diabetes Association (ADA) have established diagnostic cut-offs for these tests (8, 31). Impaired glucose tolerance (measured by the OGTT), impaired fasting glucose (IFG) (determined by the FPG), and HbA1C readings between 5.7 and 6.4% identify prediabetes. However, many health facilities in SSA rely on random blood sugar (RBS) for diabetes diagnosis due to resource constraints and late presentation. The debate about which tests are suitable for primary care screening in low-income countries (LICs) continues.

Diabetes is defined by the WHO as an FPG of less than 7.0 mmol/l (126 mg/dl) or a 2-hour OGT of less than 11.1 mmol/l (200 mg/dl) (see Table 1) (8). In 2011, the WHO concluded that HbA1c could be used as a diagnostic test for diabetes, with a cut-off value of 6.5% (32). Because type 2 diabetes develops slowly, most people experience prediabetes, a high-risk state for diabetes development and adverse outcomes. Prediabetes is defined as blood glucose levels greater than usual but not high enough to cause diabetes (8). Individuals at risk have one or both of the following prediabetic conditions, according to the WHO (8): impaired fasting glucose (IFG), defined as an FPG concentration of 6.1 to 6.9 mmol/l (110 to 125 mg/dl) and, if measured, a 2-hour plasma glucose of 7.8 mmol/l (140 mg/dl); and impaired glucose tolerance (IGT), defined as an FPG concentration of less than 7.0 mmol/l (<126 mg/dl) and, if measured, a 2-hour plasma glucose of 7.8 mmol/l (140 mg/dl).

Table 1. Diagnostic criteria for diabetes and intermediate hyperglycaemia (according to the World Health Organisation) (8, 32)

Type 2 diabetes		
Fasting glucose (mmol/l) [a]	**OR**	≥7.0 mmol/l (126 mg/dl)
2-hour glucose (mmol/l) [ab]		≥11.1 mmol/l (200 mg/dl)
HbA_1c		≥6.5%
Impaired Fasting Glucose (IFG)		
Fasting glucose (mmol/l) [a]	**AND**[c]	6.1 to 6.9 mmol/l (110 to 125 mg/dl)
2-hour glucose (mmol/l) [ab]		<7.8 mmol/l (<140 mg/dl)
Impaired Glucose Tolerance (IGT)		
Fasting glucose (mmol/l) [a]	**AND**	<7.0 mmol/l (126 mg/dl)
2-hour glucose (mmol/l) [ab]		≥7.8 mmol/l (<140 mg/dl)

[a] Venous plasma glucose concentration.

[b] Measured two hours after ingestion of 75g oral glucose load.

[c] If only fasting glucose concentration is measured, IGT cannot be excluded.

1.5 Risk factors for T2DM

A complex interplay of genetic and environmental factors is thought to be the cause of type 2 diabetes (13, 26-29). As a result, risk factors can be divided into modifiable and can be prevented, and those that are not modifiable and cannot be prevented (33). Genetic susceptibility, age, gender, family history, and ethnic origin are all non-modifiable risk factors for T2DM. Although multiple genes have been related to T2DM, the ability of a genetic risk score to predict future diabetes is limited (26). Furthermore, the rising T2DM rate in populations with relatively stable gene pools suggests that other factors play a role in T2DM development (30). Behavioural risk factors (tobacco use, harmful alcohol use, poor nutrition [low fruit and vegetable intake], and physical inactivity), as well as pathophysiology risk factors, are all modifiable risk factors (obesity, hypertension, diabetes, and hypercholesterolemia).

1.5.1 Non-modifiable risk factors of diabetes (age and gender)

1.5.1.1 Age

Type 2 diabetes mellitus risk rises dramatically with age (12, 30). Type 2 diabetes is uncommon in most populations before 30 years, but it rises rapidly and steadily as people get older (34, 35). Age is a strong risk factor in prospective observational studies, regardless of major linked lifestyle risk variables such as obesity (36). This is especially concerning at a time when people's lives are lengthening. According to the IDF, the number of individuals in SSA with diabetes will rise from 19 million in 2019 to 45 million by 2045 (1), owing primarily to population ageing. In SSA, studies have found a link between diabetes prevalence and rising age (37-40). For example, a study (37) of 4733 people in Ghana found that the prevalence of diabetes and prediabetes rises with age, with the oldest age group (64 years and beyond) having the highest frequency.

The mechanism linking ageing to T2DM can be explained by an age-related increase in visceral body fat, pro-inflammatory cytokines, and a decline in mitochondrial and endocrine function (41, 42), explaining an age-related decline in beta-cell function and glucose homeostasis. However, it is unclear whether the glucose intolerance that comes with age is a normal part of the ageing process or age-related obesity and physical inactivity.

1.5.1.2 Gender

Gender differences appear to be crucial in the epidemiology, pathophysiology, treatment, and outcomes of many diseases, but they tend to be especially relevant for NCDs, such as T2DM (43). The prevalence of prediabetes, such as IFG and IGT, has been found to differ by gender. According to studies, men have a higher prevalence of IFG than women, but women have a greater frequency of IGT (43-46). The reason for these differences in early dysglycaemia is unknown but could involve the effect of gonadal hormones. Indeed, menopausal hormone therapy with oestrogens decreases fasting glucose while impairing glucose tolerance (47, 48).

Gender differences in T2DM prevalence are also noticeable. Overall, men have a higher prevalence of diabetes than women, but there are more women with diabetes than men (30). Type 2 diabetes mellitus was estimated to affect 240 million men and 223 million women in 2019, according to the IDF 2019 Atlas (1). There are also gender disparities in T2DM incidence that vary across the lifetime, with females having significantly higher rates of T2DM in their childhood (49) but males having a much greater diabetes prevalence in midlife (50), and rates in later life are equivalent between the sexes. The offered reason for

this fact is the combined effect of a greater proportion of older women than males in most populations and the growing frequency of diabetes with age.

Men have slightly greater rates of T2DM than women, according to studies conducted in Western European or Asian populations (51-54). Similarly, the European Prospective Investigation into Cancer and Nutrition (EPIC) found that men have a higher risk of diabetes than women in many European countries (55). Similarly, research in SSA has reported a significant gender differential in diabetes prevalence (56-59). Hilawe et al. (57) observed that women in Southern Africa were more likely than men to develop T2DM in a comprehensive review and meta-analysis, while Abubakar et al. (60) found no such gender disparity in the prevalence of T2DM in West Africa. Gatimu et al. (56) found that females had a higher prevalence of diabetes than males (2.16%; 95% CI 1.69–2.76 vs 1.73%; 95% CI 1.28–2.33) in their study of Ghanaians aged 50 and over.

1.5.2 Modifiable risk factors of diabetes

The fast-rising incidence of diabetes shows that environmental factors play a significant role in diabetes development. The evidence regarding the key risk factors of type 2 diabetes, such as overweight and obesity, an unhealthy diet, and physical inactivity is summarised in this section.

1.5.2.1 Overweight and obesity

Obesity and overweight are linked to a slew of adverse health outcomes throughout a person's life. Obesity has been linked to an increased risk of diabetes, hypertension, a variety of NCDs (including coronary heart disease, stroke, and cancer), as well as conditions such as obstructive sleep apnoea and osteoarthritis (61). Obesity and overweight are among the top causes of morbidity and mortality worldwide, and the burden of these diseases is increasing (62). Obesity prevalence has increased by approximately 300% worldwide since 1975, with nearly 2 billion individuals and over half a billion adults being classified as overweight or obese in 2016 (63).

Overweight and obesity are major public health issues in Swaziland. Obesity was found to be prevalent in the Swazi population, particularly among women (23%), according to the Swaziland Demographic Health Survey (DHS) 2006-07 (64). According to the Swaziland Ministry of Health's Stepwise Approach to Surveillance (STEPS) survey (19), over 20.5% of the adult population was obese, with a significant proportion (59.9%) of women being overweight. In 2016, the World Health Organisation (WHO) (2) estimated that 14% of Swazi individuals were obese, with women having a higher prevalence (22%) than men (4%).

The prevalence of general obesity was estimated to be 5.5% in a recent study (20) done among HIV-infected patients in a busy rural health centre in the Lubombo region, Swaziland. However, this study did not include measures of central obesity (such as WC or WHR), which are known to be more accurate than BMI in detecting an increased risk of T2DM and high blood pressure (65). Unlike the Lubombo study, Rabkin et al. (21) did not include obesity measures among their Manzini health facility study respondents.

The upsurge in the prevalence of T2DM is directly linked to increases in the prevalence of obesity. It is estimated that excess weight is responsible for roughly 90% of T2DM cases (11). Insulin resistance and insulin insufficiency are the two primary mechanisms that link obesity and diabetes pathogenesis (66). Insulin sensitivity refers to insulin's ability to regulate the circulating free fatty acids (FFA) and glucose absorption (67) by mediating disposal into skeletal muscle, limiting gluconeogenesis in the liver (68), and suppressing lipolysis in adipose tissue (69). In a typical scenario, an increase in blood glucose after eating causes pancreas cells to release insulin. In conjunction with glucose, insulin increases the absorption of glucose from the blood into cells for glycolysis or storage as glycogen in the liver, muscle, or adipose tissue. Hepatic gluconeogenesis is suppressed as a result of this. GLUT4 is a glucose transporter that is primarily expressed in muscle and adipose tissue. GLUT4 is recruited from the cytosol to the cell membrane in response to insulin stimulation to transport glucose from the outside to the cell's interior. In glucose absorption and muscle glycogen synthesis, this is the rate-limiting stage (70, 71).

There is a lack of initial insulin production (first phase) in response to a glucose load in an abnormal or insulin-resistant state, resulting in postprandial hyperglycaemia—chronic hyperinsulinaemia results from an increased second-phase insulin response. Insulin-responsive tissues are unable to sensitise or respond to insulin effectively. Glucose absorption, glycolysis, and glycogen synthesis are all hampered by insulin. Insulin resistant pancreatic β-cells become overworked, tired, and apoptotic over time, eventually losing their function (72, 73). Hyperglycaemia occurs in the absence of insulin.

Both impaired insulin release and insulin resistance have been identified as important contributors to developing type 2 diabetes in longitudinal studies (74, 75). Insulin resistance was found to be a major risk factor for the development of type 2 diabetes in a study of 200 non-diabetic Pima Indians (74), while a low acute insulin response to glucose was considered an additional but weaker risk factor. However, hepatic overproduction of glucose did not predict the occurrence of diabetes. In a Mexican-American study, Haffner et al. (75) confirmed the impact of insulin resistance and insulin insufficiency. In a seven-year investigation, the researchers discovered that decreased insulin production and increased insulin resistance are independently associated risks for T2DM.

1.5.2.2 Diet

The quality of nutrition and excessive caloric consumption is primarily responsible for the global epidemics of adiposity (e.g. overweight/obesity) and T2DM (13). The composition of one's diet appears to influence the risk of T2DM. Diets low in fibre but high in saturated fat have been linked to an increased risk of T2DM (76). Nevertheless, intervention studies have shown that diets high in fibre but low in saturated fat can help in the prevention of T2DM (77). Fruit and vegetables, which are high in fibre and other micronutrients but low in glycaemic load and energy density, have been shown to reduce T2DM (78, 79), hypertension, and cardiovascular disease (80). Similarly, there is evidence of a positive association between salty processed food consumption and T2DM (81) and hypertension (82).

In a large prospective study, Bazzano et al. (78) followed up 71 340 female nurses free of diabetes, CVD, and cancer for 18 years to determine the association between fruit, vegetables, and fruit juice intake and development of T2DM. The study's findings showed that eating green leafy vegetables and fruits was linked to a lower risk of T2DM (78). In addition, Villegas et al. (79) observed that vegetable consumption was significantly linked with a lower incidence of T2DM in a large cohort of women with no history of T2DM or any other chronic condition in China. On the other hand, fruit consumption did not appear to be associated with a decreased incidence of T2DM.

Schulze et al. (83) reported that individuals who consumed one or more sweet drinks per day had an 83% higher chance of developing T2DM than those who consumed less than one sweet drink per month in a prospective trial of more than 50,000 women. In contrast to Schulze et al., Malik et al. (84) found no evidence of a link between sweet drink consumption and the risk of T2DM. The fructose component of sugar in sweet drinks is considered a singularly harmful macronutrient and has been suggested to lead to obesity, hyperlipidaemia and insulin resistance; key risk factors for T2DM and CVDs (85).

According to previous reports, Swazis have adopted Westernised lifestyles and eat more Western meals than indigenous foods (86, 87). Furthermore, according to Kgaphola and Viljoen (87), most Swazis prefer Western-style foods to indigenous foods (rich in green leafy vegetables). In the STEPS survey (21), most participants (92.1%) said they ate fewer than five servings of fruits and vegetables per day, with only half (52.3%) saying they ate one to two servings per day.

1.5.2.3 Lifestyles

Type 2 diabetes (and other NCDs) can be prevented with lifestyle modification (88). In at-risk individuals or those with prediabetes, T2DM, or increased blood pressure, prompt intervention through lifestyle modification will avert or postpone the disease progression (3). The benefits of lifestyle modification, including quitting smoking, adopting a healthy diet, exercising moderately, and drinking alcohol moderately for the prevention and treatment of T2DM and hypertension, have been extensively demonstrated (88-91). In their modelling analysis, Kontis et al. (89) found that lowering the prevalence of six risk factors, including smoking and harmful alcohol use, can reduce mortality due to CVDs and T2DM, with LMICs anticipated to enjoy the biggest benefits. Lifestyle modification effectively prevents the occurrence of prediabetes or its progression to T2DM (92, 93), as well as helps in managing T2DM (90).

1.5.2.3.1 Physical inactivity

Physical activity is an important aspect of energy balance and weight control since it is the primary predictor of energy expenditure (94). Physical activity has numerous benefits, including lowering the risk of ischemic heart disease, stroke, diabetes, and breast and colon cancer (94). According to the World Health Organisation, moderate physical exercise (about 150 minutes per week) decreases the risk of diabetes by 27%, colon cancer by 21–25% and ischemic heart disease by 30%. (94). On the other hand, physical inactivity accounts for 7% of the global burden of T2DM, and is defined as insufficient physical activity to satisfy the WHO 2010 recommendations (95). Insufficient physical exercise is one of the top ten causes of death worldwide, accounting for 3.2 million deaths per year (96). Physically inactive persons have a 20-30% higher risk of all-cause mortality than those who engage in at least 150 minutes of moderate-intensity physical exercise or 75 minutes of vigorous-intensity physical activity each week, as recommended by the WHO (94).

In 2016, one in every three adults aged 18 and up was insufficiently physically active (i.e., they did not engage in at least 150 minutes of moderate-intensity physical exercise per week, or the equivalent) (97). Women were more affected than men, with 32% of females failing to meet the necessary level of physical activity, compared to males (23%). In 2016, high-income countries had a greater frequency of physical inactivity than low-income countries (37% versus 16%). The prevalence of physical inactivity has not decreased globally over the last two decades, with 29% in 2001 and 28% in 2016. (97).

Physical activity of moderate intensity can reduce the risk of T2DM, according to a meta-analysis (98) of ten prospective cohort studies done in the United States, Europe, and Japan. Compared to almost no walking, regular walking (defined as 2.5 hours of brisk walking) was significantly associated with a lower incidence of T2DM (RR 0.70; 95% CI 0.58-0.84). The beneficial influence of physical activity is also well

documented in SSA. Individuals who engage in physical activity have a lower chance of developing T2DM, according to studies conducted in Southern (99, 100), East (101), and West Africa (102-107). For example, physical inactivity was an independent and substantial risk factor for uncontrolled T2DM in South Africa by Adeniyi et al. (99). According to the findings of this study (99), those who lived a sedentary lifestyle were 21 times more likely to have uncontrolled T2DM than those who were physically active.

The involvement of distinctive pathways may explain the beneficial effect of physical activity. Aerobic exercise improves fatty acid oxidation by increasing mitochondrial density and oxidative enzyme activity and stimulating insulin-independent and insulin-dependent skeletal muscle glucose uptake. (108).

1.5.2.3.2 Alcohol consumption

Alcohol is the third most important risk factor for illnesses and disability worldwide and the most important in middle-income countries (3). Alcohol is responsible for 60 various diseases and injuries, and it is suspected of being involved in another 200 (3). Alcohol intake was responsible for an estimated three million deaths in 2016, accounting for 5.3% of all deaths worldwide (109). Surprisingly, Africa had the largest age-standardised alcohol-related disease and injury burden in 2016, despite Europe having the highest alcohol consumption (109). The high burden of alcohol-related disease and damage in Africa was due to the high prevalence of cardiovascular disease, tuberculosis, digestive diseases, and injuries, all of which have alcohol as a significant predictor (109). Other adverse consequences of harmful alcohol use include societal issues (violence, child abuse, and work absenteeism), as well as high healthcare expenditures (3).

Observational studies have found a U-shaped relationship between alcohol use and T2DM (110). Evidence suggests that moderate alcohol use (1–3 drinks/day) is associated with a lower risk of T2DM, but heavy alcohol consumption ($\geqslant$3 drinks/day) is associated with a higher risk of T2DM (110). Excessive alcohol use (60 g per day for males and 50 g per day for women) was substantially related to a higher risk of T2DM, according to a meta-analysis of 20 prospective cohort studies (110) from the United States, Europe, Asia, and Australia. Moderate alcohol consumption (22 g for males and 24 g for women) was protective against diabetes. Howard et al. (111) observed that moderate alcohol use was related to a lower incidence of T2DM in a systematic review.

The link between alcohol use and T2DM in SSA is not fully understood. Heavy alcohol intake (>21 units/week) was linked to a greater prevalence of T2DM in Nigeria, according to Nyenwe et al. (106). Similarly, in a study conducted in rural South Africa by Motala et al. (100), previous alcohol consumption was an independent risk factor for diabetes. People who had consumed alcohol were about three times more

likely to develop diabetes than those who had not consumed alcohol previously (p=0.009; OR 2.79; 95% CI 1.29 – 6.03). In the Kenyan investigation, Ayah et al. (112) found that heavy alcohol consumption was associated with a higher prevalence of T2DM.

Chege, on the other hand, discovered no significant link between alcohol intake and T2DM in cross-sectional research in a Kenyan rural mission hospital in 2010 (113), and other researchers in SSA also agreed with this conclusion (99, 114, 115). Alcohol use and the risk of T2DM were also found to be inversely related in several studies. For example, women who drank alcohol daily had a lower risk of diabetes (OR 0.18; 95% CI 0.04 – 0.82) in a cross-sectional study conducted by Gatimu et al. (56) to describe the prevalence of diabetes among individuals aged 50 years and older in Ghana. Stanifer et al. backed up this conclusion (116).

1.5.2.3.3 Smoking

Tobacco smoking is one of the biggest preventable causes of mortality worldwide, with one person dying every six seconds (117). Tobacco usage kills six million people worldwide each year, with a third to half of the smokers dying fifteen years before their time (118). Men (12%) were more affected than women (7%), and it is estimated that tobacco smoking will kill more than 175 million people worldwide in the next decade, with the number of deaths rising by more than 8 million each year unless concrete action is taken quickly (117). In addition, estimates show that by 2030, tobacco will have killed over half a billion individuals alive today (117).

Existing knowledge suggests that smoking behaviour is a risk factor for T2DM (1). Tobacco use shows a substantial link to T2DM, either as a standalone risk factor or in combination with other risk factors, including centripetal obesity (119, 120). A meta-analysis of 25 prospective cohort studies involving 1.2 million participants from the United States, Europe, and Asia found that active smokers were 45% more likely than non-smokers to acquire T2DM (RR 1.44; 95% CI 1.31–1.58) (121). There was a dose-response relationship: those who smoked more had a higher RR than those who smoked less; heavier active smokers had a higher risk of type 2 diabetes (RR 1.61; 95% CI 1.43–1.80), while lighter active smokers (RR 1.29; 95% CI 1.13–1.48) and former smokers (RR 1.23; 95% CI 1.14–1.33) had weaker associations (121).

Smoking and the risk of T2DM have been linked in studies conducted in SSA. Danquah et al. (122) found a substantial positive correlation between smoking and T2DM in a Ghanaian epidemiological survey; diabetes patients were significantly more likely to be smokers than controls (p<0.001). This finding is in line with the findings of Faurhoult-Jepsen et al. (123), who found that smokers are twice as likely to develop diabetes as non-smokers (OR 2.12; 95% CI 0.89 – 5.04). This link between T2DM and cigarette smoking has been verified in other investigations (112, 124, 125). This result corroborated Peer et al.'s (126) findings,

who discovered that those with diabetes had considerably lower rates of cigarette smoking than people with normal blood sugar levels (p<0.001). However, numerous studies (106, 113, 115, 127) found no evidence of a link between T2DM and cigarette smoking.

The exact mechanism linking cigarette smoking to an increased risk of T2DM is unknown. Nonetheless, nicotine increases sympathetic activity, increases circulating levels of catecholamines, growth hormone, adrenocorticotropic hormone, cortisol, prolactin, and beta-endorphin, and decreases oestrogen levels, all of which are very hostile to insulin's function. As a result, smoking lowers insulin synthesis, lowers glucose catabolism, and raises glucose levels in the body (128). Smoking has been linked to IGT and insulin resistance in studies (129, 130). Nicotine infusion, for example, worsened insulin resistance in people with T2DM but not in non-diabetic participants in a double-blind, cross-over, placebo randomised experimental research (130).

1.5.3 Socio-economic determinants of T2DM

Socio-economic status (SES) remains a topic of interest in health due to the belief that high SES households have access to a range of goods, services, and social connections that benefit their health. There is also a concern that many low SES households lack access to the same resources; thus, they are at risk of health problems (131). Socio-economic status has been categorised into social class and social categorisation of position (132). The former refers to the economic interdependence between groups or individuals in a population (133). Social class is based on economic disparity suggesting an inequality between owners of resources and non-owners who work for them (132). Socio-economic position (SEP) is the distribution of social class components such as occupation, income, wealth, education, and social status (132). The term ‘socioeconomic status’ encompasses both aspects of SEP, and these terms can be used interchangeably.

Although the causal pathway between SES and disease is not yet fully understood, SES contributes to developing T2DM through complex processes involving access to healthcare services and information, availability of healthy foods and places to exercise, economic and occupational opportunities, and individual lifestyle choices (133). Studies conducted in developed countries have consistently documented an inverse association between T2DM and SES (134-137). However, the pattern of association is different (138-141) and inconsistent in developing countries. Some studies in SSA reported a positive association between SES and T2DM (56, 126, 142) and some reported an inverse association (127), whereas others found no association at all (115, 143).

A meta-analysis of 23 prospective case-control and cohort studies from Europe, Asia, Africa, and the Americas, including the United States, was conducted to summarise the overall association of SES with the risk of T2DM (144). The overall risk of developing T2DM increased among participants with a lower SES,

including lower levels of education (RR 1.41; 95% CI 1.28 – 1.51), occupation (RR 1.31; 95% CI 1.09 – 1.57), and income (RR 1.40; 95% CI 1.04 – 1.88).

Causal pathways of the association between SES and T2DM are not fully understood. However, SES may contribute to the development of T2DM through processes involving lack of access to health care services, healthy foods, places to exercise, and occupational opportunities, leading to unhealthy lifestyle practices (145).

1.6 Problem statement and significance of the study

This thesis focuses on four knowledge gaps regarding the burden of type 2 diabetes in a lower-middle-income setting in SSA.

1.6.1 Statement of the problem

There is a scarcity of epidemiology data on the prevalence of T2DM and prediabetes in Swaziland. To the researcher's knowledge, no epidemiological study has estimated the age-adjusted prevalence of T2DM and prediabetes, even though diabetes ranks third among the ten leading causes of all hospital admissions in Swaziland (18). A previous study in this setting investigated the possibility of screening for diabetes among HIV infected patients (21). However, the study did not report age-adjusted prevalence rates for T2DM and prediabetes (Paper I). Such information is necessary for our understanding of the burden of T2DM and prediabetes in Swaziland.

In 2016, NCDs accounted for nearly 40% of all deaths in Swaziland (2), representing a 54.2% increase from the 2014 figures. According to the WHO (2), the Swazis suffer more from CVD, T2DM, cancer, and COPD. However, little is known about the risk factors predisposing Swazis to NCDs, especially T2DM, prediabetes, and hypertension in Swaziland. Moreover, current epidemiological data on NCD risk factors is lacking in Swaziland. There is thus a need for current epidemiological data to understand the dietary and lifestyle factors predisposing Swazis to these chronic diseases (Paper II). Such data is vital to justify investment in preventive strategies at individual, healthcare facility, and population level.

Obesity is the significant modifiable independent predictor of T2DM, prediabetes, and hypertension. In SSA, the prevalence of obesity and overweight has been increasing at an alarming rate, with Southern Africa being the most affected (143). In Southern Africa, the highest obesity burden and overweight occurs in Swaziland, particularly among women (146). The increasing burden of overweight and obesity and its associated T2DM, hypertension, CVD, and cancers in SSA are thought to result from changes in lifestyle, demographics, and nutrition. Few studies have explored the sociodemographic and lifestyle factors that underlie key intermediate-risk factors like overweight and obesity in Swaziland (Paper III). These

underlying risk factors are essential for proper lifestyle modification (90-92) and to curtail the growing burden of NCDs in SSA.

Clinical trials have demonstrated the beneficial impact of weight reduction for individuals at increased risk of T2DM (147, 148), and it can also help patients with high BP (149). Therefore, an accurate definition of overweight and obesity is clinically essential to address the growing public health concern regarding NCDs. Measures for tracking obesity and overweight are either direct or surrogate, but the latter are preferred due to their simplicity and practicality (150, 151). Surrogate measures such as BMI, WC, and WHR are preferred, but it is still unclear which of these surrogate measures is the best to reflect an increased risk of T2DM or hypertension among non-Caucasians. However, cut-off values for obesity indices in predicting future T2DM, hypertension, and CVD are known to be population-specific (152). Consequently, the ability of these obesity measures to predict an increased risk of T2DM and hypertension in people from SSA may differ from that of other ethnic groups (Paper IV).

1.6.2 Significance of the research

The studies in this thesis contain novel contributions to the body of knowledge for public health and disease prevention. The prevalence of T2DM, prediabetes, and hypertension was estimated in Swaziland's second biggest public health facility. Also, socioeconomic status influenced the prevalence of T2DM and prediabetes. Understanding the type 2 diabetes risk factors will help NCD policy and assist in devising cost-effective and culturally acceptable interventions. Finally, these studies may assist clinicians in devising alternative screening practices for obesity and overweight.

1.7 Conceptual framework

Disease conditions can be related to a single vector, a lifestyle behaviour, or an environmental factor. Social epidemiology seeks to understand how social factors lead to lifestyle changes, resulting in risk factors and diseases (153). The growing interest in multi-factor models of disease causation has highlighted the importance of social factors; this has led to an increasing number of studies on the social epidemiology of diabetes (154). Brown et al. (155), in their review, conceptualised the relationship between socio-economic status and health for diabetic patients. Similarly, Brown (156) suggested a multi-level approach involving interventions at the patient, health system, and clinician levels to address disparities in diabetes care. Likewise, Golden et al. (157) considered the multiple contributors to health disparities, including biological, clinical, and non-clinical influences on diabetes. Finally, in a recent comprehensive review, Gary-Webb et al. (154) summarised current evidence on the influence of social determinants on the development of type 2 diabetes.

Type 2 diabetes is associated with obesity through the lens of social epidemiology. This study therefore explored the factors leading to obesity and examined how the relationship between lifestyle, socioeconomic status, and obesity contributes to diabetes (see figure 1). The relationships between these factors and type 2 diabetes have not been studied previously in Swaziland. This study used the social epidemiology framework to describe the prevalence of T2DM in the Manzini region of Swaziland. Similarly, the framework guided the development of a data collection instrument. The distribution of T2DM in this population (Paper I) varies among different groups (non-modifiable risk factors; age and gender), due to differences in peoples' exposure to material circumstances (modifiable risk factors) (Paper II), across different dimensions of SES (Paper I, II); which creates differential experiences of, and vulnerability to, the intermediate-risk factors (overweight/obesity, raised blood glucose, raised BP) (Paper II, III, IV).

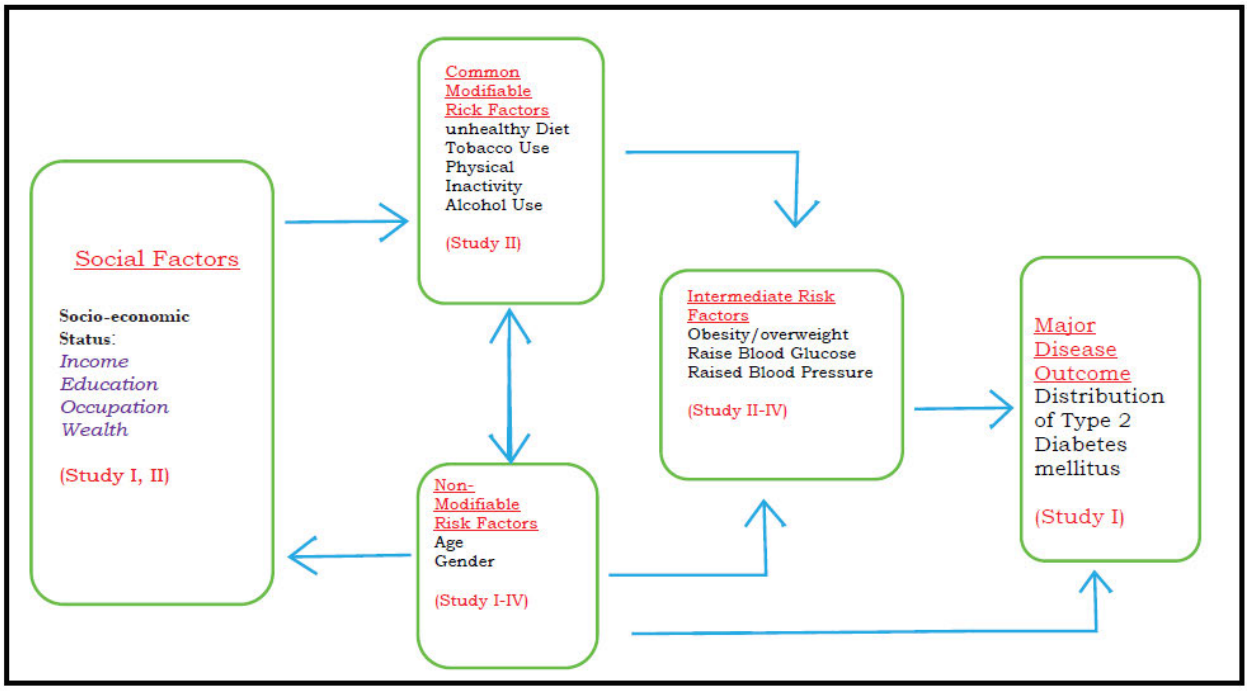

Figure 1. Conceptual Framework

1.8 Aims and objectives

1.8.1 Aim

- To determine the prevalence of type 2 diabetes mellitus and analyse the influence of environmental and lifestyle factors on the development of type 2 diabetes among patients in a tertiary hospital in Manzini, Swaziland.

1.8.2 Specific objectives

- To estimate the prevalence of type 2 diabetes mellitus and prediabetes among adult outpatients in a tertiary hospital in Manzini, Swaziland (Paper I).
- To determine the dietary and lifestyle factors associated with T2DM, prediabetes, and hypertension among adult outpatients in Manzini, Swaziland (Paper II).
- To estimate the prevalence of overweight and obesity and determine their associated factors among adult outpatients in Manzini, Swaziland (Paper III).
- To evaluate the ability of body mass index, waist circumference, and waist-to-hip ratio as predictors of type 2 diabetes and hypertension risk in Swazi adults and to estimate their optimal cut-off levels (Paper IV).

1.9. Methods

1.9.1 Introduction

This thesis comprises of four papers describing the methods and findings relevant to T2DM prevalence and risk factors in a tertiary hospital setting. Paper I estimates the prevalence of T2DM and prediabetes among adults 18 years and older attending the Outpatient Department (OPD) at the Raleigh Fitkin Memorial (RFM) Hospital in Manzini. Paper II then examines the dietary and lifestyle factors associated with T2DM, prediabetes, and hypertension in the same population. Paper III estimates the prevalence of overweight and obesity and determines their associated factors. Paper IV then evaluates the ability of standard anthropometric indices (BMI, WC, WHR) to identify the future risk of T2DM/prediabetes (abnormal glucose metabolism) and hypertension and determines their cut-off values.

1.9.2 Study setting and study population

This study was conducted at Raleigh Fitkin Memorial (RFM) Hospital, located in Manzin, the hub of Swaziland. Raleigh Fitkin Memorial Hospital, situated in the Manzini region, is the second-largest public health facility in Swaziland. It is a regional referral and government sub-vented teaching hospital. The mission hospital and its different service units draw patients from the Manzini region and neighbouring communities in the adjacent regions, including the Mbabane – Manzini – Siteki corridor.

1.9.3 Study design and sample selection

Overall, a cross-sectional study design was used for the study from February to March 2019 among 385 patients who visited the OPD of the Raleigh Fitkin Memorial Hospital in Manzini, Swaziland. All patients who visited the OPD during the data collection period were included. Patients were included in the sample if they resided in the Manzini region; were 18 years of age and above; had fasted for eight hours before the screening, and willingly consented to participate in the study. However, patients with active infection or using corticosteroids, who were pregnant, who had a temperature higher than 101.4 °F (38.6 °C), were taking antibiotics or anti-malaria medications or who were unwilling to participate were excluded. A representative sample of the medical and surgical outpatient population was surveyed. A systematic random sampling technique was applied to sample 385 individuals, whereby every 3rd individual visiting the OPD was approached to participate in the study, bearing in mind the inclusion criteria. As remarked by Castillo (158), systematic random sampling allows the researchers to add a degree of a system into the random selection of subjects and ensures that the population is evenly sampled. The study population comprised of patients reporting to the Outpatient Departments daily (for reasons other than diabetes and hypertension) from 2 February to 19 March 2019. The researcher obtained a list of all patients attending the OPD and allocated a number to each one. To select the first patient to be in the sample, a table of random numbers was used. The patient with the number chosen was requested to voluntarily participate in the study. Thereafter, every third patient on the list was approached to participate in the study. In the case of selected patients who declined to participate, the next patient in the list replaced them. The same procedure was followed if the selected patients decided to withdraw their participation during the study.

The sample size was estimated with the formula for a cross-sectional study by Daniel (159): $[Z^2 (PQ)/ \delta^2]$, where Z=1.96, the standard normal deviate at 95% confidence, P=0.5 (estimated prevalence of the problem under study, assumed to be 50% to achieve the maximum sample size), Q = 0.5 ([100% - P] [or 1-P]), and δ=0.05, represents a sampling error of 5%. The sample size was 385 patients reporting to the Medical and Surgical Outpatient Departments of the Raleigh Fitkin Memorial Hospital. This method of sampling has some selection bias, but it is easier to perform and less time-consuming (158).

Four hundred and eleven (411) subjects were interviewed among the four hundred and forty subjects invited to participate, yielding a response rate of 93.4%. Of the 440 subjects invited, a total of 55 subjects were excluded due to being younger than 18 years of age (13 subjects), being a resident outside of the Manzini region (27 subjects), pregnancy (2 subjects), and high temperature (3 subjects). An individual withdrew for fear of the needle prick. Completed fasting blood glucose readings were available for 394 subjects, but 9 subjects had completed questionnaires with missing data (see Figure 2 in Appendix A).

1.9.4 Measurements

Data was collected at three levels: biomedical measurements, anthropometric measurements, and a questionnaire to assess the socio-demographic characteristics of the respondents.

1.9.4.1 Biomedical measurements

The fasting blood glucose (FBG) and oral glucose tolerance (OGT) testing was done using a glucometer (On Call® EZ II, ACON Laboratory, Inc., USA) according to the manufacturer's instructions. A 27 – gauge solid core Lancet was used to access capillary whole blood from the participant's finger. According to the manufacturer's instruction, the first drop of blood was discarded and a second drop, approximately 1 µl, was used for analysis. A single level control calibration of the On Call EZ II was performed daily, whenever a new vial of the test strip was used, and whenever the meter was dropped. Fasting blood glucose was measured between 08:00 and 12:00, after a minimum of 8 hours of overnight fasting. To determine the oral glucose tolerance (OGT), 75 g of glucose (Dextrose Monohydrate, MEDICOLAB, South Africa) was dissolved in 300 ml of water and given to the respondent to drink within 5 minutes after a taking an FBG reading. After a two-hour interval, the glucose test was performed again.

Blood pressure was measured using a sphygmomanometer (FORA Fully Auto Desk P30 Plus Spygmo Digital with 24 – 43 cm WIDR Cuff). The blood pressure measurement was taken while the participant was in the sitting position, using the right upper arm after a five minute rest period. Two readings were taken during the interview at fifteen minute intervals.

1.9.4.2 Anthropometric measurements

Weight was measured in kilograms (kg) using a weighing scale (FORA Digital Multi-function Diamond Scale), and height was measured in centimetres (cm) using a stadiometer. Weight was measured with the participants wearing light clothing and barefoot. Waist circumference (to the nearest 0.1 cm) was measured using a measuring tape, midpoint between the last palpable rib and the suprailiac crest, while participants were standing and breathing normally. Hip circumference was measured at the widest point around the greater trochanters. The waist and hip circumferences were measured with the measuring tape parallel to the floor. All measurements were taken by a trained research assistant (a nurse), twice per participant, and the average reading was recorded.

1.9.4.3 Socio-demographic and lifestyle variables

A structured questionnaire was used to collect data on the socio-demographic and lifestyle variables, including demographic characteristics, socio-economic physical activity, tobacco and alcohol use, consumption of fruits, vegetables, and sweet drinks. The socio-demographic variables collected included age, divided into six groups (15-24, 25-34, 35-44, 45-54, 55-64, and ⩾65 years [Paper I] and 18–27, 28–37, 38–47, 48–57, 58–67, ⩾68 years [Paper II]; gender; occupation, considered as a student/unemployed, self-employed and a salaried job; and education, categorised as no formal, primary or secondary or higher education. The different age categories used in Paper 1 were due to age-standardisation. The Swaziland Demographic and Health Survey used for age-standardisation in Paper 1 employed the 15 years and older age categories. Principal component analysis (PCA) was used to generate wealth quintiles from the asset variables. Asset variables included a radio or transistor, a television, mobile phone, non-mobile phone, refrigerator, stove, and watch/clock. Each principal component was the sum of each variable multiplied by its weight. The components were ordered so that the first principal component explained the most substantial amount of variation in the data. Therefore, the first principal component was used to represent the wealth index because it explained the largest possible amount of variation in the original data (160) (see Figure 3). This wealth index was then ranked into five quintiles (since the wealth index was a continuous variable), dividing all participants into five equal groups; lowest, second, third, fourth, and the highest quintiles (Paper I). In Paper II, the first principal component was used to represent the wealth index, categorised into three levels: lower, middle, and highest SES levels.

Insufficient physical activity was defined as self-reports of less than 150 minutes of moderate-intensity activity or less than 75 minutes of vigorous-intensity work, recreation, or travel per week (94). Smoking was defined as self-reported former or current tobacco use, including smokeless tobacco products, snuff, and pipes. Harmful alcohol use was defined as the consumption of five or more standard drinks per day for men and four or more standard drinks per day for women (161). Alcohol use included beer, wine, spirits, and a local brew (such as buganu). Consumption of sweet drinks was defined as self-reported consumption of sweet coffee, sweet tea, soda, and other sweet beverages per week. Rare consumption of sweet drinks was defined as the consumption of fewer than three drinks per week. Moderate sweet drink consumption was defined as the consumption of four to ten drinks per week, while consumption of more than eleven sweet drinks per week was considered excessive (161). Salt use included the use of raw salt and salty stock cubes or powders. Consumption of salty processed foods included the consumption of salty snacks, canned salty foods, and salty foods prepared at fast-food restaurants. Adequate consumption of fruits and vegetables was considered as the consumption of three or more servings daily. One serving of vegetables was taken as one cup of raw green leafy vegetables or half a cup of other raw or cooked vegetables (tomatoes,

carrots, onions) or half a cup of vegetable juice. One serving of fruit was taken as one medium-sized apple, banana, orange, or half a cup of cooked or canned fruit or half a cup of juice from fruit (but not artificially flavoured).

1.9.4.4 Definitions

The prevalence of T2DM was defined to comprise of all participants with known diabetes (previous diagnosis of diabetes or using anti-diabetic medications) and those with a fasting blood glucose (FBG) ⩾ 7.0 mmol/L (⩾126 mg/dL) or a random blood glucose (RBG) ⩾ 11.1 mmol/dL (> 200 mg/dL) and a 2hr glucose concentration during an OGTT. Prediabetes was defined as an FBG between 6.1 and 6.9 mmol/L (110–125 mg/dL) for impaired fasting glucose (IFG) or a 2hr glucose concentration during an OGTT between 7.8 (140 mg/dL) and 11.0 mmol/L (199 mg/dL) for impaired glucose tolerance (IGT) based on the WHO/IDF recommendation (162). Abnormal glucose metabolism (AGM) was defined as IFG, IGT, or T2DM.

In Papers I - and II, the participants were hypertensive (stage 1) if their mean systolic blood pressure (SBP) was 130–139 mmHg or their mean diastolic blood pressure (DBP) was 80-89 mmHg. Stage 2 hypertension was defined as a mean SBP of 140–179 mmHg and a DBP ⩾ 90 mmHg. Participants were considered to have a hypertensive crisis if their mean SBP was ⩾180 mmHg or if their mean DBP was ⩾ 120 mmHg. A mean SBP of 120–129 and a mean DBP of < 80 mmHg was considered an elevated blood pressure. Participants on anti-hypertensive treatment were also included. Hypertension definitions were made according to the American College of Cardiology/American Heart Association guidelines (163). In Papers III and IV, hypertension was defined as a systolic blood pressure (SBP) ⩾ 140 mmHg and/or a diastolic blood pressure (DBP) ⩾ 90 mmHg or currently on antihypertensive medication (164).

General obesity was defined as a BMI ⩾ 30 kg/m² while obesity stages I, II, and III were defined as BMIs of 30-34.9, 35-39.9 and ⩾ 40 kg/ m², respectively according to the WHO definitions (165). Underweight and overweight were defined as a BMI < 18.5 and a BMI of 24.5 – 29.9, respectively (165). Abdominal obesity (central obesity) was defined according to the WHO guidelines (166). Waist circumference was defined as normal, overweight, and obese for men (< 94, 94–102 and ⩾ 103 cm) and women (⩽ 80, 80–88, and ⩾ 89 cm), respectively and > 94 cm in men or > 80 cm in women. Raised WHR was defined as a WHR >1.0 for men and >0.85 for women.

1.9.4.5 Data collection team

The data collection team comprised of the principal investigator and two research assistants (a medical doctor and a nurse). The research assistants underwent training before the commencement of fieldwork.

1.9.4.6 Data management and analysis

Data collected in the completed questionnaires and data collection form were entered into MS Excel and screened for missing data, outliers, and normality using the Kolmogorov-Smirnov (K-S) one sample test before being exported to SPSS version 26 (IBM Corp., Armonk, NY, USA) for analysis. The results of the Kolmogorov-Smirnov test were significant, $p<0.05$. These results suggest that the variables (age, blood glucose, BMI, WC, WHR) are unlikely to have been produced by a normal distribution; thus, normality cannot be assumed. However, the mean of any random variable will be approximately normally distributed as sample size increases according to the Central Limit Theorem. Therefore, with a sufficiently large sample size (n > 50), deviations from normality will have little effect on the results (167). A two-sided p-value < 0.05 was considered statistically significant in all four papers.

1.9.4.6.1 Paper I

The calculation of the prevalence of T2DM and prediabetes was based on the method used by Miller (168). A Chi-square test was applied to examine the association between the independent demographic and biometric variables and abnormal glucose metabolism (AGM) (T2DM and prediabetes). Analysis of variance (ANOVA) was used to examine the group and the main effect of the categorical independent variables (age groups, gender) on the continuous dependent fasting blood glucose (FBG) levels.

1.9.4.6.2 Paper II

The prevalence of hypertension was calculated. A Chi-square test was applied to examine the association between the independent socio-demographic and behavioural variables and prediabetes, T2DM, and hypertension. A binary logistic regression with a backward conditional method was performed to assess the variables that were associated with T2DM, prediabetes, and hypertension.

1.9.4.6.3 Paper III

The prevalence of overweight and obesity was calculated according to the BMI, WC and WHR. A Chi-square test was used for bivariate data analysis, and univariate ANOVA was used to examine the group and the main effect of the categorical independent variables (age groups, gender) on the continuous dependent body mass index, waist circumference, and waist-to-hip ratio, respectively. A binary logistic regression

with a forward conditional method was performed to assess which independent variables could predict the development of general obesity (BMI) and central obesity (WC and WHR).

1.9.4.6.4 Paper IV

The prevalence rates for T2DM and prediabetes and hypertension were compared according to sex, educational levels, age groups, and levels of general (BMI), and central (WC and WHR) obesity. A Chi-square test was applied to examine the association between the independent demographic and biometric variables and AGM and hypertension. Receiver operating characteristic (ROC) analysis was used to determine which of the measures of general and central adiposity had the best predictive ability for identifying future T2DM and hypertension risk, while the area under the ROC curve (AUC) and it's 95% CI was used to estimate the optimal cut-off value for each of the obesity indices. Diagnostic performance and the optimal cut-off value were determined using the Youden index that minimises 1 – (sensitivity + specificity) or equivalently maximises the sum of sensitivity and specificity in ROC space.

1.9.4.6.5 The ethical and scientific review

The study was approved by the Biomedical Research Ethics Committee (BREC) of the University of Kwa Zulu-Natal (UKZN) (Reference: BE 385/18) and the Research Ethics Committee (REC) of the Ministry of Health in Swaziland. Participation was voluntary and written informed consent was obtained from each participant who was identified anonymously.

The main ethical issue in these studies was the need to follow-up participants who were newly diagnosed with T2DM and hypertension during the data collection phase. However, all of the participants with abnormal glucose levels and raised blood pressure were given a referral note for the Raleigh Fitkin Memorial for proper management of their condition. Also, free counselling was provided to the participants with IFG, IGT, and raised BP to visit the diabetes clinic for further evaluation and management of their condition.

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CHAPTER TWO

PREVALENCE OF ABNORMAL GLUCOSE METABOLISM AMONG ADULTS ATTENDING AN OUTPATIENT DEPARTMENT AT A TERTIARY REFERRAL HOSPITAL IN SWAZILAND: A CROSS-SECTIONAL STUDY

In the current chapter, the prevalence of type 2 diabetes mellitus and pre-diabetes among patients in a tertiary hospital in Manzini, Swaziland, is estimated. The findings from this chapter contribute to the limited research on T2DM prevalence in Swaziland. The manuscript resulting from this chapter has been published by the peer-reviewed journal, BMC Public Health.

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Prevalence of abnormal glucose metabolism among adults attending an outpatient department at a tertiary referral hospital in Swaziland: a cross-sectional study

Mojeed Akorede Gbadamosi* and Boikhutso Tlou

Abstract

Background: The exact prevalence of type 2 diabetes mellitus (T2DM) and pre-diabetes in Swaziland remains unknown. Estimates suggest that the prevalence rate of type 2 diabetes mellitus is between 2.5 and 6.0% in Swaziland. The disparity in these estimates is due to a lack of quality data but the prevalence of diabetes is increasing in Swaziland. This study estimates the prevalence of type 2 diabetes mellitus and pre-diabetes among patients in a tertiary hospital in Manzini, Swaziland.

Methods: A cross-sectional observational survey was used to estimate the crude and age-adjusted prevalence rates of diabetes and pre-diabetes (impaired fasting glucose (IFG) and impaired glucose tolerance (IGT)) in the Manzini regional referral hospital of Swaziland. Diabetes was defined as a fasting blood glucose (FBG) ≥ 7.0 mmol/L (126 mg/dL) and pre-diabetes was defined as an FBG of 6.1–6.9 mmol/L (110–125 mg/dL) and an FBG < 7.0 mmol/L (< 126 mg/dL), respectively for IFG and IGT. A random sample of 385 participants was used. Data analysis was done using SPSS version 26 and the level of statistical significance was set at $\alpha < 0.05$.

Results: The crude prevalence of type 2 diabetes mellitus and pre-diabetes was 7.3% [95% CI 4.9–10.3] and 6.5% [95% CI 4.2–9.4], respectively, with clear gender differences in the prevalence of diabetes (men 1.6% vs women 5.7%, $p = 0.001$). On the other hand, significantly more men (3.6%) had pre-diabetes than women (2.9%) ($p = 0.004$). The overall age-adjusted prevalence rates of type 2 diabetes mellitus and pre-diabetes were 3.9 and 3.8%, respectively. Among the diabetic group, 3 (10.7%) had known T2DM, whereas 25 (89.3%) were newly diagnosed during the study. Advancing age, gender, raised blood pressure, abnormal body mass index, and wealth index were significant risk factors for T2DM or prediabetes.

Conclusion: The prevalence of type 2 diabetes mellitus among adult outpatients in the Raleigh Fitkin Memorial hospital was higher than previously reported in the health facility in Manzini; suggesting the need for routine T2DM screening at outpatient departments.

Keywords: Abnormal glucose metabolism, Diabetes, Pre-diabetes, Prevalence, Swaziland

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Background

The exact prevalence of type 2 diabetes mellitus (T2DM) in Swaziland remains unknown. The International Diabetes Federation (IDF) [1] reported that the proportion of adults living with T2DM in Swaziland was 2.5%. On the contrary, the World Health Organisation (WHO) [2] estimated the prevalence of T2DM in Swaziland to be 6%. Both the IDF and WHO extrapolated data from a similar country to estimate the T2DM prevalence for Swaziland, due to absence of original data from Swaziland. Furthermore, a recent Stepwise approach to surveillance (STEPS) survey conducted in 2014 highlighted the significance of the burden of chronic diseases of lifestyle in Swaziland [3]. The survey findings revealed that about 14.2% of the respondents had raised blood glucose, while 9.8% had impaired fasting glycemia (IFG).

The STEPS survey [3] attributed the rising prevalence of chronic diseases (including diabetes mellitus) to the high rates of obesity, physical inactivity, smoking, and alcohol consumption in the Swazi population. Therefore, the Swaziland government established the National Non-Communicable Diseases Programme with a focus on cardiovascular diseases, diabetes, cancer, and other chronic diseases [4]. Furthermore, the Ministry of Health (MOH) developed the National Non-Communicable Diseases Policy [5] and a strategic plan for 2012–2017 [6] to guide the implementation of non-communicable diseases (NCD) prevention, management, and control. There is thus a serious need for current epidemiological data.

Furthermore, about 8.8% of the STEPS respondents aged 40–69 years had cardiovascular disease [3]. The morbidity and mortality statistics for chronic diseases showed alarming rates [3]. The Swaziland Ministry of Health (MOH) [4] also reported that diabetes mellitus was responsible for 73,290 attendances at out-patient departments of all health facilities in 2016, representing a 16.8% increase from the 2015 figures. Similarly, mortality due to diabetes mellitus was unacceptably high and has increased sharply from 45 cases in 2014, to 88 in 2015, and finally to 109 cases in 2016 [4].

To the researchers' knowledge, no epidemiological study has been conducted in Swaziland to estimate the age-adjusted prevalence of T2DM and pre-diabetes, even though diabetes ranked third among the ten leading causes of all hospital admissions in Swaziland in 2016 [4]. Previous studies in Swaziland have investigated the influence of diabetes on the quality of life [7] as well as the prevalence of diabetic retinopathy [8], and a case has been made for strengthening chronic care services in the kingdom [9]. Similarly, risk factors for non-communicable diseases (NCDs) in Swaziland have been reported [3]. A study by Rabkin et al. in 2016 investigated the possibility of screening for diabetes among HIV-positive patients [10]. However, the study did not report age-adjusted prevalence rates for pre-diabetes and diabetes. To address these gaps, the current study was conducted to determine the prevalence of T2DM and pre-diabetes in a tertiary hospital in the Manzini region of Swaziland. Quantifying the prevalence of T2DM and pre-diabetes among patients attending the out-patient departments (OPD) at Raleigh Fitkin Memorial (RFM) will contribute to the understanding of the burden of T2DM in Swaziland. Findings from this study will facilitate planning and implementation of cost-effective interventions for the prevention and management of diabetes mellitus, by adding new scientific information to the existing body of knowledge.

Methods

Study design

This study was an observational, cross-sectional, hospital-based study.

Study setting

Raleigh Fitkin Memorial (RFM) Hospital, situated in the Manzini region, is the second largest public health facility in Swaziland. It is a regional referral and government sub-vented teaching hospital. The mission hospital and its different service units draw patients from the Manzini region as well as neighbouring communities in the adjacent regions including the Mbabane – Manzini – Siteki corridor.

Population and sample

A cross-sectional study was conducted from February to March 2019 among 385 patients who visited the OPD of the RFM Hospital in Manzini, Swaziland. All patients who visited the OPD during the data collection period were included. Patients were included in the sample if they resided in the Manzini region; were 18 years of age and above; had fasted for 8 h before the screening, and willingly consented to participate in the study. However, patients with active infection or using corticosteroids; who were pregnant; who had a temperature greater than 101.4 °F (38.6 °C); were taking antibiotics or anti-malaria medications or who were unwilling to participate were excluded. A representative sample of the medical and surgical outpatient population was surveyed. A systematic random sampling technique was applied to sample 385 individuals, whereby every 3rd individual visiting the OPD was approached to participate in the study, bearing in mind the inclusion criteria. As remarked by Castillo [11], systematic random sampling allows the researchers to add a degree of a system into the random selection of subjects and ensures that the population is evenly sampled.

The sample size was estimated with the formula for a cross-sectional study by Daniel [12]:

$$n = \frac{Z^2(PQ)}{\delta^2}$$

Z = 1.96. (The standard normal deviation at 95% confidence)

P = 0.5 (Estimated prevalence of the problem under study, assumed to be 50% to achieve the maximum sample size)

Q = 0.5 ((100% - P) (or 1-P))

δ = 0.05 (The precision or maximum acceptable error)

n = Sample size

$$n = \frac{(1.96)^2 \times (0.5)(0.5)}{(0.05)^2}$$

n = 384.16

The sample size was 385 patients reporting to the Medical and Surgical out-patient departments of the Raleigh Fitkin Memorial Hospital. This method of sampling has some selection bias but it is easier to perform and less time consuming.

Definitions

The prevalence of T2DM was defined to comprise of all participants with known diabetes and those with a fasting blood glucose (FBG) ≥ 7.0 mmol/L (126 mg/dL) or a random blood glucose (RBG) ≥ 11.1 mmol/dL (> 200 mg/dL) and/or an oral glucose tolerance test (OGTT) ≥ 11.1 mmol/dL (> 200 mg/dL). Prediabetes was defined as a FBG between 6.1 and 6.9 mmol/L (110–125 mg/dL) for impaired fasting glucose (IFG) or an OGTT between 7.8 and 11.0 mmol/L (140–199 mg/dL) for impaired glucose tolerance (IGT) based on the WHO/IDF recommendation [13]. Abnormal glucose metabolism (AGM) was defined as IFG, IGT, or T2DM.

Measures

Demographics

Demographic variables collected included age; gender; marital status; and residential location.

Socio-economic status

Participants were asked to report their level of education, categorised into five groups: no formal education; primary school; secondary school; high school; and tertiary education. Respondents' occupations and average monthly household incomes were also determined. Household wealth (assets, ownership of agricultural land and farm animals) was also recorded and used to generate wealth quintiles through principal component analysis (PCA). Principal component analysis was used to extract a set of uncorrelated principal components as weighted linear combinations of the original household asset ownership variables. Each principal component was the sum of each variable multiplied by its weight. The components were ordered so that the first principal component explained the largest amount of variation in the data. Therefore, the first principal component was used to represent the wealth index because it explained the largest possible amount of variation in the original data [14]. This wealth index was then ranked into five quintiles (since the wealth index was a continuous variable), dividing all participants into five equal groups; lowest, second, third, fourth, and the highest quintiles.

Anthropometric variables

Weight was measured in kilograms (kg) using a weighing scale (FORA Digital Multi-function Diamond Scale), and height was measured in centimeters (cm) using a stadiometer. Weight was measured with the participants wearing light clothing and barefoot. Waist and hip circumferences were assessed in centimeters (cm) using a measuring tape. Waist and hip circumferences were assessed while the participants were in a standing position.

The Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Participants were classified as underweight if their BMI was < 18.5 kg/m^2, normal weight if their BMI was between 18.5 and 24.9 kg/m^2 (inclusive), overweight if their BMI was between 25.0 and 29.9 kg/m^2 (inclusive) and obese if their BMI was ≥30 kg/m^2 [15].

A raised waist circumference was defined as a waist circumference greater than 94 cm (> 94 cm) for men, and greater than 80 cm (> 80 cm) for women, while a raised waist-to-hip ratio (WHR) was defined as a WHR greater than one (> 1.0) for men and greater than zero point eight five (> 0.85) for women, according to standardised international criteria [16].

Blood pressure

Blood pressure was measured using a sphygmomanometer (FORA Fully Auto Desk P30 Plus Spygmo Digital with 24 – 43 cm WIDR Cuff). The blood Pressure measurement was taken while the participant was in the sitting position, using the right upper arm after a 5-min rest period. Two readings were taken during the interview at 15 min intervals.

Participants were hypertensive (stage 1) if their mean systolic blood pressure (SBP) was 130–139 mmHg or their mean diastolic blood pressure (DBP) was 80-89 mmHg. Stage 2 hypertension was defined as a mean SBP of 140–179 mmHg and a DBP greater than or equal to 90 mmHg. Participants were considered to have hypertensive crisis if their mean SBP was greater than or equal to 180 mmHg or if their mean DBP was greater than or equal to 120 mmHg. A mean SBP of 120–129 and a mean DBP of less than 80 mmHg was considered as an

elevated blood pressure. Participants on antihypertensive treatment were also included. Hypertension definitions were made according to the American College of Cardiology/American Heart Association guidelines [17].

Blood glucose

The fasting blood glucose (FBG) and Oral Glucose Tolerance (OGT) testing were done using a glucometer (On Call® EZ II, ACON Laboratory, Inc., USA) according to the manufacturer's instructions. Fasting blood glucose was measured between 08:00 and 12:00, after a minimum of 8 h of overnight fasting. To determine the Oral Glucose Tolerance (OGT), 75 g of glucose (Dextrose Monohydrate, MEDICOLAB, South Africa) was dissolved in 300 ml of water and given to the respondent to drink within 5 min after a taking an FBG reading. After a two- hour interval, the glucose test was performed again.

Prevalence of pre-diabetes and type 2 diabetes mellitus

The calculation of the prevalence of T2DM and pre-diabetes was based on the method used by Miller [18]. The number of cases of T2DM or pre-diabetes was divided by the sample size to obtain the crude prevalence of T2DM or pre-diabetes, respectively. The age-adjusted prevalence rates were calculated by dividing the number of cases of T2DM or pre-diabetes, respectively in each of the 10-year age groups by the number of cases in that group, before the result was multiplied by the population proportion for that age group, based on the Swaziland Demographic and Health Survey (DHS) report [19]. (See Supplementary file 1).

Statistical analysis

All analyses were conducted using SPSS version 26 statistical software (IBM Corp., Armonk, NY, USA). Descriptive statistics (percentage) was used to describe the crude (unadjusted) prevalence rates for the sample and age-adjusted prevalence rates of T2DM and pre-diabetes. A Chi-square test was applied to examine the association between the independent demographic and biometric variables and abnormal glucose metabolism (AGM) (T2DM and pre-diabetes). Analysis of variance (ANOVA) was used to examine the group and the main effect of the categorical independent variables (age groups, gender) on the continuous dependent fasting blood glucose (FBG). A two-sided p-value < 0.05 was considered statistically significant.

Results

Description of the study population

Four hundred and eleven (411) subjects were interviewed among the 440 subjects invited to participate, yielding a response rate of 93.4%. Of the 440 subjects invited, a total of 55 subjects were excluded due to being younger than 18 years of age (13 subjects), being resident outside of Manzini region (27 subjects), pregnancy (2 subjects), and high temperature (3 subjects). An individual withdrew for fear of the needle prick. Completed fasting blood glucose readings were available for 394 subjects but 9 subjects had completed questionnaires with missing data.

Table 1 shows the characteristics of the study participants. There were 197 (51.2%) men and 188 (48.8%) women. A typical participant in this study was 38 years of age, with women being older than men (39 vs 36 years). The participants were evenly distributed in terms of areas of residence, with 50.1% (n = 192) and 49.9% (n = 191) from the rural and urban areas, respectively. A significantly higher proportion of women compared to men were overweight (33.5% vs 19.8%) and obese (33.5% vs 6.6%), unemployed (32.4% vs 21.8%), and from poor households (35.1% vs 20.8%). More men were significantly underweight (9.6%) than women (1.1%). Also, more men attained high school or college education than women (48.7% vs 34.0%). The mean systolic and diastolic blood pressures were 123.13 (16.22) mmHg and 77.83 (11.33) mmHg, respectively. According to the American College of Cardiology/American Heart Association's (ACC/AHA) definition of hypertension [17], 36.9% of the study participants had normal blood pressure, 14.8% of them had pre-hypertension and 29.4 and 17.4% had stage 1 and 2 hypertensions, respectively, while six participants (1.6%) had hypertensive crisis. There was no significant gender difference in the prevalence of hypertension.

Prevalence of pre-diabetes and type 2 diabetes mellitus

The overall prevalence rates of T2DM and pre-diabetes were 7.3 and 6.5%, respectively. The prevalence of T2DM was higher in women (3.6%) than men (2.9%). On the contrary, the prevalence of pre-diabetes was higher in men (5.7%) compared to women (1.6%). Based on the Swaziland national population estimates [19], the age-adjusted prevalence rates for T2DM and pre-diabetes were 3.9% (1.2% men vs 6.6% women) and 3.8% (4.1% men vs 3.6% women). The pre-existing T2DM was reported by three participants (10.7%) while the proportion of newly diagnosed T2DM among T2DM cases was 89.3% (Table 2).

Mean values of the fasting blood glucose (FBG) within age groups, hypertension, body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) are shown in Table 3. Considering the categories within the variables, the concentration of FBG significantly increased with advancing age and BMI. The highest blood

Table 1 Description of the study participants

Characteristics	Total	Men	Women	*p*-value
Biomedical[a]				
Sample size, n (%)	385 (100.0)	197 (51.2)	188 (48.8)	
Age (years), mean (SD)	37.77 (15.66)	36.47 (15.63)	39 (15.61)	0.094
BMI (kg/m^2), mean (SD)	25.67 (5.97)	23.17 (4.11)	28.28 (6.49)	< 0.0001**
Hip circumference (cm), mean (SD)	100.09 (13.83)	95.02 (1.96)	105.40 (13.68)	< 0.0001**
Weight (cm), mean (SD)	70.87 (15.16)	63.31 (12.74)	73.56 (16.97)	0.001**
Blood Glucose (mmol/L), mean (SD)				
Fasting Blood Glucose	5.385 (1.211)	5.286 (0.888)	5.478 (1.449)	0.141
Random Blood Glucose	7.368 (1.830)	7.117 (1.632)	8.055 (2.235)	0.149
BP (mm Hg), mean (SD)				
SBP	123.13 (16.22)	122.64 (13.99)	123.64 (18.29)	0.549
DBP	77.83 (11.33)	77.90 (10.57)	77.77 (12.11)	0.909
BMI (kg/m^2), n (%)				< 0.0001*
Underweight	21 (5.5)	19 (9.6)	2 (1.1)	
Normal	186 (48.3)	126 (64.0)	60 (31.9)	
Overweight	102 (26.5)	39 (19.8)	63 (33.5)	
Obese	76 (19.7)	13 (6.6)	63 (33.5)	
Waist circumference (cm), n (%)				0.855
Normal	221 (57.4)	112 (56.9)	109 (58.0)	
Overweight	59 (15.3)	29 (14.7)	30 (16.0)	
Obese	105 (27.3)	56 (28.4)	49 (26.1)	
Waist-to-hip ratio, n (%)				0.640
Normal	247 (64.2)	129 (65.5)	118 (62.8)	
Overweight	49 (12.7)	22 (11.2)	27 (14.4)	
Obese	43 (23.1)	46 (23.4)	43 (22.9)	
Hypertension (mmHg), n (%)				0.198
Normal	142 (36.9)	68 (34.5)	74 (39.4)	
Elevated	57 (14.8)	33 (16.8)	24 (12.8)	
Hypertension stage 1	113 (29.4)	63 (32.0)	50 (26.6)	
Hypertension stage 2	67 (17.4)	32 (16.2)	35 (18.6)	
Hypertension crisis	6 (1.6)	1 (0.5)	5 (2.7)	
Socioeconomic [b]				
Education, n (%)				0.054
No formal education	26 (6.8)	11 (5.6)	15 (8.0)	
Primary	96 (24.9)	45 (22.8)	51 (27.1)	
Secondary	101 (26.2)	44 (22.3)	57 (30.3)	
High school	118 (30.6)	67 (34.0)	51 (27.1)	
College/university degree	42 (10.9)	29 (14.7)	13 (6.9)	
Postgraduate degree	2 (0.5)	1 (0.5)	1 (0.5)	
Occupation, n (%)				0.022*
Student	49 (12.7)	28 (14.2)	21 (11.2)	
Unemployed	104 (27.0)	43 (21.8)	61 (32.4)	
Civil servant	157 (40.8)	91 (46.2)	66 (35.1)	
Self employed	58 (15.1)	30 (15.2)	28 (14.9)	

Table 1 Description of the study participants *(Continued)*

Characteristics	Total	Men	Women	*p*-value
Domestic worker	8 (2.1)	1 (0.5)	7 (3.7)	
Shop attendant	9 (2.3)	4 (2.1)	5 (2.7)	
Residence, n (%)				0.331
Rural	192 (50.1)	94 (47.7)	98 (57.2)	
Urban	191 (49.9)	103 (52.3)	88 (47.3)	
Marital status, n (%)				0.081
Single	172 (44.8)	99 (50.3)	73 (39.0)	
Married	157 (40.9)	74 (37.6)	83 (44.4)	
Staying with partner	35 (9.1)	18 (9.1)	17 (9.1)	
Widowed	14 (3.6)	5 (2.5)	9 (4.8)	
Divorced	6 (1.6)	1 (0.5)	5 (2.7)	
Average monthly income (SDE), n (%)				0.001*
< 500	41 (10.6)	18 (9.1)	23 (12.2)	
500–999	66 (17.1)	23 (11.7)	43 (22.9)	
1000–1999	92 (23.9)	41 (20.8)	51 (27.1)	
2000–2999	74 (19.2)	42 (21.3)	32 (17.0)	
≥ 3000	112 (29.1)	73 (37.1)	39 (20.7)	

[ab]Mean with SD for biomedical data and percentages for socio-demographic data
*Chi-square or Fisher's test, $p < 0.05$ was considered significant for men vs women
**Univariate ANOVA, $p < 0.05$ was considered significant for gender differences between men and women
BMI, Body mass index; BP, Blood pressure; DBP, Diastolic blood pressure; SBP, Systolic blood pressure; SD, Standard deviation; SDE: Swazi Emalangeni; n, Sample size

glucose concentration among women was observed within the age group of 55–64 years and within 45–54 years of age among men. Meanwhile, overweight and obese women (by BMI) had significantly higher blood glucose concentration levels than their counterparts of overweight and obese men ($p < 0.0001$). The blood glucose concentration levels were higher among hypertensive women than hypertensive men. Similar outcomes were obtained for gender distribution of those overweight and obese (by WC). However, the blood glucose concentration level was higher for obese men than that of obese women (by WHR).

Factors associated with pre-diabetes and type 2 diabetes mellitus

Factors associated with pre-diabetes

Table 4 shows the findings of chi-square analysis to identify the association between socioeconomic and demographic variables and the presence of diabetes and pre-diabetes (AGM). Individuals' age, raised blood pressure, and excess body weight were found to be significantly associated with pre-diabetes. Over half of the subjects with pre-diabetes were in the age group 45 years and older. The majority of the subjects with abnormal glucose were hypertensive, overweight or obese.

Table 2 Distribution of abnormal glucose metabolism according to age and gender

				Crude Prevalence						Age-adjusted Prevalence*					
	Total			Proportion of pre-diabetes			Proportion of T2DM			Proportion of pre-diabetes			Proportion of T2DM		
Age group (years)	All	M	W	All	M	W	All	M	W	All	M	W	All	M	W
15–24	91	49	42	1.0	0.5	0.5	1.0	0.0	1.0	1.0	0.9	1.0	1.0	0.0	2.0
25–34	108	63	45	1.3	1.3	0.0	1.3	0.5	0.8	0.6	0.9	0.0	0.6	0.4	0.8
35–44	84	40	44	0.3	0.0	0.2	1.8	0.5	1.3	0.1	0.0	0.2	0.7	0.4	1.0
45–54	40	13	27	1.6	1.0	0.5	1.3	0.0	1.3	0.9	1.6	0.5	0.8	0.0	1.3
55–64	31	17	14	1.8	0.8	1.0	0.8	0.3	0.5	1.0	0.7	1.3	0.4	0.2	0.7
65+	31	15	16	0.5	0.0	0.5	1.0	0.3	0.8	0.3	0.0	0.6	0.5	0.2	0.9
Total	**385**	**197**	**188**	**6.5**	**3.6**	**2.7**	**7.3**	**1.6**	**5.7**	**3.8**	**4.1**	**3.6**	**3.9**	**1.2**	**6.6**

M, men; W, women
*Based on the Swaziland Demographic and Health Survey 2006/07 [19] (See supplementary Table 1)

Table 3 Mean glucose concentrations (mmol/L) according to gender

Variables	Men	Women	Total	*P*-value
Sample, n (%)	167 (48.5)	177 (51.5)	344 (100.0)	
Age groups (years), mean (SD)				< 0.0001**
15–24	4.989 (0.7534)*	5.154 (1.1734)*	5.066 (0.9708)	
25–34	5.275 (0.6706)	5.152 (0.8303)	5.222 (0.7424)	
35–44	5.260 (0.6162)	5.395 (1.3199)	5.337 (1.0118)	
45–54	5.500 (0.8234)	5.958 (2.0777)	5.813 (1.7790)	
55–64	5.693 (0.7918)	5.879 (1.2540)	5.786 (1.0334)	
65+	5.800 (2.0356)	6.200 (2.1147)	6.029 (2.0526)	
Hypertension, mean (SD)				0.175
Normal	5.277 (1.1124)	5.277 (1.4334)	5.277 (1.2903)	
Elevated (Prehypertension)	5.281 (0.7547)	5.187 (0.7724)	5.241 (0.7565)	
Hypertension stage 1	5.114 (0.6338)	5.778 (1.5632)	5.436 (1.2191)	
Hypertension stage 2	5.622 (0.8078)	5.661 (1.5967)	5.645 (1.3189)	
Body mass index, mean (SD)				< 0.0001**
Underweight	5.073 (0.7005)*	4.450 (0.2121)	5.012 (0.6800)	
Normal	5.164 (0.7260)	5.297 (1.4047)	5.211 (1.0182)	
Overweight	5.691 (1.2969)	5.809 (0.8469)	5.765 (1.6582)	
Obese	5.454 (0.6741)	5.363 (0.9437)	5.379 (0.8976)	
Waist circumference, mean (SD)				0.706
Normal	5.237 (0.7175)	5.426 (1.1279)	5.337 (0.9589)	
Overweight	5.254 (1.6173)	5.557 (1.6577)	5.422 (1.6315)	
Obese	5.385 (0.6804)	5.542 (1.9101)	5.458 (1.3872)	
Waist-to-hip ratio, mean (SD)				0.850
Normal	5.219 (0.7566)	5.493 (1.1921)	5.358 (1.0084)	
Overweight	5.319 (1.6500)	5.563 (1.7425)	5.456 (1.6891)	
Obese	5.451 (0.6099)	5.380 (1.8600)	5.415 (1.3829)	

Hypertension is defined as normal (SBP < 120 and DBP < 80 mmHg), Elevated (SBP 120–129 and DBP < 80 mmHg); hypertension stage 1 (SBP 130–139 or DBP 80–89 mmHg); hypertension stage 2 (SBP ≥ 140 or DBP ≥ 90 mmHg)
BMI defined as underweight (< 18.5), normal (18.5–24.9), overweight (25.0–29.9) and obese (≥ 30)
Waist circumference is defined as normal, overweight and obese for men (< 94, 94–102 and ≥ 103 cm) and women (≤ 80, 80–88, and ≥ 89 cm), respectively
Waist-to-hip ratio is defined as normal, overweight and obese for men (≤ 0.95, 0.96–1.0 and ≥ 1.1) and women (≤ 0.80, 0.81–0.85, and ≥ 0.86), respectively
n, number; *$p < 0.05$ and **$p < 0.05$ significant by Univariate ANOVA (F-test) for gender difference in subgroup and group, respectively

Factors associated with T2DM

Gender and wealth index were the non-modifiable and modifiable risk factors found to be associated with T2DM. A significant proportion of women compared to men were found to have T2DM (78.6% vs 21.4%). Moreover, subjects with T2DM were found to be significantly poorer than subjects with normal glucose metabolism (39.3% vs 17.5%). Body mass index, education, occupation and household income were also found to be associated with T2DM, but these did not reach the level of statistical significance ($p > 0.05$).

Discussion

In this study the researchers reported estimates for the prevalence of T2DM and pre-diabetes, and the factors associated with these conditions among adults (18–83 years old) attending outpatient departments at the RFM in Swaziland. The overall prevalence of T2DM and pre-diabetes was 7.3 and 6.5%, respectively, with clear gender differences. The results showed a higher prevalence of T2DM (7.3%) than previously reported (5%) in this hospital. Similarly, the proportion of newly detected T2DM cases (89.3%) was high, suggesting that screening practices in this hospital were ineffective. Advancing age, female gender, excess body weight, poorest wealth index and high blood pressure were associated with a higher risk of T2DM and pre-diabetes in these Swazi adults.

The estimated T2DM prevalence of 7.3% found in the current study was higher than the 5.0% reported previously by Rabkin et al. [10] in the same setting, but lower than the estimate reported in the 2014 STEPS survey [3] in Swaziland. The difference between Rabkin et al.'s

Table 4 Demographic and socio-economic factors associated with diabetes status

Variable	NGM[b]	AGM[a]			
		Prediabetes	*p*-value	T2DM	*p*-value
Sample, n (%)	332 (86.2)	25 (6.5)		28 (7.3)[c]	
Mean age (SD)	36.58 (15.01)	45.68 (17.35)		44.82 (18.5)	
Age (years) (n, %)			0.001*		0.255
15–24	83 (25.0)	4 (6.0)		4 (14.3)	
25–34	98 (29.5)	5 (20.0)		5 (17.9)	
35–44	76 (22.9)	1 (4.0)		7 (25.0)	
45–54	29 (8.7)	6 (24.0)		5 (17.9)	
55–64	21 (6.3)	7 (28.0)		3 (10.7)	
65+	25 (7.5)	2 (8.0)		4 (14.3)	
Gender (n, %)			0.795		0.001*
Men	177 (53.3)	14 (56.0)		6 (21.4)	
Women	155 (46.7)	11 (44.0)		22 (78.6)	
Residence (n, %)			0.563		0.717
Rural	165 (50.0)	14 (56.0)		13 (46.4)	
Urban	165 (50.0)	11 (44.0)		15 (53.6)	
Marital status (n, %)			0.131		0.371
Not in union[d]	171 (51.7)	9 (36.0)		12 (42.9)	
In union[e]	160 (48.3)	16 (64.0)		16 (57.1)	
Hypertension (n, %)			0.046*		0.710
Normal	127 (38.3)	4 (16.0)		11 (38.3)	
Elevated	51 (15.4)	3 (12.0)		3 (10.7)	
Stage 1	97 (29.2)	9 (36.0)		7 (25.0)	
Stage 2	57 (17.2)	9 (36.0)		7 (25.0)	
Body mass index (n, %)			0.042*		0.052
Underweight	20 (6.0)	1 (4.0)		0 (0.0)	
Normal	170 (51.2)	6 (24.0)		10 (35.7)	
Overweight	80 (24.1)	10 (40.0)		12 (42.9)	
Obese	62 (18.7)	8 (32.0)		6 (21.4)	
Waist circumference (n, %)			0.155		0.543
Normal	189 (56.9)	19 (76.0)		13 (46.4)	
Overweight	52 (15.7)	2 (8.0)		5 (17.9)	
Obese	91 (27.4)	4 (16.0)		10 (35.7)	
Waist-to-hip ratio (n, %)			0.025*		0.221
Normal	210 (63.3)	22 (88.0)		15 (53.6)	
Overweight	41 (12.3)	1 (4.0)		7 (25.0)	
Obese	81 (24.4)	2 (8.0)		6 (21.4)	
Education (n, %)			0.154		0.087
No formal education	19 (5.7)	4 (16.0)		3 (10.7)	
Primary	78 (23.5)	7 (28.0)		11 (39.3)	
Secondary or higher	235 (70.8)	14 (56.0)		14 (50.0)	
Occupation (n, %)			0.596		0.069
Student/unemployed	129 (38.9)	10 (40.0)		14 (50.0)	
Self-employed	49 (14.8)	2 (8.0)		7 (25.0)	

Table 4 Demographic and socio-economic factors associated with diabetes status *(Continued)*

Variable	NGM[b]	AGM[a]			
		Prediabetes	*p*-value	T2DM	*p*-value
Salaried job	154 (46.4)	13 (52.0)		7 (25.0)	
Household income (SDE) (n, %)			0.977		0.065
< 999	87 (26.2)	7 (28.0)		13 (46.4)	
1000–2999	147 (44.3)	11 (44.0)		8 (28.6)	
≥ 3000	98 (29.5)	7 (28.0)		7 (25.0)	
Wealth index (n, %)			0.480		0.003*
Poorest	58 (17.5)	6 (24.0)		11 (39.3)	
Second	72 (21.7)	2 (8.0)		5 (17.9)	
Middle	64 (19.3)	6 (24.0)		0 (0.0)	
Fourth	64 (19.3)	5 (20.0)		5 (17.9)	
Richest	74 (22.3)	6 (24.0)		7 (25.0)	

[a]AGM, abnormal glucose metabolism; [b]NGM, normal glucose metabolism; [c]contains 3 (10.7%) previously diagnosed cases; [d]includes single, widow, staying with partner;
[e]includes married, staying with partner; n, number; *chi-square statistic significant at $p < 0.05$

estimate and the current study could be due to differences in the diagnostic criteria used. As pointed out by the authors, glycated hemoglobin may have underestimated the prevalence of T2DM since the subjects were HIV-infected. Similarly, the possible differences in the STEPS survey's estimate and the current study may have been due to the use of higher cut-off points in the current study. In the STEPS survey, T2DM was defined as a blood glucose reading of ≥6.1 mmol/L compared to a blood glucose reading of ≥7.0 mmol/L used in the current study.

This study's reported prevalence rate for T2DM was much higher than those reported in many studies in the Southern African sub-continent [20–22], but lower than those found in some studies in South Africa by Werfalli et al. [23] and Oni et al. [24]. The difference between the T2DM prevalence rate in the current study and estimate by Werfalli et al. could have been due differences in participants' age groups (older adults ≥50 years) and the use of self-report diagnosis instead of screening and diagnosis. It is known that the prevalence of T2DM peaks at around age 50 years [25], therefore, a higher prevalence estimate in Werfalli et al.'s study was expected. Similarly, the study by Oni et al. [24] used different diagnostic criteria (glycated haemoglobin (HbA1c)) compared to the current study which used fasting blood glucose (FBG). Oni et al. reported a lower prevalence rate for T2DM (4.1%) when diagnosed with FBG [24].

The high prevalence of newly diagnosed T2DM (89.3%) among patients found to have T2DM in the current study was consistent with the previous report in Swaziland [3] and evidence from South Africa [26], but higher than those (25–56.8%) reported in SSA [20, 21, 24, 27]. The implication of the high rate of newly diagnosed T2DM among T2DM cases was that without this study, these diabetic cases may not have sought health care for their condition until complications had set in. Moreover, the higher prevalence of newly detected cases of T2DM suggested that current screening practices in this hospital and SSA were ineffective [28]. Therefore, screening of high-risk individuals should be incorporated in the clinical practice at outpatient departments in this hospital.

The prevalence of pre-diabetes estimated in the current study (6.5%) was higher than the rates reported elsewhere in SSA: Kenya [29]; Malawi [30]; Uganda [31]; and South Africa [32]. Pre-diabetes is an intermediate metabolic state between normal glucose metabolism and T2DM, which are higher than normal glucose level and could progress to T2DM [13]. An IDF publication [33] estimated the prevalence of IGT to vary between 2.2 and 16% in Africa and asserted that the burden of T2DM would continue to escalate if nothing was done to curb the epidemy of IGT. It is therefore vital that these-at-risk groups be targeted for lifestyle changes to prevent full-blown T2DM in these individuals.

As expected, pre-diabetes was significantly associated with advancing age, consistent with previous reports in SSA [34–36]. However, a study in rural Uganda did not find an association between BMI and AGM [37], probably due to the younger age groups included (≥13 years) in their sample and the use of random blood glucose instead of fasting blood glucose results. In the current study, the proportion of obese women was significantly higher than the proportion of obese men. A possible explanation for this finding is that women are known to have higher rates of abdominal fat and insulin resistance than men [38]. These biological risk factors are

associated with a higher risk of T2DM [38]. Furthermore, hypertension was significantly associated with pre-diabetes in the current study in agreement with report elsewhere in SSA [35]. A study in Nigeria by Okpechi et al. [39] showed a high prevalence of hypertension in SSA. Many complex factors have been identified as possible reasons for this, including high salt intake, low physical activity, and genetic vulnerability to high blood pressure [39]. Therefore, these high-risk groups should be targeted for lifestyle education, particularly the need for self-monitoring of body weight and periodic checks on fasting blood glucose. The outpatient departments in this setting need to include these clinical checks and lifestyle education in their routine services.

Type 2 diabetes mellitus was associated with advancing age, consistent with previous reports in SSA [34–36]. Surprisingly, this association did not reach the level of statistical significance, probably due to the small number of T2DM cases. Also, the highest glucose concentration was found in subjects over the age of 45 years (45–64 years) comparable to findings from previous reports from South Africa [40] and Cameroon [41]. The significant gender differences observed in the prevalence rates for T2DM in the current study were consistent with findings in sub-Saharan Africa [42–44]. The wealth index was associated with elevated glucose levels in the current study, consistent with previous reports from Malawi [20] and elsewhere in Europe [45]. Most of the subjects with T2DM (39.3%) were significantly poorer compared with subjects with normal glucose metabolism (17.5%). The inequality observed in the gender distribution of the socio-economic variables in the current study was concerning. A significant proportion of diabetic women compared to diabetic men were poorly educated, unemployed and poor. This may possibly have been due to the gender division of labour in Swaziland. A greater proportion of women in Swaziland were vulnerable and excluded from strategic gender roles [19]. Therefore, measures to improve the socio-economic status of women are warranted in Swaziland to curb the growing diabetes in the kingdom.

Strengths and limitations of the study

The major strength of this study was the fact that the diagnosis of T2DM was based on the analysis of the blood samples. This prevented recall bias associated with a self-reported diabetes status. To researchers' knowledge, this study provided the first age-adjusted estimates of the prevalence of diabetes and pre-diabetes in Swaziland. These data provided a baseline upon which cost-effective and culturally acceptable intervention could be devised to address the growing burden of diabetes in Swaziland.

The major limitation of the present study was that the prevalence rates for abnormal glucose metabolism (pre-diabetes and T2DM) were determined based on the assumption that the participants who presented themselves had fasted for 8 h before screening and diagnosis. The use of glycated hemoglobin (HbA1c) would have improved the reliability of the data since the need for fasting would have been eliminated. Furthermore, the patients who presented themselves at the OPD in the hospital may not have been representative of the larger Swazi population. Therefore, extrapolating these findings to the general Swazi population should be done with caution. Lastly, some of the known risk factors of diabetes (such as genetic predisposition) were not investigated in this study.

The study's findings highlighted the need for the Swazi government to adopt policies to reduce the burden of T2DM in the Kingdom through healthcare services, with a special focus on women. This is important if the kingdom hopes to achieve the ambitious Sustainable Development [46] Goal number three (target 3.4) of reducing the NCD pre-mature mortality by one-third by 2030.

Conclusions

In conclusion, this study reported a higher prevalence of both T2DM, and pre-diabetes than previously reported among patients in this hospital. This study also found an increasing prevalence of T2DM and pre-diabetes with advancing age. Unfortunately, most patients with T2DM in this study were newly diagnosed for the disease. This indicated that the screening practices in this hospital were not effective. Therefore, it is suggested that a routine blood glucose test be incorporated into healthcare services at outpatient departments in this hospital. As demonstrated in previous studies in Swaziland and elsewhere, the findings affirmed the hypothesis that modifiable risk factors play important role in the rising prevalence of T2DM in developing countries. Hence, cost-effective and culturally acceptable health education measures are needed to promote a healthy lifestyle among patients in this setting to halt the rising burden of T2DM in Swaziland.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12889-020-08489-9.

Additional file 1: Supplementary file 1. Crude and age-adjusted prevalence rates of pre-diabetes and type 2 diabetes mellitus.

Abbreviations

AGM: Abnormal Glucose Metabolism; IFG: Impaired Fasting Glucose; IGT: Impaired Glucose Tolerance; SSA: Sub-Saharan Africa; T2DM: Type 2 Diabetes Mellitus

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Authors' contributions
MG reviewed the literature, made substantial contributions to the conception, design, and drafting of the manuscript. BT participated in the design of the study and/or the drafting of the manuscript. Both authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analysed during this study are included in this published article [and its supplementary information files].

Ethics approval and consent to participate
Ethical approval was obtained from the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal, Durban, South Africa (BE 385/18) and the Research Ethics Committee of the Swaziland Ministry of Health. Relevant permission was obtained from the hospital administration, while all participants gave informed written consent to participate in the study. Confidentiality was maintained in accordance with standard medical practice.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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CHAPTER THREE

MODIFIABLE RISK FACTORS ASSOCIATED WITH NON-COMMUNICABLE DISEASES AMONG ADULT OUTPATIENTS IN MANZINI, SWAZILAND: A CROSS-SECTIONAL STUDY

In the previous chapter, the prevalence of T2DM and pre-diabetes was estimated. Having established that these prevalence rates are high and identified modifiable risk factors for T2DM, the next step is to identify how modifiable risk factors contribute to the prevalence of these chronic NCDs. This chapter's work extends the findings from the previous chapter by determining the dietary and lifestyle factors associated with T2DM, pre-diabetes, and hypertension.

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Modifiable risk factors associated with non-communicable diseases among adult outpatients in Manzini, Swaziland: a cross-sectional study

Mojeed Akorede Gbadamosi* and Boikhutso Tlou

Abstract

Background: Four major non-communicable diseases (NCD), including T2DM, contributed to nearly three-quarters of all deaths worldwide in 2017. Dietary and lifestyle actors associated with NCDs are potentially modifiable. Therefore, this study was conducted to determine the dietary and lifestyle factors associated with T2DM, pre-diabetes, and hypertension among adult outpatients in Manzini, Swaziland.

Methods: A random sample of 385 subjects aged 18 years and above was selected. The data regarding demographics, socio-economic status, lifestyle behaviour, diet, and physical activities were collected. Additionally, participants' anthropometric measurements and vital signs were taken. A biochemical examination was done for fasting plasma glucose, and a 2-h oral glucose tolerance test, where necessary. The Statistical Package for Social Sciences (SPSS) version 26 was used for this data analysis, and the level of statistical significance was set at $p < 0.05$.

Results: A total of 385 (197 men and 188 women) subjects aged 18 years and older participated in the study. The overall prevalence of hypertension was 48.3%, while the prevalence of hypertension stage 1 and 2 were 29.4 and 19%, respectively. Smoking, SES and consumption of sweet drinks, salty processed foods, fruits, and vegetables were significantly associated with T2DM. However, in the multivariate analysis, only consumption of vegetables ($p < 0.0001$), fruits ($p = 0.014$), sweet drinks ($p = 0.042$), and salty processed foods ($p = 0.005$) remained significantly associated with T2DM. Smoking ($p = 0.002$) and consumption of fruits ($p < 0.0001$), vegetables ($p < 0.0001$), and sweet drinks ($p = 0.043$) were independently associated with pre-diabetes, while the consumption of vegetables ($p = 0.002$) and salty processed foods ($p = 0.003$) were the factors independently associated with hypertension.

Conclusions: The factors associated with T2DM, pre-diabetes, and hypertension are potentially modifiable. Therefore, interventions which target lifestyle changes at primary health care and population levels are warranted to address the growing burden of these chronic conditions in Swaziland.

Keywords: Diabetes, Hypertension, Non-communicable diseases, Out-patients, Pre-diabetes, Risk factors, Swaziland, T2DM

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Background

The burden of non-communicable diseases (NCDs) in sub-Saharan Africa (SSA) is rising and is thus expected to surpass the morbidity and mortality burden due to communicable diseases (CDs) by 2030 [1]. In 2016, NCDs were the leading cause of death globally, responsible for 71% of the 57 million deaths worldwide [2]. The four leading NCDs: cardiovascular diseases (CVDs), type 2 diabetes mellitus (T2DM), chronic respiratory diseases, and cancer, jointly contributed to 78.8% of all NCD deaths worldwide [2]. Disturbingly, in 2016, 78% of all NCD deaths occurred in low- and middle-income countries (LMICs) [2].

The number of adults affected with T2DM worldwide increased from 108 million in 2008 to nearly half a billion in 2014 [3]. In 2019, about 463 million adults were affected by T2DM globally, many of the cases were reported in LMICs [4]. The highest proportional increase in the prevalence of T2DM is anticipated to occur in SSA. Numerically, about 47 million adults are estimated to have T2DM by 2045, representing a 143% increase from the 2019 figures [4]. Pre-diabetes is a significant risk factor for the development of T2DM [4–6], which is defined as an intermediate state between normal glucose homeostasis and T2DM, with a higher than normal glucose level, but below the diagnostic threshold for T2DM [6]. According to the International Diabetes Federation (IDF) [4], pre-diabetes occurs either due to impaired fasting glucose (IFG) or impaired glucose tolerance (IGT) or both. The prevalence of pre-diabetes is increasing worldwide, and it is expected that 470 million adults will develop pre-diabetes by 2030 [6]. In SSA, the prevalence of pre-diabetes will increase dramatically by 2045, rising from 45.3 million adults in 2019 to 110.2 million adults [4]. Disturbingly, Tabak et al. [6] posit that 5–10% of pre-diabetic cases per annum will progress to overt T2DM. Therefore, it is essential to identify people with pre-diabetes for timely intervention to avert its progression to T2DM.

Hypertension, also known as raised blood pressure (BP), is a significant risk factor for many diseases, such as coronary heart disease, chronic kidney disease, and strokes [7]. Globally, 25% of men and 20% of women, or one in five adults 18 years and above, had a raised BP in 2015 [8]. Although regional differences exist in the prevalence of hypertension, the highest prevalence (27%) recorded in 2016 was in Africa [8]. From 1985 to 2015, the global prevalence of raised BP has nearly doubled, with LMICs being the most affected [8]. Hypertension and T2DM are two of the metabolic risk factors, besides overweight/obesity and hyperlipidaemia, which contributes to the growing burden of NCDs in SSA [2]. Both conditions exert a substantial financial burden on individuals, families, communities, and the health system of any country [2]. Therefore, it is important to identify individuals with raised BP for lifestyle intervention, together with counselling for those individuals at risk.

According to WHO [1], NCDs are caused by four key risk factors: tobacco use, harmful use of alcohol, unhealthy diet, and physical inactivity. Alternatively, the NCD risk factors have been categorised as modifiable behavioural, non-modifiable factors (mainly age, gender, family history, ethnicity) and metabolic risk factors [2]. Timely intervention, through lifestyle modification, will avert or delay the progression of the disease in at-risk individuals or those affected by pre-diabetes, T2DM or elevated BP [1]. The benefits of lifestyle modification, such as smoking cessation, a healthy diet, moderate physical activity, and moderate alcohol use for the prevention and control of T2DM and hypertension have been well documented [6, 9–11]. Kontis et al. [11] reported, in their modelling study, that mortality due to CVDs and T2DM can be reduced by lowering the prevalence of six risk factors, which includes smoking and the harmful use of alcohol, with LMICs expected to reap most of the benefits. Studies have demonstrated the effectiveness of lifestyle modification in delaying the onset of pre-diabetes or its progression to T2DM [12, 13], as well as the control of T2DM [10], mainly through healthy diets [14].

In Swaziland, NCDs accounted for 37% of all deaths in 2016, representing a 54.2% increase from the 2014 figures [2]. According to WHO, the Swazi's suffer more from CVD, Type-2 diabetes, cancer, and Chronic Obstructive Respiratory Diseases (COPDs) [2]. In Swaziland, hypertension was ranked first among the ten leading cases reported at outpatient departments (OPD) during 2016, while T2DM was the third leading case reported at OPDs [15]. Of note is that T2DM was the leading contributor to in-patient admissions, followed by hypertension, responsible for 15, and 11% of in-patient admissions respectively in 2016. Similarly, T2DM was the second leading cause of NCD deaths in Swaziland in 2016. Disturbingly, the mortality attributable to T2DM has been increasing steadily since 2014, rising from 47 deaths in 2014 to 109 deaths in 2016 [15].

There is a paucity of current epidemiological data on NCD risk factors, especially T2DM, pre-diabetes, and hypertension in Swaziland to be able to identify high-risk individuals for timely intervention. There is a need for epidemiological data to understand the dietary and lifestyle factors predisposing people to these chronic diseases. Therefore, this study is aimed at identifying the diet and lifestyle risk factors associated with T2DM, pre-diabetes, and hypertension among patients attending the OPD in a Manzini tertiary hospital.

Methods

A detailed description of the examination procedures and the participants' characteristics has been provided

elsewhere [16]. Briefly, 385 patients attending the OPD at Raleigh Fitkin Memorial Hospital in Manzini, Swaziland were included in the study. Fasting blood glucose and oral glucose tolerance (OGT) testing were done using a glucometer (On Call® EZ II, ACON Laboratory, Inc., USA). Type 2 diabetes mellitus and pre-diabetes (impaired fasting glucose and impaired glucose tolerance) were defined according to WHO criteria [17]. The blood pressure measurement and definitions were made according to the American College of Cardiology/American Heart Association (ACC/AHA) guidelines [18].

Anthropometric measurements were taken and defined according to standardised criteria [19, 20]. Socio-demographic, dietary, and lifestyle variables were collected from all participants using a questionnaire. Socio-demographic variables collected included age, divided into six groups (18–27, 28–37, 38–47, 48–57, 58–67, ≥68); gender; occupation, considered as a student/unemployed, self-employed and a salaried job; and education, categorised as no formal, primary or secondary or higher education. Principal component analysis (PCA) was used to generate wealth quintiles from the asset variables. The first principal component was used to represent the wealth index, categorised into three: lower, middle, and highest SES levels. Insufficient physical activity was defined as self-reports of less than 150 min of moderate-intensity activity or less than 75 min of vigorous-intensity work, recreation, or travel per week [21].

Smoking was defined as self-reported formal or current tobacco use, including smokeless tobacco products, snuff, and pipes. Harmful alcohol use was defined as consumption of five or more standard drinks per day for men and four or more standard drinks per day for women [22]. Alcohol use included beer, wine, spirits, and a local brew (such as *buganu*). Consumption of sweet drinks was defined as self-reported consumption of sweet coffee, sweet tea, soda, and other sweet beverages per week. Rare consumption of sweet drinks was defined as the consumption of fewer than three drinks per week. Moderate sweet drink consumption was defined as a consumption of 4 to 10 drinks per week, while consumption of more than 11 sweet drinks per week was considered excessive. Salt use included the use of raw salt and salty stock cubes or powders. Consumption of salty processed foods included consumption of salty snacks, canned salty foods, salty foods prepared at fast-food restaurants. Adequate consumption of fruits and vegetables was considered as the consumption of three or more servings daily. One serving of vegetables was taken as 1 cup of raw green leafy vegetables or, half a cup of other raw or cooked vegetables (tomatoes, carrots, onions) or half a cup of vegetable juice. One serving of fruit was taken as one medium-sized apple, banana, orange, or half a cup of cooked or canned fruit or half a cup of juice from fruit (but not artificially flavoured).

Statistical analysis

All analyses were conducted using Statistical Package for Social Sciences (SPSS) version 26 (SPSS Inc., Chicago, USA). Descriptive statistics (percentages) were used to describe the crude (unadjusted) prevalence rates for T2DM, pre-diabetes and hypertension. A Chi-square test was applied to examine the association between the independent socio-demographic, behavioural variables and pre-diabetes, T2DM, and hypertension. A binary logistic regression with a backward conditional method was performed to assess variables that could predict the development of T2DM, pre-diabetes, and hypertension. A two-sided p-value < 0.05 was considered statistically significant.

Results

General characteristics of the study population

The characteristics of the study participants, consisting of 197 (51.2%) men and 188 (48.8%) women respectively, according to diabetes status and gender, are summarised in Table 1. The prevalence of T2DM was higher among women compared to men, but pre-diabetes was more common among men than women. Both men and women with T2DM had a similar age (46 vs 45 years). Contrarily, men with pre-diabetes were younger than women with pre-diabetes (41 vs 51 years). Amongst men and women, the prevalence of abnormal glucose metabolism differed significantly with their smoking status.

Table 2 shows the characteristics of the study participants according to blood pressure (BP) status and gender. The overall prevalence of hypertension was 48.3% (see Supplementary file 1); the prevalence of stage 1 and stage 2 was 29.4 and 19.0%, respectively, with 14.8% of all participants identified as having elevated BP (prehypertension). The prevalence of hypertension (24.9%) was higher among men than women (19.2%), with hypertensive men being significantly older than hypertensive women (45 vs 41 years). More men had an elevated BP than women (8.6% vs 6.2%), but women with an elevated BP had a similar age compared with male counterparts (34 vs 33 years). In both genders, raised BP varied significantly by age, BMI, and waist circumference.

A gender differential was observed in the lifestyle, dietary habits, physical activity, and anthropometric variables (See Supplementary File 1). Significantly more women were physically less active than men (69.1% vs 47.2%, $p < 0.0001$). A higher proportion of women consumed salty processed foods (35.6% vs 32.0%), more regularly (22.4% vs 19.3%) compared to men. A similar pattern was observed in the distribution of excessive salt use (33.1% vs 24.4%). Also, fewer women than men consumed at least three servings of vegetables per day (74.5% vs 78.5%). More men were reportedly current tobacco users than women (18.8% vs

Table 1 Characteristics of the study population according to glucose metabolism status and gender

	Men (*n* = 197)				Women (*n* = 188)			
	Normal n (%)	Pre-diabetes n (%)	T2DM [a] n (%)	*p*-value	Normal n (%)	Pre-diabetes n (%)	T2DM n(%)	*p*-value
n (%)	177 (46.0)	14 (3.6)	6 (1.6)		155 (40.3)	11 (2.8)	22 (5.7)	
Mean age (years) n (SD)[b]	35.76 (15.43)	41.36 (15.92)	46.00 (18.52)	0.138	37.53(14.51)	51.18 (18.26)	44.50 (18.48)	0.004**
Age group (years)				0.247				0.062
18–27	63 (92.6)	4 (5.9)	1 (1.5)		46 (86.8)	2 (3.8)	5 (9.4)	
28–37	55 (93.2)	3 (5.1)	1 (1.7)		39 (92.9)	0 (0.0)	3 (7.1)	
38–47	24 (88.9)	1 (3.7)	2 (7.4)		37 (84.1)	1 (2.3)	6 (13.6)	
48–57	11 (78.6)	3 (21.4)	0 (0.0)		15 (68.2)	4 (18.2)	3 (13.6)	
58–67	12 (75.0)	3 (18.8)	1 (6.2)		12 (70.6)	2 (11.8)	3 (17.6)	
≥ 68	12 (92.3)	0 (0.0)	1 (7.7)		6 (60.0)	2 (20.0)	2 (20.0)	
Hypertension status				0.334				0.248
Normal	62 (91.2)	3 (4.4)	3 (4.4)		65 (87.5)	1 (1.4)	8 (10.8)	
Elevated (Pre-hypertension)	30 (90.9)	2 (6.1)	1 (3.0)		21 (87.5)	1 (4.2)	2 (8.3)	
Stage 1	59 (93.7)	3 (4.8)	1 (1.6)		38 (76.0)	6 (12.0)	6 (12.0)	
Stage 2	26 (78.8)	6 (18.2)	1 (3.0)		31 (77.5)	3 (7.5)	6 (15.0)	
Body mass index				0.171				0.398
Underweight	18 (94.7)	1 (5.3)	0 (0.0)		2 (100.0)	0 (0.0)	0 (0.0)	
Normal	117 (92.1)	5 (4.0)	4 (3.2)		53 (88.3)	1 (1.7)	6 (10.0)	
Overweight	31 (79.5)	6 (15.4)	2 (5.1)		49 (77.8)	4 (6.3)	10 (15.9)	
Obese	11 (84.6)	2 (15.4)	0 (0.0)		51 (81.0)	6 (9.5)	6 (9.5)	
Waist circumference				0.121				0.224
Normal	156 (90.7)	10 (5.8)	6 (3.5)		43 (89.6)	1 (2.1)	4 (8.3)	
≥ 94 cm (men)/≥80 cm (women)	21 (84.0)	4 (16.0)	0 (0.0)		112 (80.0)	10 (7.1)	18 (12.9)	
Waist-to-hip ratio				0.069				0.832
Normal	164 (91.6)	11 (6.1)	4 (2.2)		51 (83.6)	4 (6.6)	6 (9.8)	
≥ 0.95 (men)/≥0.80 (women)	13 (72.2)	3 (16.7)	2 (11.1)		104 (81.9)	7 (5.5)	16 (12.6)	
Education				0.547				0.220
No formal education	9 (81.8)	2 (18.2)	0 (0.0)		10 (66.7)	2 (13.3)	3 (20.0)	
Primary	39 (86.7)	4 (8.9)	2 (4.4)		39 (76.8)	3 (5.9)	9 (17.6)	
Secondary or higher	129 (91.5)	8 (5.7)	4 (2.8)		106 (86.9)	6 (4.9)	10 (8.2)	
Socio-economic status				0.248				0.487
Lower	55 (87.3)	5 (7.9)	3 (4.8)		50 (78.1)	3 (4.7)	11 (17.2)	
Middle	68 (95.8)	2 (2.8)	1 (1.4)		51 (86.4)	4 (6.8)	4 (6.8)	
Higher	54 (85.7)	7 (11.1)	2 (3.2)		54 (83.1)	4 (6.2)	7 (10.8)	
Physical activity				0.937				0.866
No	84 (90.3)	6 (6.5)	3 (3.2)		107 (82.3)	7 (5.4)	16 (12.3)	
Yes	93 (89.4)	8 (7.7)	3 (2.9)		48 (82.8)	4 (6.9)	6 (10.3)	
Smoking history				0.022*				0.001*
No	91 (95.8)	3 (3.2)	1 (1.1)		89 (89.0)	0 (0.0)	11 (11.0)	
Yes	86 (84.3)	11 (10.8)	5 (4.9)		66 (75.0)	11 (12.5)	11 (12.5)	
Alcohol use				0.740				0.570
No	68 (91.6)	4 (5.4)	2 (2.7)		60 (85.7)	4 (5.7)	6 (8.6)	
Yes	109 (88.6)	10 (8.1)	4 (3.3)		95 (80.5)	7 (5.9)	16 (13.6)	

[a] T2DM, Type 2 diabetes mellitus.
[b] SD, Standard deviation.
**$p < 0.05$ according to univariate ANOVA
* $p < 0.05$ according to chi square Pearson statistic or Likelihood ratio
n Number

17.6%), while a higher proportion of men consumed more sweet drinks than women (30% vs 26.1%).

Risk factors for pre-diabetes and T2DM

In the binary logistic regression models (with a backward conditional elimination method), the absence of the condition was used as a reference group. The results of the analyses are presented in Table 3. The bivariate analysis comparing the effect of each of the risk factors on the risk of developing pre-diabetes revealed that secondary or higher education, previous or current smoking status, consumption of salty processed foods, consumption of sweet drinks, and vegetable consumption were risk factors significantly associated with pre-diabetes. Possession of secondary or higher education and consumption of fruits and vegetables reduced the risk of pre-diabetes, whereas smoking and consumption of salty processed foods and sweet drinks increased the risk of pre-diabetes.

Participants with a secondary or higher education had a 28.3% reduction in the risk of developing pre-diabetes compared to those without formal education (crude odds ratio (COR) 0.283; 95% CI 0.09, 0.95, $p = 0.04$). This association was observed in the multivariate analysis but was attenuated by the consumption of sweet drinks, smoking, fruits, and vegetable consumption. Similar results were obtained for the association between consumption of salty processed foods and pre-diabetes in the multivariate analysis. No significant association was observed between consumption of salty processed foods and the risk of pre-diabetes. However, participants who consumed salty processed foods moderately or regularly were at a 48% increased risk of pre-diabetes compared to their counterparts who rarely consumed processed foods.

The significant association between the consumption of vegetables and pre-diabetes status remained after adjusting for smoking, consumption of salty processed foods, and consumption of fruits. Interestingly, the value of adjusted odds ratio (AOR) remained the same as the COR value; participants who consumed at least three or more servings of vegetables per day were at a 5% reduced risk of pre-diabetes compared to participants who did not (AOR 0.048; 95% CI 0.02, 0.15; $p < 0.0001$). Also, participants who consumed at least three servings of fruits daily had a 26% reduction in the risk of developing pre-diabetes compared to those who did not. The AOR improved by 5.5% from the crude odds ratio value when sweet drinks, vegetables and smoking were controlled for in the multivariate analysis. Previous and current smoking status is associated with a 790% increased risk of pre-diabetes, with a slight change in the odds ratio (AOR 8.895; 95% CI 2.27, 34.82; $p = 0.002$). Consumption of sweet drinks was not significantly associated with pre-diabetes in the bivariate analysis. Interestingly, it had a significant association with pre-diabetes in the multivariate model after adjusting for smoking, fruits, and vegetable consumption. Consumption of sweet drinks was significantly associated with a 248% increased risk of developing pre-diabetes (AOR 3.479; 95% CI 1.04, 11.65; $p = 0.043$).

In the bivariate analysis, only socio-economic status (SES) was significantly associated with T2DM risk, with participants in the middle SES stratum having a 32% reduction in the risk of developing T2DM compared to those in the lowest SES stratum. However, this association was no longer significant after adjustment was made for sweet drinks, salty processed food, fruit and vegetable consumption in the multivariate analysis. Consumption of fruits and vegetables was protective of T2DM risk, whereas consumption of sweet drinks and salty processed foods was associated with an increased risk of developing T2DM. Participants who consumed at least three servings each of fruits and vegetables daily had a reduced the risk, 12 and 5% respectively, of developing T2DM compared to those who did not. Contrarily, participants who consumed salty processed foods moderately and regularly were at a 600% increased risk of developing T2DM, compared to those who consumed these foods rarely. Similarly, participants who consumed sweet drinks moderately and excessively were at 219% increased risk of T2DM compared to their counterparts who did not.

Risk factors for elevated BP and hypertension

Table 4 shows the risk factors associated with an elevated BP and hypertension in both bivariate and multivariate analyses. The consumption of vegetables and salty processed foods were individually significantly associated with hypertension in the multivariate analysis. Participants who consumed at least three servings of vegetables daily had a 42% reduced risk of developing hypertension, compared to those who did not. On the other hand, the consumption of salty processed foods was associated with a 110% increased risk of hypertension. Moderate and regular alcohol use was associated with a 59% increased risk of developing hypertension compared to non-alcohol use in the bivariate analysis, but this association was not significant in the multivariate analysis.

Surprisingly, none of the risk factors were significantly associated with an elevated BP in both bivariate and multivariate analyses. In the multivariate analysis, however, primary and secondary or higher education were individually associated with lower odds of elevated BP. Participants with primary and secondary or higher educational qualifications had a 28 and 71% lower risk, respectively, of elevated BP compared with participants without a formal education.

Table 2 Gender distribution of study participants and prevalence of raised blood pressure

	Men (n = 197)				Women (n = 188)			
	Normal n (%)	Elevated BP n (%)	HTN n (%)	p-value	Normal n (%)	Elevated BP n (%)	HTN n (%)	p-value
n (%)	68 (17.7)	33 (8.6)	96 (24.9)		74 (19.2)	24 (6.2)	74 (19.2)	
Mean age (years) n (SD)[b]	31.79 (13.08)	32.70 (15.83)	41.07 (16.03)	< 0.0001**	34.12 (12.54)	34.42 (13.14)	44.53 (16.79)	< 0.0001**
Age group (years)				0.006*				0.005*
18–27	32 (47.1)	15 (22.1)	21 (30.9)		27 (50.9)	10 (18.9)	16 (30.2)	
28–37	21 (35.6)	9 (15.3)	29 (49.2)		22 (52.4)	5 (11.9)	15 (35.7)	
38–47	7 (25.9)	4 (14.8)	16 (59.3)		14 (31.8)	5 (11.4)	25 (56.8)	
48–57	3 (21.4)	2 (14.3)	9 (64.3)		7 (31.8)	2 (9.1)	13 (59.1)	
58–67	4 (25.0)	0 (0.0)	12 (75.0)		3 (17.6)	2 (11.8)	12 (70.6)	
≥ 68	1 (7.7)	3 (23.1)	9 (61.2)		1 (10.0)	0 (0.0)	9 (90.0)	
Body mass index				0.010*				0.008*
Underweight	11 (57.9)	1 (5.3)	7 (36.8)		1 (50.0)	0 (0.0)	1 (50.0)	
Normal	46 (36.5)	26 (20.6)	54 (42.9)		35 (58.3)	7 (11.7)	18 (30.0)	
Overweight	10 (25.6)	4 (10.3)	25 (64.1)		22 (34.9)	6 (9.5)	35 (55.6)	
Obese	1 (7.7)	2 (15.4)	10 (76.9)		16 (25.4)	11 (17.5)	36 (57.1)	
Waist circumference				0.016*				0.005*
Normal	65 (37.8)	29 (16.9)	78 (45.3)		28 (58.3)	6 (12.5)	14 (29.2)	
≥ 94 cm (men)/≥80 cm (women)	3 (12.0)	4 (16.0)	18 (72.0)		46 (32.9)	18 (12.9)	76 (54.3)	
Waist-to-hip ratio				0.738				0.810
Normal	63 (35.2)	29 (16.2)	29 (16.2)		22 (36.1)	8 (13.1)	31 (50.8)	
≥ 0.95 (men)/≥0.80 (women)	5 (27.8)	5 (27.8)	4 (22.2)		52 (40.9)	16 (12.6)	59 (46.5)	
Education				0.100				0.112
No formal education	2 (18.2)	3 (27.3)	6 (54.5)		4 (26.7)	1 (6.7)	10 (66.7)	
Primary	21 (46.7)	3 (6.7)	21 (46.7)		17 (33.3)	4 (7.8)	30 (58.8)	
Secondary or higher	45 (31.9)	27 (19.1)	69 (48.9)		53 (43.4)	19 (15.6)	50 (41.0)	
Socio-economic status				0.388				0.289
Lower	25 (39.7)	12 (19.0)	26 (41.3)		25 (39.1)	4 (6.2)	35 (54.7)	
Middle	23 (32.4)	14 (19.7)	34 (47.9)		25 (42.4)	8 (13.6)	26 (44.1)	
Higher	20 (31.7)	7 (11.1)	36 (57.1)		24 (36.9)	12 (18.5)	29 (44.6)	
Physical Activity				0.740				0.582
No	30 (32.3)	15 (16.1)	48 (51.6)		54 (41.5)	15 (11.5)	61 (46.9)	
Yes	38 (36.5)	18 (17.3)	48 (46.2)		20 (34.5)	9 (15.5)	61 (46.9)	
Smoking history				0.996				0.542
No	33 (34.7)	16 (16.8)	46 (48.4)		40 (40.0)	15 (15.0)	45 (45.0)	
Yes	35 (34.3)	17 (16.7)	50 (49.0)		34 (38.6)	9 (10.2)	45 (51.1)	
Alcohol use				0.240				0.395
No	31 (41.9)	11 (14.9)	32 (43.2)		31 (44.3)	10 (14.3)	29 (41.4)	
Yes	37 (30.1)	22 (17.9)	64 (52.0)		43 (36.4)	14 (11.9)	61 (51.7)	

HTN Hypertension; *n* Number; *SD* Standard deviation; *$p < 0.05$ according to Pearson or Likelihood ration chi square; **$p < 0.05$ according to Univariate ANOVA.

Discussion

The present study assessed the modifiable risk factors associated with pre-diabetes, T2DM, and hypertension among adult outpatients in Manzini, Swaziland. Consumption of vegetables was independently associated with a lower risk of T2DM, pre-diabetes, and hypertension. The consumption of sweet drinks was an independent and significant determinant of T2DM and pre-diabetes, while the consumption of salty processed foods was significantly associated with T2DM and hypertension

Table 3 Crude and adjusted odds ratios for risk factors associated with pre-diabetes and T2DM

	Pre-diabetes				T2DM			
	COR	95% CI	AOR	95% CI	COR	95% CI	AOR	95% CI
Education								
No formal education	1				1			
Primary	0.426	0.11–1.61			0.893	0.23–3.52		
Secondary or higher	0.283*	0.09–0.95			0.377	0.10–1.43		
SES								
Lower	1				1			
Middle	0.662	0.22–1.97			0.315*	0.11–0.90		
Higher	1.337	0.52–3.46			0.625	0.26–1.51		
Physical activity [a]								
No	1				1			
Yes	1.250	0.55–2.82			0.642	0.28–1.46		
Smoking history								
No	1		1		1			
Yes	8.684***	2.55–29.58	8.895*	2.27–34.82	1.579	0.73–3.44		
Alcohol use								
No	1				1			
Yes	1.333	0.56–3.18			1.569	0.67–3.67		
Sweet drink consumption								
No	1		1		1		1	
Yes	2.516	0.98–6.46	3.479*	1.08–11.65	1.986	0.85–4.64	3.185*	1.04–4.75
Salty processed food								
No	1				1		1	
Yes	4.048*	1.48–11.04			8.434**	2.50–28.48	7.01*	1.77–5.72
Fruits consumption								
No	1		1		1		1	
Yes	0.206***	0.09–0.48	0.261*	0.09–0.76	0.122***	0.05–0.30	0.120***	0.04–0.38
Vegetables consumption								
No	1		1		1		1	
Yes	0.048***	0.02–0.14	0.048***	0.02–0.15	0.032***	0.01–0.10	0.047***	0.01–0.16

AOR Adjusted odds ratio; 95% *CI* 95% Confidence interval; *COR* Crude odds ratio; *SES* Socio-economic status.
[a] Participants meet the WHO recommended physical activity per week.
*$P < 0.05$, **$P < 0.001$, ***$P < 0.0001$

risk. Smoking was a significant determinant of pre-diabetes. In the univariate models, socio-economic status, education, and alcohol use were significantly associated with T2DM, pre-diabetes, and hypertension. Significant gender differences were observed in the prevalence of T2DM, pre-diabetes, and hypertension.

The protective impact of vegetable consumption on the risk of T2DM, pre-diabetes, and hypertension observed in the present study is expected, and is consistent with reports from Sub-Saharan Africa and elsewhere [23–25]. Studies have shown that the adequate consumption of fruit and vegetables reduces T2DM [23, 24], hypertension and cardiovascular incidences [26] as they are high in fibre and other micronutrients, but low in glycaemic load and energy density [23, 24]. Surprisingly, the inverse relationship observed between the consumption of fruits, and the risk of hypertension did not reach the level of statistical significance — the reason for this warrants further investigation.

The consumption of sweet drinks, which included sweet coffee, sweet tea, soda, and other sweetened beverages, was independently significantly associated with T2DM and pre-diabetes in the present study, consistent with previous reports elsewhere [27, 28]. In a prospective study of more than 50,000 women, Schulze et al. [29] found an 83% increased risk of developing T2DM for

Table 4 Crude and adjusted odds ratio of factors associated with elevated BP and hypertension

	Prehypertension				Hypertension			
	COR	95% CI	AOR	95% CI	COR	95% CI	AOR	95% CI
Education								
No formal education	1		1		1			
Primary	0.276	0.06–1.24	0.284	0.06–1.27	0.503	0.18–1.41		
Secondary or higher	0.704	0.19–2.62	0.711	0.19–2.64	0.455	0.17–1.21		
SES								
Lower	1				1			
Middle	1.432	0.67–3.05			1.025	0.60–1.75		
Higher	1.349	0.62–2.94			1.211	0.71–2.07		
Physical activity [a]								
No	1				1			
Yes	1.303	0.70–2.42			1.023	0.65–1.60		
Smoking history								
No	1				1			
Yes	0.887	0.48–1.64			1.104	0.71–1.71		
Alcohol use								
No	1				1			
Yes	1.329	0.71–2.50			1.588*	1.01–2.49		
Salt use								
No	1				1			
Yes	0.993	0.54–1.84			1.624*	1.04–2.54		
Salty processed food								
No	1				1		1	
Yes	0.672	0.36–1.26			2.248***	1.44–3.52	2.100*	1.32–3.34
Fruits consumption								
No	1				1			
Yes	1.040	0.53–2.06			0.688	0.43–1.10		
Vegetables consumption								
No	1				1		1	
Yes	0.941	0.40–2.20			0.368***	0.21–0.64	0.422*	0.24–0.75

AOR Adjusted odds ratio; 95% *CI*, 95% Confidence interval; *COR* Crude odds ratio; *SES* Socio-economic status.
[a] Participants meet the WHO recommended physical activity per week.
*$P < 0.05$, **$P < 0.001$, ***$P < 0.0001$
Backward conditional.

those who consumed ≥1 sweet drink per day compared with those who consumed < 1 sweet drink per month. Unlike the present study and that of Schulze et al. [29], a study by Malik et al. [30] did not observe a significant association between the consumption of sweet drinks and the risk of T2DM. It is suspected that the age differential may have played a role since the majority of the consumers in Malik et al.'s study [30] were young adults. More importantly, the fructose component of sugar in sweet drinks is considered a singularly harmful macronutrient and has been suggested to lead to obesity, hyperlipidemia and insulin resistance, key risk factors for T2DM and CVDs [31].

In the present study the consumption of salty processed foods was a significant determinant of T2DM, pre-diabetes, and hypertension. Like the present study, evidence elsewhere has shown a positive relationship between the consumption of salty processed food and T2DM [32] and hypertension [33]. In the present study, individuals who consumed salty processed foods moderately or regularly were seven times more likely to develop T2DM or pre-diabetes and twice as likely to develop hypertension, compared to those consumers who did so rarely. A possible explanation for this is that the consumption of processed food, high in non-water-soluble fats, contributed to the weight gain observed

among the participants (reflected in the obesity indices). It is well known that obesity is the most important risk factor for T2DM, pre-diabetes and hypertension [2]. The influence of the consumption of salty processed foods on the NCD risk is a scarcely investigated subject in SSA, therefore more studies are needed to understand the mechanisms linking the consumption of salty processed foods to cardio metabolic diseases.

In the present study smoking was an independent determinant of pre-diabetes, consistent with previous reports from SSA and elsewhere [34, 35]. Individuals in the present study with a previous or current smoking history were eight times more likely to develop pre-diabetes, compared to non-smokers. Studies have reported a positive association between smoking and insulin resistance [36, 37]. The nicotine present in cigarettes induces a sympathetic discharge and raises the levels of antagonistic hormones, which reduces the insulin action. Thus, smoking elevates glucose levels in the body through reduced insulin production and reduced insulin action [37]. Surprisingly the association between smoking and a T2DM risk was not statistically significant in the multivariate analysis. Nevertheless, a smoking cessation intervention is warranted in this population to prevent the progression of T2DM in patients with elevated blood glucose levels.

Household wealth and education were the socioeconomic variables independently associated with T2DM and pre-diabetes, respectively. Respondents from a lower SES household were significantly at risk of T2DM, whereas a mid-level SES was significantly associated with a reduced T2DM risk, consistent with findings elsewhere [38, 39]. However, this finding is contrary to the positive association found among outpatients in Ghana [25]. Recent epidemiological studies in SSA have observed an increased risk of T2DM among individuals from high SES households [40–42]. Prospective studies are needed in SSA to understand the influence of SES on the risk of T2DM, pre-diabetes and hypertension are SSA. In a Kenyan study by Mohammed et al., a primary education was inversely associated with pre-diabetes [43]. In the present study, participants with a secondary or higher education were at a 31.5% reduced risk of developing pre-diabetes. Mohammed et al. found a lower risk of developing pre-diabetes among participants with a primary education in Kenya [43]. Studies conducted in Europe have shown the beneficial influence of a formal education on the risk of diabetes [44, 45]. This finding shows the importance of education in reversing pre-diabetes to prevent its progression into full T2DM.

Moderate or excessive consumption of alcohol was significantly associated with the risk of hypertension in the present study. The Stepwise approach to surveillance (STEPS) survey [46] in Swaziland identified alcohol as a significant risk factor for NCDs, including hypertension. Like the present study, Peer et al. [47] found an increased risk of hypertension among black Southern Africans with excessive alcohol use. Excessive consumption of alcohol is a known risk factor for hypertension, while the moderate use of alcohol has a protective effect on hypertension [48]. There is a need to address the harmful use of alcohol in this setting.

Physical inactivity is an independent predictor of T2DM, pre-diabetes and hypertension [49]. Surprisingly, physical inactivity was not significantly associated with T2DM, pre-diabetes, and raised BP in this study. This finding is consistent with findings from Nigeria [50] but differs from a report which found physical inactivity is associated with an increased risk of HTN [51]. Nevertheless, the promotion of recommendations by the WHO on physical activity for health should be sustained.

The prevalence rate (6.5%) estimated for pre-diabetes (IFG/IGT) in the present study is lower than 9.8%, as previously reported in Swaziland in 2015 [46], possibly due to the higher cut-off used in the present study. Tabak et al. [6] indicated that 5–10% of individuals with pre-diabetes might progress to the T2DM stage, and are at risk of macrovascular complications, including CVD [52]. Nevertheless, evidence suggests that the beneficial impact of lifestyle modification allows many individuals with pre-diabetes to either prevent or delay the onset of T2DM [6, 13–15]. Therefore, individuals with pre-diabetes should be targeted for lifestyle intervention strategies to prevent escalating the T2DM burden in Swaziland.

The present study affirms the sex differences reported previously in SSA concerning the distribution of pre-diabetes, T2DM, and hypertension [42, 50]. The differences found in the sex distribution of chronic diseases in the present study may have been due to the gender differences observed in the behavioural variables between men and women. More women tended to be physically inactive, overweight and obese compared to their male counterparts. Therefore, gender must be considered when devising a lifestyle intervention to prevent and control these diseases. The high burden of T2DM, pre-diabetes, elevated BP and hypertension observed in the present study imply a potential rise in complications due to these chronic diseases, since many of the participants were unaware of their condition before participating in the present study. It is known that individuals with hyperglycaemia and hypertension are at higher risk of cardiovascular diseases such as stroke, IHD and chronic kidney disease [52]. Presently, cardiovascular diseases are among the leading causes of death in Swaziland [2, 15]. Therefore, the burden of CVDs could escalate unless the rising burden of its risk factors, like T2DM, pre-diabetes, and hypertension are controlled. Robust public health lifestyle interventions targeting individuals at risk of pre-diabetes, T2DM and

hypertension are warranted. Such interventions should address the harmful use of alcohol and excessive consumption of sweetened beverages and of salty processed foods, including excessive raw salt use. Moreover, public health education and health promotion are needed to emphasise the beneficial influence of fruit and vegetable consumption, moderate physical activities, and the cessation of smoking.

Study strengths and limitations

The cross-sectional nature of this study was a major limitation. Causal inference between exposure and disease outcomes is precluded. Population-based prospective studies on the influence of modifiable risk factors on the burden of NCDs is therefore warranted in Swaziland. Similarly, the use of the self-reported history on the use of tobacco and alcohol, dietary habits, and physical activity may have subjected the findings to recall bias. This potential bias may partly explain the lack of significant associations observed between physical activity and the NCDs investigated.

Despite the above limitations, this study has highlighted the rising burden of diabetes and hypertension in this public health facility in Swaziland. These findings may assist the hospital management to provide better care for the patients. It may also serve as a useful tool for the Ministry of Health in the planning of intervention programmes to control these NCDs in Swaziland. This study examined the influence of lifestyle, diets, and socio-economic status on the risk of T2DM, pre-diabetes, and hypertension. To the researcher's knowledge, no study has examined the impact of modifiable risk factors on chronic diseases in this health facility or in Swaziland.

This study highlights the need for a multi-faceted and multi-sectoral approach to lifestyle modifications to arrest the growing burden of chronic diseases in Swaziland. Public health policymakers, programme managers, and health care practitioners in Swaziland need to promote the benefits of proper nutrition and healthy lifestyles. Health policymakers need to develop strategies to promote a healthy lifestyle among the general population. The government needs to introduce policies to regulate the negative influence of transnational food companies and limit the harmful use of alcohol. Also, the government needs to demonstrate its commitment to tobacco control, notably banning tobacco advertisements.

Conclusions and recommendations

In conclusion, the consumption of fruits, vegetables, sweet drinks, and salty processed foods were the independent risk factors associated with T2DM and pre-diabetes (except for processed foods). Consumption of vegetables was protective against the risk of hypertension, whereas smoking was associated with increased odds of hypertension. The prevalence of hypertension was higher than in previous reports, and the high prevalence of elevated BP and pre-diabetes require urgent lifestyle intervention. Therefore, health planners and policymakers in Swaziland and SSA must implement lifestyle modification interventions, while the activities of the transnational companies and tobacco advertisers should be adequately regulated.

Further longitudinal studies are urgently needed to examine the impact of modifiable risk factors on the risk of NCDs, to address the growing burden of NCDs in Swaziland.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12889-020-08816-0.

Additional file1: Supplementary file 1. Gender distribution of hypertension, lifestyle and anthropometric variables

Abbreviations

BP: Blood pressure; NCD: Non-communicable diseases; SSA: Sub-Saharan Africa; T2DM : Type 2 diabetes mellitus; SES: Socio-economic status

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Authors' contributions

MG reviewed the literature, made substantial contributions to the conception, design, and drafting of the manuscript. BT participated in the design of the study and/or the drafting of the manuscript. Both authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information file].

Ethics approval and consent to participate

Ethical approval was obtained from the Biomedical Research Ethics Committee (BREC).
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Ethics Committee of the Swaziland Ministry of Health. Relevant permission was obtained from the hospital administration, while all participants gave informed written consent to participate in the study. Confidentiality was maintained in accordance with standard medical practice.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Publisher's Note

CHAPTER FOUR

OVERWEIGHT, OBESITY AND ASSOCIATED FACTORS, AND A COMPARATIVE ANALYSIS OF THE ANTHROPOMETRIC INDICES OF OBESITY AS PREDICTORS OF T2DM/PREDIABETES AND HYPERTENSION IN SWAZI ADULTS

Obesity and overweight are some of the significant determinants of cardio-metabolic and other chronic diseases, including T2DM. In the previous chapters (Two and Three), it was established that the distribution of T2DM in the Swazi population varies among different groups (non-modifiable and modifiable risk factors). This creates differential experiences of and vulnerability to the intermediate risk factors for T2DM, prediabetes and hypertension, including overweight and obesity. Having established that obesity and overweight are significant determinants of T2DM and other cardio-metabolic diseases, the next step is to identify which of the anthropometric measures is best for identifying the risk for prediabetes/T2DM and hypertension.

The work in this chapter extends the findings from Chapter Two by estimating the prevalence of obesity and overweight in the Swazi population and by determining the factors associated with these conditions. These findings are extended by evaluating the ability of body mass index, waist circumference and waist-to-hip ratio to be used as predictors of type 2 diabetes and hypertension risk in Swazi adults for the first time, and by estimating their optimal cut-off levels for the first time.

This chapter comprises of two manuscripts that have been submitted to the Tropical Medicine and International Health and BMC Nutrition journal, respectively are currently under review.

Overweight, Obesity and Associated Factors: A Cross-sectional Study of Adult Outpatients at a Swazi Hospital

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Abstract

Background: Obesity, overweight and associated factors are major public health concerns in Swaziland. The prevalence of obesity and overweight in Swaziland's general population is increasing, but there is limited data on the situation is like in clinical settings. This study aimed to estimate the prevalence of obesity and overweight and their associated risk factors.

Methods: A cross-sectional study of 385 randomly selected adult outpatients was conducted from February to March 2019 at the Raleigh Fitkin Memorial Hospital, Manzini, Swaziland. Height, weight, waist- and hip-circumferences, sociodemographic and lifestyle factors were assessed. BMI, WC, and WHR were measured using standardised methods. Overweight was defined as BMI = 25 kg/m^a and obesity was defined as BMI $\geqslant$ 30 kg/m^a. Overweight was defined based on WC 94–101.9 cm and 80–87.9 cm in men and women respectively, and obesity based on WC $\geqslant$ 102 cm in men and $\geqslant$ 88 cm in women. Overweight was defined based on WHR 0.95–0.99 and WHR 0.80–0.84 in men and women respectively and obesity was based on WHR $\geqslant$ 1 in men and $\geqslant$ 0.85 in women. Binary logistic regression was used to identify the factors associated with being overweight/obese.

Results: Of the 385 participants, 5.5% were underweight. The overall prevalence of obesity according to WC, WHR, BMI was 29.1%, 25.7%, and 19.7%. The highest prevalence of overweight (26.5%) was estimated with BMI. The overall prevalence of overweight estimated with WC and WHR was 13.8% and 11.9%. Significant gender differences were observed in the prevalence of obesity and overweight ($p<0.0001$). Highest SES (AOR 1.68; 95% CI 1.01-2.81) (BMI) and (AOR 2.15; 95% CI 1.24-3.73) (WC), consumption of salty processed foods (AOR 1.58; 95% CI 1.03-2.44) (WHR) increased the odds of being overweight/obese. Physical activity (AOR 0.57; 95% CI 0.38-0.87) (by BMI) (AOR 0.58; 95% CI 0.37-0.90) (WHR) and consumption of vegetables were protective against the risk of overweight/obesity (AOR 0.54; 95% CI 0.33-0.89) (WC). An average household income of SDE 3000 or higher was also associated with lower odds of being overweight/obese (AOR 0.39; 95% CI 0.22-0.69) (by WHR).

Conclusions: According to our study, obesity and overweight are highly prevalent among adult outpatients in this clinical setting, particularly among women. Factors independently associated with higher odds of being overweight/obese in the population studied were highest SES and income, and salty processed foods consumption, inadequate consumption of vegetables and insufficient physical activity. This finding provides an important baseline for the monitoring of obesity and overweight cases in the future, and highlights the need for community-based interventions to address the growing burden of obesity/overweight in Swaziland. Highest SES and income, consumption of vegetables and salty processed foods and physical activity were independent risk factors associated with overweight/obesity.

Keywords: Body mass index, Central obesity, Obesity, Overweight, Risk factors, Waist circumference.

Background

The prevalence of obesity worldwide has increased since 1975 by nearly 300%, with about 2 billion and over half a billion adults considered overweight and obese, respectively, in 2016 (1). Previously considered conditions of the industrialised countries, overweight and obesity are now prevalent in low- and middle-income countries (LMICs), including sub-Saharan Africa (SSA) (2). Based on the estimates of the World Health Organisation (WHO), the prevalence of overweight among adults between 25-64 years in Southern Africa is 40-60% (3). In SSA, the rising prevalence of obesity and overweight co-exist with the increasing prevalence of non-communicable diseases (NCDs), with an anticipated highest increase in NCD deaths of 27% in Africa over the next decade (4). In Swaziland, the prevalence of overweight and obesity has also increased in the general population over the last two decades (5). In the last two decades, obesity prevalence increased from 16.2% to 26.2% among Swazi women and from 2.2% to 5.4% among adult Swazi men (5).

In the USA's clinical settings, the prevalence of overweight and obesity among adult outpatients was about 80% (6, 7). In a study of 4378 outpatients drawn across Africa and the Middle East, the overall prevalence of general obesity defined by body mass index (BMI) was 37% (8); the overall prevalence of central obesity defined by waist circumference (WC) was 68%. Other observational studies conducted in developing countries have reported a general obesity prevalence of 27-33% and overweight 32-38% among outpatients (9-11). An American study found that obesity significantly extends the number of visits in the outpatient department (OPD) (6). Likewise, a time burden study conducted among outpatients in the USA shows that 40 minutes of primary care providers' time spent on obesity cases is enough to see two additional patients (12).

Obesity and overweight are typified by abnormal or excess fat accumulation that can potentially negatively affect health.1 Obesity results from an imbalance between calories consumption (poor diet) and calories utilisation (low physical activity and a sedentary lifestyle) (1). The rising prevalence of obesity worldwide is commonly attributed to genetic factors, dietary and physical activity patterns, and the increasing availability of highly fatty foods (13). The driving force behind these patterns incorporates globalisation, which is perceived to be directing a broad nutrition transition in numerous nations, characterised by a move from rich traditional foods to energy-dense western diets and a progressively sedentary lifestyle (14, 15). Epidemiological studies have demonstrated the beneficial impact of physical activity and healthy diets in reducing the risk of weight gain and related chronic diseases (16-18). On the other hand, longitudinal studies have shown the harmful effect of processed foods on weight gain and obesity (19, 20). Additionally, evidence from industrialised countries indicates a higher obesity prevalence among people with a lower socioeconomic status. Contrarily, the available evidence in SSA shows inconsistent results, with some

studies suggesting a strong positive association between high SES and obesity, whereas others reported an inverse association (21).

The assessment of fat mass and definitions of overweight and obesity utilise many approaches, a few of which are complex or intrusive and are inapplicable beyond clinical settings to recognise candidates for weight control (22-24). In routine clinical practice and epidemiological studies, the most used measure to define overweight and obesity is BMI, a measure of general obesity.1 Besides, waist circumference (WC) and waist-to-hip ratio (WHR) have been used as measures of central obesity (visceral adiposity) (25). Increased weight and WC are strongly associated with CVD risk factors such as T2DM and hypertension in many populations (26-28).

Although NCD-related research has increased in Swaziland, including a survey on NCD risk factors (29), there are still limited facility-based studies in Swaziland that have precisely estimated overweight and obesity prevalence in adult outpatients (a potentially high-risk population) and the associated factors. The few facility-based studies conducted in Swaziland provided valuable insight on obesity, but none of them estimated the prevalence with waist circumference and waist-to-hip ratio. The evidence indicates that central obesity, particularly waist circumference, is more associated with cardiometabolic risk (26-28, 30). Thus, this study aimed to estimate the prevalence of overweight and obesity and to determine the associations of overweight, obesity, and its related sociodemographic, dietary, and lifestyle factors in an adult outpatient sample at Raleigh Fitkin Memorial Hospital, Swaziland.

Methods

Detailed descriptions of the examination procedures, the participants' characteristics and the behavioural variables have been provided elsewhere (31, 32). Briefly, 385 patients attending the OPD at Raleigh Fitkin Memorial Hospital in Manzini, Swaziland, were included in the study.

Anthropometric measurements

For each participant in this study, anthropometric measurements of body height and weight were assessed using standard protocols. Body weight (to the nearest 0.1 kg) was measured with a digital scale (FORA Digital Multi-function Diamond Scale), with participants in light clothing and barefoot. Height (to the nearest 0.1 cm) was measured with a stadiometer (SECA, Germany), with participants barefoot. Body mass index (BMI) was calculated as weight in kg divided by height in m^2. Waist circumference (to the nearest 0.1 cm) was measured using a measuring tape, midpoint between the last palpable rib and the suprailiac crest, while participants were standing and breathing normally. Hip circumference was measured at the widest point around the greater trochanter. The waist and hip circumferences were measured with the tape

parallel to the floor. Waist-to-hip ratio (WHR) was defined as the ratio of the WC to the hip (WC [cm]/HC [cm]).

Definition of general and central obesity

Participants were considered to have general obesity if their BMI was $\geqslant$30 kg/m^2. Overweight was defined as a BMI between 25.0 and 29.9 kg/m^2. Participants were classified as underweight if their BMI was less than 18.5 kg/m^2. Participants with a BMI between 18.5 and 24.9 kg/m^2 (inclusive) were considered to be of a normal weight. The BMI definition is according to the WHO standards (13), and the abdominal obesity (central obesity) was defined according to the WHO guidelines (33). Men with a WC of less than 94 cm and women with a WC of less than 80 cm were classified as having a normal weight. Men with a WC between 94 and 101.9 cm and women with a WC between 80 and 87.9 cm were classified as being overweight. Participants were classified as having central obesity if their WC was 102 cm or higher (in men), or 88 cm or higher (in women). Based on the WHR, men and women with a WHR of less than 0.9 or 0.8 respectively were classified as having a normal weight. Overweight was defined as a WHR of between 0.95 and 0.99 (inclusive) for men and from 0.80 to 0.84 for women. Obesity was defined as a WHR of 1.0 or higher (men) or 0.85 or higher (women).

Statistical methods

The SPSS software version 26 was used for all statistical analyses. The Chi-square test was used for the bivariate data analysis. A binary logistic regression with a forward conditional method was performed to assess which independent variables could predict the development of general obesity (BMI) and central obesity (WC and WHR). A two-sided p-value < 0.05 was considered statistically significant.

Results

Prevalence of underweight, overweight and obesity

The overall prevalence of central obesity as measured by WC (29.1%) and WHR (25.7%) was higher than the obesity prevalence estimated by BMI (19.7%). Based on the BMI, about 27% of the adult outpatients were overweight, with 14% and 12% estimated to be overweight using WC and WHR (Table 1).

The age and gender distribution of underweight, overweight and obesity are shown in Table 2. Regardless of the anthropometric measurement used, women always had a higher prevalence of overweight and obesity than men. In contrast, more men (9.6%) were underweight than women (1.1%) based on their BMI. Based on BMI, about 20% and 34% of the women were overweight and obese, with significantly more women (33.5%) than men (6.6%) in the obese category. Large differences were observed in the prevalence of

obesity in the age groups 18-27, 58-67 and 38-47 years, where the ratios of obese women to obese men were 10 (15.1% vs 1.5%), 9 (58.8% vs 6.2%) and 7 (50% vs 7.4%) respectively. The difference in the prevalence of obesity between men and women by WC was generally large, except in the 38-47 years group, where the ratio of obese women to obese men was 4 (72.2% vs 18.5%). The largest difference was observed in the youngest age group 18-27 years (28.3% vs 0%). Based on the WHR, a large difference was observed in the prevalence of obesity between men and women in all age groups, except the 58-67 years group, where the ratio of obese women to obese men was 3 (70% vs 23.1%). The largest difference was observed in the 28-37 years group (35.7% vs 0%).

Among the men, BMI produced the highest prevalence of overweight across all age groups. A similar pattern was observed among the women, except in the 58-67 years age group where WC yielded the highest prevalence of overweight (35.3% vs 29.1% and 11.8%). No consistent pattern was observed in the prevalence of obesity among men across the age groups. WHR produced the highest obesity estimate (23.1%) in the oldest age group (68 years or older). Both WC and WHR produced the same estimate in the 48-57 years group (7.1%), while BMI and WC estimated the obesity prevalence at 7.7% for men in the $\geqslant$ 68 years age group.

Table 1. Characteristics of the study population according to overweight/obesity status

		Overweight			Obese		
Characteristic	n	BMI	WC	WHR	BMI	WC	WHR
Age group (years)							
18 - 27	121	17.4**	6.6**	9.9**	7.4**	12.4**	9.9**
28 - 37	101	23.8	14.9	10.9	15.8	20.8	14.9
38 - 47	71	31.0	15.5	16.9	33.8	52.1	39.4
48 - 57	36	38.9	11.1	11.1	33.3	52.8	55.6
58 - 67	33	33.3	23.4	12.1	33.3	36.4	32.4
≥68	23	43.5	26.1	13.0	17.4	34.8	43.5
Overall	**385**	**26.5**	**13.8**	**11.9**	**19.7**	**29.1**	**25.7**
Gender							
Male	197	19.8**	7.6**	5.1**	6.6**	5.1**	4.1**
Female	188	33.5	20.2	19.1	33.5	54.3	4.8
Residence							
Rural	192	25.5	16.1	13.0	22.9	32.3	29.7*
Urban	191	26.7	11.0	11.0	16.8	25.7	21.5
Education							
No formal education	26	38.5	11.5	7.7	19.2	42.3	42.3*
Primary	96	24.0	13.5	14.6	24.0	35.4	32.3
Secondary or higher	263	26.2	14.1	11.4	18.3	25.5	21.7
Socioeconomic status							
Lower	127	27.6	11.8	15.7	14.2	25.2	26.0
Middle	130	25.4	13.1	9.2	20.0	30.0	24.6
Higher	128	26.6	16.4	10.9	25.0	32.0	26.6
Occupation							
Student/unemployed	153	24.2	13.7	11.1	19.0	29.4	31.4
Self-employed	58	27.6	12.1	10.3	22.4	24.1	24.1
Salaried job	174	28.2	14.4	13.2	19.5	35.5	21.3
Average income (SDE)							
<1000	107	31.8	11.2	13.1	19.6	374.0	36.4*
1000 - 2999	166	24.7	13.9	14.5	18.7	27.1	22.9
≥3000	112	24.1	16.1	7.1	21.4	24.1	19.6
Fruit consumption							
No	126	27.8	15.1	12.7	20.6	29.4	25.4
Yes	259	25.9	13.1	11.6	19.3	29.0	25.9
Vegetable consumption							
No	89	29.2	18.0*	5.6	25.8	37.1*	37.1*
Yes	290	25.5	12.1	13.4	17.6	26.9	22.4

Physical Activity[a]							
No	233	31.4*	13.9	14.3*	20.6	32.7	29.1*
Yes	162	19.8	13.6	8.6	18.5	24.1	21.0
Smoking							
No	195	25.1	13.8	14.4	16.9	25.6	21.5
Yes	190	27.9	13.7	9.5	22.6	32.6	30.0
Alcohol							
No	144	27.8	10.4	9.0	17.4	27.1	23.6
Yes	241	25.7	15.8	13.7	21.2	30.3	27.0
Sweet drink consumption							
Rarely	161	28.6	13.0	13.0	15.5	29.2	26.1
Moderately/excessively	224	25.0	14.3	11.2	22.8	29.0	25.4
Salty processed food consumption							
No	175	24.0	10.9	9.7	16.6*	26.3	21.7
Yes	210	28.6	16.2	13.8	27.4	31.4	29.0

BMI, body mass index; WC, waist circumference; WHR, waist-hip-ratio

n, sample size; SDE, Swazi Emalangeni

[a]Participants who met the WHO recommended physical activity per week.

*$p < 0.05$, **$p < 0.0001$ according to Pearson or Likelihood ration Chi square

Prevalence of underweight, overweight and obesity

The overall prevalence of central obesity, as measured by WC (29.1%) and WHR (25.7%), was higher than the obesity prevalence estimated by BMI (19.7%). Based on the BMI, about 27% of the adult outpatients were overweight, with 14% and 12% estimated to be overweight using WC and WHR (Table 1).

The age and gender distribution of underweight, overweight and obesity are shown in Table 2. Regardless of the anthropometric measurement used, women always had a higher prevalence of overweight and obesity than men. In contrast, more men (9.6%) were underweight than women (1.1%), based on BMI. Based on BMI, about 20% and 34% of the women were overweight and obese, with significantly more women (33.5%) than men (6.6%) in the obese category. Large differences were observed in the prevalence of obesity in the age groups 18-27, 58-67 and 38-47 years of age, where the ratios of obese women to obese men were 10 (15.1% vs 1.5%), 9 (58.8% vs 6.2%) and 7 (50% vs 7.4%). The difference in the prevalence of obesity between men and women by WC was generally large, except in the 38-47 years group, where the ratio of obese women to obese men was 4 (72.2% vs 18.5%). The largest difference was observed in the youngest age group, 18-27 years (28.3% vs 0%). Based on the WHR, a large difference was observed in the prevalence of obesity between men and women in all age groups, except the 58-67 years of age group,

where the ratio of obese women to obese men was 3 (70% vs 23.1%). The largest difference was observed in the 28-37 years of age group (35.7% vs 0%).

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Table 2. Gender distribution of overweight and obesity by BMI, WC and WHR

		BMI			WC		WHR	
Age group	n	Underweight[a]	Overweight	Obese	Overweight	Obese	Overweight	Obese
Men								
18-27	68	10.3	8.8	1.5	0.0	0.0	2.9	0.0
28-37	59	10.2	22.0	8.5	8.5	3.4	1.7	0.0
38-47	27	7.4	22.2	7.4	7.4	18.5	3.7	7.4
48-57	14	14.3	21.4	21.4	7.1	7.1	14.3	7.1
58-67	16	12.5	37.5	6.2	18.8	6.2	12.5	12.5
≥68	13		38.5	7.7	30.8	7.7	15.4	23.1
Total	**197**	**9.6**	**19.8**	**6.6**	**7.6**	**5.1**	**5.1**	**4.1**
Women								
18-27	53		28.3	15.1	15.1	28.3	18.9	22.6
28-37	42	2.4	26.2	26.2	23.8	45.2	23.8	35.7
38-47	44	2.4	36.4	50.0	20.5	72.7	25.0	59.1
48-57	22		50.0	40.9	13.6	81.8	9.1	86.4
58-67	17		29.4	58.8	35.3	64.7	11.8	70.6
≥68	10		50.0	30.0	20.0	70.0	10.0	70.0
Total	**188**	**1.1**	**33.5**	**33.5**	**20.2**	**54.3**	**19.1**	**48.4**

BMI: Body mass index. Overweight was defined as a BMI between 25–29.9 and obesity as a BMI ≥ 30 kg/m² in men and women.
WC: Waist circumference. Overweight was defined based on a WC 94–101.9 cm and 80–87.9 in men and women respectively, and obesity was based on a WC ≥ 102 cm in men and ≥ 88 cm in women.
WHR: Waist-to-hip ratio. Overweight was defined based on a WHR 0.95–0.99 and a WHR 0.80–0.84 in men and women respectively, and obesity was based on a WHR ≥ 1 in men and ≥ 0.85 in women)

[a]Combined underweight prevalence was 5.5%

Factors associated with overweight/obesity

Table 3 shows the results of the binary logistic regression models to determine the modifiable factors associated with being overweight/obese. The highest SES and consumption of salty processed foods were the modifiable factors found to increase the odds of being overweight/obese based on BMI in the unadjusted model. Adequate vegetable consumption and sufficient physical activity were found to be protective of the risk of being overweight/obese. In the adjusted model, only the highest SES remained significantly positively associated with being overweight/obese. Participants who were from a household in the highest SES level were twice more likely to be overweight/obese than their counterparts in the lowest SES level (AOR 1.6; 95% CI 1.01-2.81). Also, only sufficient physical activity remained significantly associated with a reduced risk of being overweight/obese. Participants who attained the WHO recommended level of physical activity per week were at 57% reduced risk of being overweight/obese compared to those who did not (AOR 0.57; 95% CI 0.38-0.86).

Consumption of vegetables was protective against the risk of being overweight/obese according to WC. Also, consumption of salty processed foods increased the odds of being overweight/obese. After adjusting for confounders, the highest SES remain positively associated with overweight/obese and consumption of vegetables remained independently associated with lower odds of being overweight/obese. Participants from households in the highest SES level were two times more likely to be overweight/obese than those from the lowest SES level (AOR 2.15; 95% CI 1.24-3.73). Compared with participants who ate less than five servings of vegetables per day, those who ate at least five servings per day were less likely to be overweight/obese (AOR 0.54; 95% CI 0.3-0.89).

Based on WHR, the consumption of salty processed foods was significantly associated with being overweight/obese, whereas an average household income of SDE 1000-2999 or $\geqslant$3000 and adequate physical activity were associated with reduced odds of being overweight/obese. In the adjusted model, the three factors maintained their association with overweight/obese. Participants from households with an average income of SDE 3000 or more were at a 39% (AOR 0.39; 95% CI 0.22-0.69) reduced risk of being overweight/obese than those from households with an average income of less than 1000 SDE. Participants who were more physically active were less likely to be overweight/obese compared to their counterparts who were less physically active (AOR 0.58; 95% CI 0.37-0.90). Participants who consumed salty processed foods moderately or regularly were at a 58% increased risk of being overweight/obese than those who do not or rarely consumed processed foods.

Table 3. Crude and adjusted odds ratios for risk factors associated with being overweight or obese

		BMI		WC		WHR	
Factor	n	COR [95% CI]	AOR [95% CI]	COR [95% CI]	AOR [95% CI]	COR [95% CI]	AOR [95% CI]
Education							
No formal education	26	1		1		1	
Primary education	96	0.68 [0.28-1.62]		0.82 [0.35-1.96]		0.88 [0.37-2.10]	
Secondary or higher education	263	0.59 [0.28-1.33]		0.56 [0.25-1.26]		0.49 [0.49-1.11]	
Socioeconomic status							
Lowest	127	1	1	1	1	1	
Middle	130	1.16 [0.71-1.90]	1.27 [0.76-2.12]	1.29 [0.78-2.12]	1.50 [0.87-2.55]	0.71 [0.43-1.19]	
Highest	128	1.49 [0.91-2.44]	1.68 [1.01-2.81]*	1.60 [0.97-2.64]	2.15 [1.24-3.73]*	0.84 [0.51-1.39]	
Occupation							
Student/unemployed	153	1		1		1	
Self-employed	58	1.32 [0.72-2.42]		0.75 [0.40-1.40]		0.71 [0.38-1.34]	
Salaried job	174	1.20 [0.78-1.86]		1.07 [0.69-1.66]		0.71 [0.46-1.12]	
Average income (SDE)							
<1000	107	1		1		1	1
1000-2999	166	0.72 [0.45-1.18]		0.73 [0.45-1.20]		0.61 [0.37-0.99]*	0.66 [0.39-1.09]
≥3000	112	0.79 [0.47-1.34]		0.71 [0.42-1.21]		0.37 [0.21-0.66]**	0.39 [0.22-0.69]**
Fruit consumption							
No	126	1		1		1	
Yes	259	0.88 [0.57-1.34]		0.91 [0.59-1.40]		0.97 [0.63-1.51]	
Vegetable consumption							
No	89	1		1	1	1	
Yes	290	0.62 [0.38-0.99]*		0.52 [0.32-0.84]*	0.54 [0.33-0.89]*	0.75 [0.46-1.22]	
Physical activity[a]							

No	223	1	1	1	1	1
Yes	162	0.57 [0.38-0.86]*	0.57 [0.38-0.87]*	0.69 [0.46-1.04]	0.55 [0.36-0.84]*	0.58 [0.37-0.90]*
Smoking						
No	195	1			1	
Yes	190	1.41 [0.94-2.10]			1.32 [0.88-1.98]	
Alcohol						
No	144	1		1	1	
Yes	241	1.07 [0.71-1.62]		1.42 [0.93-2.17]	1.41 [0.92-2.18]	
Consumption of sweet drinks						
Rarely	161	1		1	1	
Moderately/excessively	224	1.16 [0.77-1.74]		1.05 [0.69-1.57]	0.90 [0.59-1.36]	
Consumption of salty processed foods						
No	175	1		1	1	1
Yes	210	1.52 [1.02-2.28]*		1.54 [1.02-2.32]*	1.64 [1.08-2.49]*	1.58 [1.03-2.44]*

AOR, adjusted odds ratio; BMI, body mass index. Overweight was defined as a BMI between 25–29.9 kg/m² and obesity as a BMI ≥ 30 kg/m² in men and women

CI, confidence interval; COR, crude odds ratio; SDE, Swaziland Emalangeni.

WC, waist circumference. Overweight/obese according to WC is defined as≥ 94 cm (men)/≥80 cm (women).

WHR, waist-to-hip ratio. Overweight/obese according to WHR is defined as ≥ 0.95 (men)/≥0.80 (women).

[a]Participants who met the WHO recommended physical activity per week.

*p<0.05; **p<0.0001.

Discussion

As the first study to estimate the prevalence of central obesity and associated factors in a Swazi outpatient sample, a relatively high burden of overweight and obesity and a low prevalence of underweight was observed, particularly among women. Highest wealth quintile, high income, insufficient physical activity, consumption of salty processed foods, and inadequate consumption of vegetables were the modifiable factors significantly associated with being overweight/obese. Central obesity (as measured by WHR) was more pronounced in rural areas than in urban areas. There was no significant difference between alcohol users and non-alcohol user samples in terms of being overweight or obese.

The low prevalence of underweight found in the present study is consistent with the previous reports in Swaziland29 and elsewhere in SSA, namely Malawi (34) and Uganda (35). In contrast to the present study; a Kenyan study (36) reported a higher prevalence of underweight, particularly in rural adults. The rural-urban divide may have played a role in the variation observed between the present study and the Kenyan study. The higher prevalence of underweight found in the present study among men (9.6%) as opposed to women (1.1%) confirms the previous findings in Swaziland (29) and elsewhere in SSA (34-38).

A previous study (39) conducted in the Lubombo region, Swaziland, reported a considerably lower prevalence of overweight (BMI$\geqslant$25 kg/m^2) (5.5%) among HIV-infected patients than the present study which reported an overweight prevalence of 26.5% (by BMI). However, the estimated prevalence of overweight in the present study (26.5%) is consistent with an estimate from the STEPs survey (23.4%) for the general population in Swaziland (29). No comparable estimate exists in Swaziland for the prevalence of overweight estimated by WC and WHR. The lower prevalence of overweight as estimated by either WC or WHR than the estimate using BMI has been reported among adults in Australia (40), while in contrast, studies conducted in South Africa (41) and Nigeria (42) have reported a higher prevalence of overweight by WC or WHR than BMI.

The general obesity prevalence estimated in the present study is consistent with an estimate from the STEPs survey (29), but higher than the national estimate of 14% estimated by the WHO (43). Nevertheless, general obesity prevalence ranges from 30% to 60% in the Southern Africa subregion (35, 41, 44-46). Previous reports in Swaziland (29, 39) focused on general obesity (BMI) only, but the present study confirms the epidemic nature of overweight and obesity in Swaziland.

The estimated prevalence of central obesity by WC was 29.1% (men 5.1% vs women 54.3%) and 25.7% by WHR (men 4.1% vs women 48.4%). The prevalence of central obesity (as assessed by WC, the most commonly used measure) in the present study is consistent with the estimates from the studies conducted among adults (35-60 years) in Malawi (34) and Uganda (47) but lower than the prevalence reported among

adult outpatients (⩾18 years) in South Africa (41) and Nigeria (42). Methodological differences may have played a part in the observed variations in the central obesity prevalence in these studies and the present study. The higher prevalence of central obesity than the prevalence of generalised obesity in the present study indicates the need to include the former in the screening and management of NCDs, particularly at the primary health care level. As shown by Owolabi et al. (41), BMI might underestimate or misclassify at-risk individuals.

Moreover, visceral fat is more dangerous to health than subcutaneous fat and studies have reported a strong association between visceral fat and cardiovascular risk factors, T2DM and hypertension in many populations (26-28). The INTERHEART study,48 a case-control study of large participants in 52 countries, found that WC was a stronger predictor of myocardial infarction than BMI. Therefore, there is a need for the Swaziland Ministry of Health to review the clinical guidelines for managing NCDs by incorporating WC as one of the vital signs to be monitored at health facilities.

The significant gender differences observed in the present study in the prevalence of overweight, general, and central obesity is a well-established finding and is consistent with previous findings (34, 36). Like the findings from many studies in developing countries (34, 44, 49), women were found to be more overweight and obese than men in the present study. Contrarily, findings from studies conducted in developed countries suggest than adult men were more overweight and obese than adult women (17, 50). The gender differential observed in the present study can be explained by complex sociocultural pathways that encourage weight gain among African women (38, 39). In many African societies, weight gain among women is considered as a sign of beauty, affluence and good health (37, 51). Secondly, women generally have a higher percentage of body fat compared to men, and there are indications that the basal fat oxidation is lower in females than men, thereby contributing to higher fat storage in women (13).

Both socioeconomic and lifestyle variables were independently associated with overweight/obesity in the present study. However, the socioeconomic statuses showed conflicting results in their association with central obesity (by WC and WHR). For instance, household income appeared to be protective against the risk of excessive adiposity (by WHR), but household wealth tended to increase the risk of developing excessive central adiposity (by WC) and general obesity (by BMI). It has been established that SES shows a negative gradient in the prevalence of overweight or obesity in industrialised countries (52). These results are inconsistent with those in SSA, with some studies suggesting a strong positive association between high SES and obesity, whereas others reported an inverse association (21). Like the present study, some studies have also reported a strong positive association between higher SES and obesity (35, 37). In contrast, other studies have found an inverse association between SES and obesity (53, 54). However, these studies have used education to measure SES, unlike the present study, which used the wealth index. The increase

observed in the likelihood of being overweight/obese with a higher SES in the present study may be related to changing dietary patterns, decreasing physical activity and an increasing availability of high-fat foods (55, 56), driven by globalisation and nutritional transition (15). Individuals of a higher SES can afford the more expensive, highly refined, and energy-dense western foods (57) but have little opportunities for physical activities (58).

Studies in developed countries have demonstrated that individuals with higher incomes or higher education levels are less likely to be overweight/obese (59), while the results are inconsistent and controversial in developing countries (21). A Chinese study reported that individuals with a higher household income, but lower education level were at a higher risk of being obese (60). However, studies in SSA have reported a positive gradient between household income and central obesity (42, 61). The lower prevalence of central obesity (as measured by WHR) observed in the present study among individuals with high household income should be interpreted with caution. A recent review (62) showed that the impact of income on weight might follow an inverted U-shape. This is because people with a high income may invest more time and money in weight loss for the sake of appearance and health, whereas people with a low income may spend heavily on food (62). Further studies are thus needed to understand the influence of SES on obesity risk.

Dietary and lifestyle factors associated with being overweight/obese in the present study included the consumption of fruits and vegetables, physical activity, and consumption of salty processed foods. Vegetable consumption was protective against the risk of being overweight/obese (by WC). Cross-sectional (63), retrospective (11) and prospective studies (16, 17) have found an inverse relationship between a diet rich in fruits and vegetables or fibre/wholegrain and central obesity, but a positive association between diets high in fried foods or refined grains and central adiposity (19, 20). The protective influence of vegetable consumption against the odds of increased central obesity is expected since vegetables are known to contain micronutrients which protect against the accumulation of body fat (64). Vegetable and fruit consumption induces a decrease in body weight, and studies have shown that diets rich in vegetables reduce WC (65, 66). The observed positive association between overweight/obesity and poor diet (consumption of salty processed food) has been documented elsewhere (65). Salty processed foods in the present study included packaged salty snacks, canned salty food including pickles and preserves, and salty food prepared at a fast-food restaurant. Studies have reported a positive association between the consumption of snacks, processed foods and fast-foods and central obesity (20, 67); for instance, a study conducted in Brazil found that foods containing snacks, fats, and chicken were associated with increased WHR (67).

The observed association between physical activity and lower prevalence of overweight/obesity in the present study has been demonstrated in SSA (34, 37, 46, 68 and elsewhere previously. Shayo and Mugusi

(68) reported that individuals who engaged in vigorous physical activities had lower risks for obesity compared to their counterparts who did less vigorous physical activities. Among outpatients, a study in Italy also demonstrated the beneficial impact of physical activities on overweight/obesity (69).

Although alcohol consumption was not an independent predictor of obesity in the present study, it was nonetheless significantly positively associated with central obesity (WHR) in the univariate analysis. Studies investigating the association between alcohol consumption and central obesity have produced inconsistent results (70). For example, a Korean study demonstrated that alcohol consumption was a contributing factor to an increase in body weight and body fat (71). Surprisingly, smoking was not significantly associated with either general or central obesity in the present study. Research has shown that current smokers have a lower mean BMI than former smokers or those who never smoked (72), and this trend was observed in the present study with smokers having a higher prevalence of overweight but not obesity.

Besides gender mentioned above, the rural residence was another demographic variable found to be significantly associated with central obesity (WHR) in the present study. Surprisingly, this trend was observed in the prevalence of central obesity as well, although this difference did not reach the level of statistical significance. Like the present study, a study conducted in Australia (73) reported higher rates of overweight and obesity among rural residents. Women who live in rural areas tend to have poorer health outcomes and higher rates of ill health compared with those living in urban areas (74). In contrast to the present study, studies have reported higher obesity rates among urban residents than their rural counterparts in Uganda (47) Kenya (36) and Malawi (34).

Study strengths and limitations

To our knowledge, this is the first study reporting on the prevalence of central obesity in the Manzini region of Swaziland. Also, this is the first study assessing the influence of globalisation on obesity in Manzini, Swaziland. Such important information is essential for crafting effective public health policies and clinical guidelines. The use of standard procedures and the use of trained personnel to assess general and central obesity further give credence to the findings of this study, however, the cross-sectional nature of this study precludes causal inferences. Therefore, prospective studies are needed to establish a causal relationship between socioeconomic and lifestyle variables and the outcome variable (obesity) in Swaziland. In addition, the use of self-reporting for socio-economic and lifestyle variables may have led to recall and reporting biases, which may have affected the accuracy of the results.

Conclusion

In conclusion, this study's results revealed a high prevalence of overweight and obesity among adult outpatients in this health facility. Socioeconomic and lifestyle variables (modifiable factors) were independently associated with being overweight and obese. High SES (highest wealth quintile) was significantly associated with general obesity (by BMI) and central obesity (by WC), and consumption of salty processed foods increased the risk of central obesity (by WHR). High income was significantly inversely associated with central obesity (by WHR), and the consumption of vegetables appeared to be protective against the risk of central obesity (by WC). Vigorous physical activity was protective against the risk of general (by BMI) and central (by WHR) obesity, and gender and rural residence were the non-modifiable factors associated with obesity and overweight in this study.

There is an urgent need for the management of this health facility and the Swaziland Ministry of Health to develop intervention programmes to promote healthy lifestyles and reduce the high prevalence of overweight or obesity and its subsequent complications such as T2DM and HTN among patients and Swazis.

Authors' contributions

MG reviewed the literature, and made substantial contributions to the conception, design, and drafting of the manuscript. BT participated in the design of the study and/or the drafting of the manuscript. Both authors read and approved the final manuscript.

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Ethical considerations

The study was approved by the Biomedical Research Ethics Committee (BREC) of the University of Kwa Zulu-Natal (UKZN) (Reference: BE 385/18). Participation was voluntary and written informed consent was obtained from each participant.

Competing interests

The authors declare that they have no competing interests.

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Comparative Analysis of Anthropometric Indices of Obesity as Predictors of T2DM/Prediabetes and Hypertension in Swazi Adults: A Cross-Sectional Study

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Abstract

Background: Obesity is a well-established risk factor for type 2 diabetes, hypertension and other cardiometabolic disorders. However, it is unclear which of the several obesity measures is the best to predict type 2 diabetes/prediabetes and hypertension risks. This study aimed to compare the predictive ability of BMI, WC, and WHR in identifying type 2 diabetes/prediabetes and hypertension risk and determine their optimal cut-off levels.

Methods: Adult outpatients aged 18 years and older were enrolled into a cross-sectional study in Manzini, Swaziland. Participants were screened for type 2 diabetes and hypertension. Anthropometric indices of weight, height, and waist and hip circumferences were collected to determine body mass index, waist circumference and waist-to-hip ratio according to a standard protocol. Receiver operating characteristic (ROC) analysis was used to compare the three anthropometric indices' predictive ability and estimate their optimal cut-off values for high fasting plasma glucose and raised systolic blood pressure.

Results: Among men with diabetes or prediabetes, WC yielded the highest area under the ROC curve (AUC) (0.708) than either WHR (AUC=0.663) or BMI (AUC=0.646). Among women with diabetes or prediabetes, WC yielded a slightly higher AUC (0.582) than BMI (AUC=0.570) or WHR (AUC=0.563). WHR and WC yielded a higher AUC (0.774 vs 0.704) among men with a raised SBP than BMI (AUC=0.628). Among women with raised SBP, the performance of WC (AUC=0.774) was better than that of BMI (AUC=0.736) or WHR (AUC=0.679). The optimum cut-off values of all three anthropometric indices to discriminate diabetes/prediabetes risk estimated for males and females in this study were BMI (23.35 vs 25.45 kg/ m^2), WC (81.50 vs 79.0 cm) and WHR (0.85 vs 0.82). The optimal cut-off points for all three indices to discriminate the hypertension risk in men and women were 22.8 and 28.95 kg/ m^2 for BMI, 78.50 and 89.5 cm for WC, and 0.86 for WHR.

Conclusions: Overall, WC yielded the best predictive ability in comparison to WHR or BMI for discriminating diabetes/prediabetes and hypertension risk in this study. Therefore, we recommend using WC in addition to BMI for identifying T2DM/prediabetes and hypertension risk in the clinical settings in Swaziland and SSA.

Keywords: Adults, Hypertension, Obesity, Swaziland, T2DM, Waist circumference.

Background

Obesity is the significant independent predictor of type 2 diabetes (T2DM) (1, 2) and hypertension (HTN) (3). Obesity and its associated conditions reduce the quality of life and result in premature mortality (4). In a pooled analysis of 97 studies, Flegal *et al.* (5) found that obesity was associated with higher all-cause mortality. Globally, 1.9 billion and over 600 million adults were overweight and obese, respectively, in 2014 (6). The increasing global epidemic of overweight and obesity appears to be catching up with sub-Saharan African (SSA) (1, 7), as in SSA the prevalence of obesity and overweight has increased at an alarming rate (8), with Southern Africa being the most affected (4). In Southern Africa, the greatest burden of obesity and overweight occurs in Swaziland, particularly among women (9). A recent analysis of the Demographic and Health Survey from 32 SSA countries revealed that Swaziland has the highest prevalence of overweight (27.7%) and obesity (23%) (9). Furthermore, the Stepwise Approach to Surveillance (STEPS) Survey conducted in Swaziland reported that 23.4% (59.9% women; 26% men) and 20.5% (49.9% women; 20.8% men) of the respondents were overweight and obese, respectively (10).

The increasing burden of obesity and associated T2DM, hypertension, other cardiovascular diseases, and cancers in SSA is thought to result from lifestyle changes, demographics, and nutrition (11-13). Clinical trials have demonstrated the beneficial impact of weight reduction for individuals who have an increased risk of T2DM (14-15) and can help patients with high blood pressure (BP) (16). Consequently, an accurate definition of overweight and obesity is clinically important to address this public health concern. Early detection of overweight and obesity will prevent prediabetes and T2DM, hypertension, and other chronic conditions.

Measures for tracking obesity are either direct or surrogate (17), but the latter are currently being used globally due to their simplicity and practicality (18). For instance, direct measures such as magnetic resonance imaging (MRI) and computed tomography (CT) are the gold standards for detecting abdominal obesity (18). However, their clinical suitability in this regard has been queried since they are harmful, costly and time-consuming (18). As a result, surrogate measures of general obesity such as BMI, and central obesity such as waist circumference and waist-to-hip ratio, which are simple, cost-effective and less harmful are preferred (17, 18). However, it is still unclear which of these surrogate measures of overweight and obesity best reflect an increased risk of type 2 diabetes/prediabetes or hypertension among non-Caucasians (19), such as sub-Saharan Africans. Although BMI is currently being used worldwide for tackling overweight and obesity, measures of central obesity such as waist circumference have shown a greater ability to detect T2DM, hypertension, and cardiovascular disease (CVD) risk (20, 21).

Furthermore, BMI does not differentiate muscle from the fat mass (22) and cannot distinguish between peripheral fat and abdominal fat (23), when abdominal fat has been recognised as being the most clinically relevant type of fat in humans (17). Among the measures of abdominal obesity, waist circumference has been identified to have a superior predictive ability in detecting T2DM and hypertension risk (24). However, cut-off values for obesity indices in predicting T2DM, hypertension, and CVD risk are known to be population-specific (17, 19). Consequently, the ability of these obesity measures to predict type 2 diabetes/prediabetes and hypertension risk in people from SSA, and Swaziland in particular, may differ from that in other ethnic groups. Therefore, the present study was conducted to compare the predictive ability of BMI, WC, and WHR in identifying type 2 diabetes/prediabetes and hypertension risk and to determine their optimal cut-off levels.

Methods

A detailed description of the examination procedures, the participants' characteristics, and the description of the behavioural variables has been provided elsewhere (25, 26). Briefly, 385 patients attending the OPD for reasons other than diabetes or hypertension at the Raleigh Fitkin Memorial Hospital in Manzini, Swaziland, were included in this cross-sectional study. All patients who visited the OPD during the data collection period were included. Patients were included in the sample if they resided in the Manzini region; were 18 years of age and above; had fasted for 8 hours before the screening, and willingly consented to participate in the study. However, patients with active infection or using corticosteroids; who were pregnant; who had a temperature greater than 101.4 °F (38.6 °C); were taking antibiotics or anti-malaria medications or who were unwilling to participate were excluded. A representative sample of the medical and surgical outpatient population was surveyed.

Blood glucose

After observing a minimum of 8 hours' overnight fast, capillary blood was taken from a finger prick and analysed for fasting plasma glucose (FPG) concentration using On Call® EZ II, ACON Laboratory, Inc., USA) according to the manufacturer's instructions. Type 2 diabetes, impaired fasting glucose (IFG) and impaired glucose tolerance (IGT) were defined according to the 2003 WHO guidelines (27). Type 2 diabetes mellitus was defined as a fasting blood sugar (FBS) of > 7.0 mmol/l (27).

Blood pressure

Trained research assistants measured the blood pressure of the participants according to the American Heart Association (AHA) guidelines (28). The measurements were repeated after a minimum of 15 minutes, and mean values were recorded as the blood pressure. Hypertension was defined as a systolic blood pressure

(SBP) ⩾ 140 mmHg and a diastolic blood pressure (DBP) ⩾ 90 mmHg, or currently on antihypertensive medication (29).

Anthropometric measurements

Bodyweight (to the nearest 0.1 kg) was measured with participants in light clothing and barefoot, using a digital scale (FORA Digital Multi-function Diamond Scale). Height (to the nearest 0.1 cm) was measured with a stadiometer (SECA, Germany) while participants were barefoot. Body mass index (BMI) was calculated as the weight in kg divided by the height in m^2. Waist circumference (WC) (to the nearest 0.1 cm) was measured using a measuring tape, midpoint between the last palpable rib and the suprailiac crest, while participants were standing and breathing normally. Hip circumference (HC) was measured at the widest point around the greater trochanter. The waist and hip circumferences were measured with the tape parallel to the floor, and the waist-to-hip ratio (WHR) was defined as the ratio of WC to the hip (WC (cm)/HC (cm).

Definition of general and central obesity

General obesity was defined as a BMI⩾30 kg/m^2, while obesity stages I, II and III were defined as BMIs of 30-34.9, 35-39.9, and ⩾ 40 kg/ m^2, respectively according to the WHO's definitions (30). Underweight and overweight were defined as a BMI < 18.5 and a BMI of 24.5 – 29.9, respectively (30). Waist circumference was defined as normal, overweight, and obese for men (< 94, 94–102 and ⩾ 103 cm) and women (⩽ 80, 80–88, and ⩾ 89 cm), respectively. A raised WHR was defined as a WHR of >1.0 for men and >0.85 for women.

Statistical methods

Statistical analyses were conducted using SPSS version 26. A Chi-square test was applied to examine the association between the independent demographic and biometric variables and T2DM/prediabetes as well as hypertension. Besides subjects with T2DM/prediabetes and those with a normal glucose metabolism level, raised SBP and normal SBP were compared according to the anthropometric measurements including weight, height, hip circumference, BMI, WC, WHR using univariate ANOVA. Receiver operating characteristic (ROC) analysis was used to compare which of the measures of general (BMI) and central adiposity (WC and WHR) had the best predictive ability for identifying T2DM/prediabetes and hypertension risk. The area under the ROC curve (AUC) and (with 95% CI) was used to estimate the optimal cut-off value for each of the anthropometric indices. Diagnostic performance and the optimal cut-off value were determined using the Youden index that minimises 1 – (sensitivity + specificity) or

equivalently maximises the sum of sensitivity and specificity in the ROC space. A two-sided p-value < 0.05 was considered statistically significant in all analyses.

Results

Characteristics of the study population

Tables 1 and 2 show the general characteristics of the study population. The mean age (standard deviation) of the study participants was 37.77 (15.66) years; 36.47 (15.63) years for men and 39.14 (15.61) years for women, respectively. A total of 197 (51.2%) men and 188 (48.8%) women participated in the study. The overall crude prevalence of T2DM/prediabetes and hypertension was 13.8% and 13.0%, respectively. There was a significant gender difference in the prevalence of T2DM/prediabetes (p=0.035), but the difference was not statistically significant in the case of hypertension (p>0.05). Moreover, a significant age differential was observed in the prevalence of T2DM/prediabetes and hypertension. The highest prevalence of T2DM/prediabetes (32.3%) was seen in the 55 – 64 years age group, while the lowest (8.8%) occurred in the youngest group (p = 0.002). The prevalence of hypertension, however, peaked in the 65 years and older age group (p< 0.0001) (Table 1). There was a significant difference between participants with elevated glucose levels who possessed secondary or higher levels of education and those with normal glucose levels (p=0.025), and a similar association was seen in hypertensive compared with normotensive subjects (p<0.0001). Compared to participants who possessed a formal education, illiterates were more likely to develop T2DM/prediabetes or hypertension. General obesity (BMI) was significantly associated with T2DM/prediabetes (p=0.017) and hypertension (p<0.0001), but no significant association was observed between central obesity (WC and WHR) and T2DM/prediabetes (p>0.05) (Table 1). In both genders, the mean of the three anthropometric indices (BMI, WC, WHR) was higher in subjects with elevated glucose levels than in subjects with normal glucose levels (p<0.05 in all cases), and in subjects with a raised SBP compared to normotensive subjects (p<0.0001 in all cases). The mean values of all of the anthropometric indices (BMI, WC, WHR) were significantly higher in men with T2DM/prediabetes compared to men with normal glucose levels (p<0.05), but the association did not reach the level of statistical significance in women (p>0.05). Nevertheless, the mean of all three anthropometric indices yielded higher values in men and women with a raised SBP compared to their normotensive counterparts (p<0.05) (Table 2).

Table 1. Characteristics of the study population

	Glucose Status			Hypertension Status		
Characteristics	**NGM**	**AGM**	***p*-value**	**Normal**	**Hypertensive**	***p*-value**
N	332 (86.2)	53 (13.8)		335 (87.0)	50 (13.0)	
Sex			0.035*			0.277
Men	177 (89.8)	20 (10.2)		175 (88.8)	22 (11.2)	
Women	155 (82.4)	33 (17.6)		160 (85.1)	28 (14.9)	
Age group (years)			0.002*			<0.0001*
15 – 24	83 (91.2)	8 (8.8)		90 (99.9)	1 (1.1)	
25 – 34	98 (90.7)	10 (9.3)		101 (93.5)	7 (6.5)	
35 -44	76 (90.5)	8 (9.5)		73 (86.9)	11 (13.1)	
45 – 54	29 (72.5)	11 (27.5)		32 (80.0)	8 (20.0)	
55 – 64	21 (67.7)	10 (32.3)		23 (74.2)	8 (25.8)	
65+	25 (80.6)	6 (19.4)		16 (51.6)	15 (48.4)	
Education			0.027*			<0.0001*
No formal education	19 (73.1)	7 (26.9)		17 (65.4)	9 (34.6)	
Primary	78 (81.2)	18 (18.8)		78 (81.2)	18 (18.8)	
Secondary or higher	235 (89.4)	28 (10.6)		240 (91.3)	23 (8.7)	
BMI			0.017*			<0.0001*
Underweight	20 (95.2)	1 (4.8)		19 (90.5)	2 (9.5)	
Normal	170 (91.4)	16 (8.6)		172 (92.5)	14 (7.5)	
Overweight	80 (78.4)	9 (18.8)		89 (87.3)	13 (12.7)	
Obesity Stage I	39 (81.2	9 (18.8)		36 (75.0)	12 (25.0)	
Obesity Stage II	12 (75.0)	4 (25.0)		14 (87.5	2 (25.0)	
Obesity Stage III	11 (91.7)	1 (8.3)		5 (41.7)	7 (58.3)	
WC			0.865			0.123
Normal	189 (85.5)	32 (14.5)		186 (84.2)	35 (15.8)	
Overweight	52 (88.1)	7 (11.9)		55 (93.2)	4 (6.8)	
Obese	91 (86.7)	14 (13.3)		94 (89.5)	11 (10.5)	
WHR			0.319			0.269
Normal	210 (85.0)	37 (15.0)		211 (85.4)	36 (14.6)	
Overweight	41 (83.7)	8 (16.3)		46 (93.6)	3 (6.1)	
Obese	81 (91.0)	8 (9.0)		78 (87.6)	11 (12.4)	

AGM, abnormal glucose metabolism; BMI, body mass index; NGM, normal glucose metabolism; SBP, systolic blood pressure; WC, waist circumference; WHR, waist-to-hip ratio.

* Chi-square test significant at $p<0.05$

Table 2. The mean anthropometric measures according to gender

	Glucose Status			Hypertension Status		
Anthropometric measures	**NGM**	**AGM**	**p-value**	**Normal**	**Hypertensive**	**p-value**
Men						
Weight (kg)	67.72±12.52	73.57±13.82	0.052	67.71±12.59	73.08±13.24	0.062
Height (cm)	171.69±7.19	171.63±8.43	0.972	171.66±7.41	171.86±6.49	0.900
BMI (kg/m²)	22.97±4.05	25.00±4.433	0.036*	22.97±4.04	24.77±4.05	0.053
Hip circumference (cm)	94.83±12.23	96.75±9.42	0.497	94.81±11.85	96.68±12.99	0.0001*
Waist circumference (cm)	80.53±10.64	87.55±9.49	0.005*	80.39±10.42	88.05±10.90	0.001*
Waist-to-hip ratio	0.85±0.07	0.86±0.08	0.002*	0.85±0.08	0.92±0.08	<0.0001*
Women						
Weight (kg)	73.50±17.60	73.82±13.85	0.921	71.30±15.10	86.45±21.16	<0.0001*
Height (cm)	161.81±7.05	159.47±6.06	0.079	161.57±6.86	160.41±7.35	0.413
BMI (kg/m²)	28.12±6.73	29.02±5.24	0.470	27.33±5.60	33.71±8.42	<0.0001*
Hip circumference (cm)	105.17±13.41	106.49±15.07	0.617	103.45±12.30	116.54±15.95	<0.0001*
Waist circumference (cm)	88.83±15.91	93.30±17.81	0.153	87.18±15.01	103.57±16.56	<0.0001*
Waist-to-hip ratio	0.84±0.10	0.88±.015	0.073	0.84±0.11	0.89±0.11	0.021*
Total						
Weight (kg)	70.42±15.35	73.73±13.70	0.14	69.43±13.94	80.57±19.15	<0.0001*
Height (cm)	167.08±8.66	164.06±9.16	0.020*	166.84±8.75	165.45±8.99	<0.0001*
BMI (kg/m²)	25.37±6.03	27.50±5.25	0.016*	25.05±5.31	29.78±8.21	<0.0001*
Hip circumference (cm)	99.66±13.78	102.81±14.96	0.123	98.94±12.80	107.80±17.65	<0.0001*
Waist circumference (cm)	84.41±13.97	91.13±15.36	0.001*	83.63±13.24	96.74±16.21	<0.0001*
Waist-to-hip ratio	0.85±0.08	0.89±0.13	0.002*	0.85±0.09	0.90±0.10	<0.0001*

AGM, abnormal glucose metabolism (pre-diabetes and diabetes); NGM, normal glucose metabolism; SBP, systolic blood pressure
*Significant at p<0.05

Predictive ability of BMI, WC and WHR for the detection of elevated blood glucose and hypertension, and their appropriate cut-off values

Table 3 shows the ability of all the anthropometric indices (BMI, WC, WHR) to discriminate between T2DM/prediabetes and normal glucose levels, and between a raised SBP and normotension. For T2DM/prediabetes, WC yielded the strongest predictive potential in both the men (71%) and women (58%). The predictive values for all three anthropometric indices were statistically significant in men ($p<0.05$), but not in women ($p>0.05$). Among the three anthropometric indices, BMI had a weaker predictive power, except for T2DM/prediabetes where WHR had a weaker predictive ability in women.

In men, WHR showed the highest predictive (76%) ability to discriminate subjects with raised SBP from normotensive subjects, while WC (77%) yielded the highest in women. Except for BMI, all three anthropometric indices' predictive ability was significant in both genders ($p<0.05$). The predictive ability of BMI and WC was higher in women than men in terms of hypertension risk, while contrarily the WHR had a higher predictive ability in men (76%) than in women (70%).

The ROC curve based on the AUC was used to compare the anthropometric indices' predictive power with the risk of T2DM/prediabetes (Fig. 1) and hypertension (Fig. 2). To identify the risk of T2DM/prediabetes, the optimum cut-off value for BMI estimated for males (23.55 kg/ m^2) and females (24.45 kg/ m^2) was approximately the same. The optimum cut-off values estimated for WC (81.50 cm) and WHR (0.85) were higher in males than in females (79.0 cm for WC and 0.82 for WHR) (Table 3; Fig. 1).

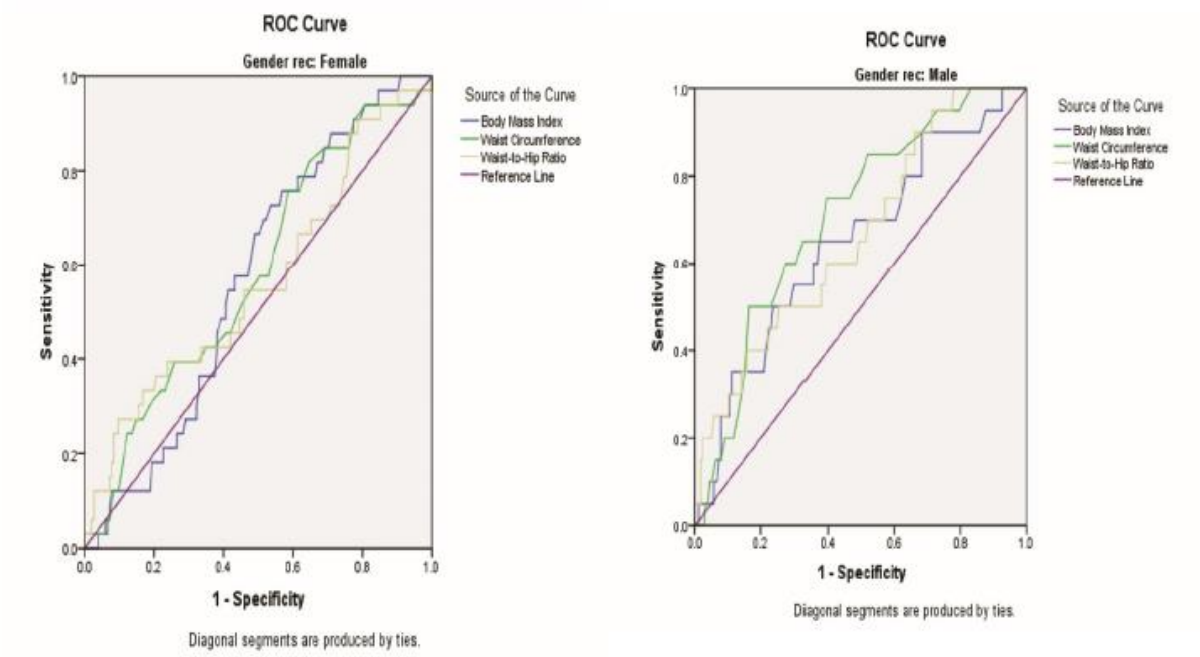
To identify the hypertension risk, the optimum cut-off points estimated for BMI (28.95 kg/m^2 vs 22.80 kg/m^2) and WC (89.5 cm vs 78.50 cm) were higher in females than in males. For the WHR, the optimum cut-off value (0.86) estimated for males and females was the same (Table 3; Fig. 2).

Table 3. Diagnostic accuracy of different anthropometric indices for the detection of prediabetes/diabetes and hypertension and their optimal cut-off values according to gender

Anthropometric indices	AUC (95%CI)	SE	Optimal cut-off	Sensitivity	Specificity	*p*-value
Elevated Blood Glucose						
Men						
BMI	0.646 (0.516 - 0.776)	0.066	23.35	0.600	0.633	0.032*
WC	0.708 (0.599 - 0.816)	0.055	81.50	0.650	0.627	0.002*
WHR	0.663 (0.542 - 0.785)	0.062	0.85	0.650	0.486	0.017*
Women						
BMI	0.570 (0.475 - 0.665)	0.048	25.45	0.758	0.400	0.209
WC	0.582 (0.478 - 0.687)	0.053	79.00	0.848	0.277	0.139
WHR	0.563 (0.450 - 0.677)	0.058	0.82	0.606	0.406	0.254
Raised Systolic Blood Pressure						
Men						
BMI	0.628 (0.506 - 0.750)	0.062	22.80	0.636	0.560	0.051
WC	0.704 (0.593 - 0.815)	0.057	78.50	0.773	0.503	0.002*
WHR	0.764 (0.677 - 0.850)	0.044	0.86	0.818	0.606	<0.0001*
Women						
BMI	0.736 (0.640 - 0.834)	0.049	28.95	0.750	0.669	<0.0001*
WC	0.774 (0.681 - 0.866)	0.047	89.50	0.821	0.600	<0.0001*
WHR	0.679 (0.563 - 0.796)	0.059	0.86	0.714	0.613	0.002*

BMI=body mass index, WC=waist circumference, SE=standard error, WHR=waist-to-hip ratio, AUC=area under the ROC curve, ROC=receiver operating characteristic

*Statistically significant at $p< 0.05$



a b

Fig. 1: Receiver operating characteristic curves of different anthropometric measures for the detection of abnormal glucose metabolism according to gender (a) men (b) women

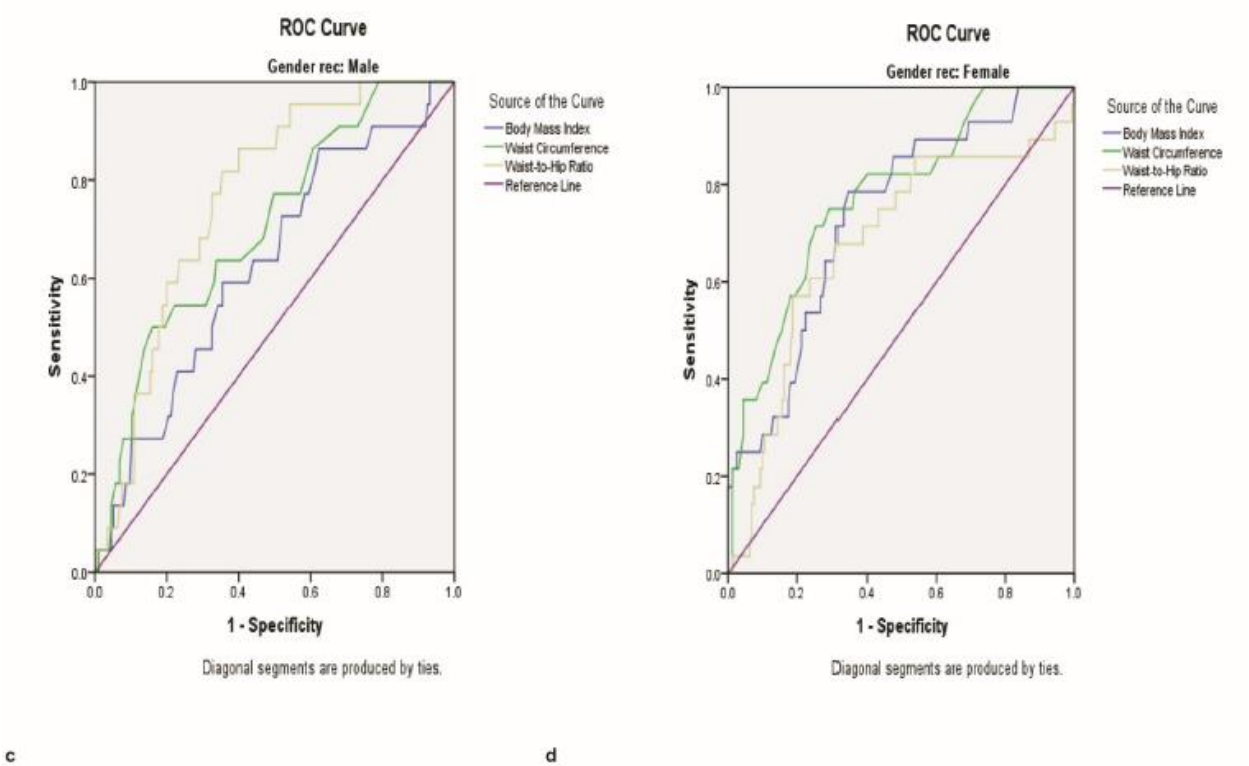


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Fig. 2: Receiver operating characteristic curves of different anthropometric measures for the detection of raised systolic blood pressure according to gender: (a) men (b) women

Discussion

To our knowledge, this is the first study to compare the predictive ability of BMI, WC and WHR as potential predictors of T2DM/prediabetes and hypertension risk, and to estimate their gender-specific optimum cut-off values in Swaziland. This study compared the performance of BMI, WC and WHR as potential predictors of T2DM/prediabetes and hypertension risk. Our results show that WC produced the highest predictive potential for T2DM/prediabetes risk, particularly among men. Also, WC and WHR performed better than BMI in their ability to discriminate subjects with raised SBP from normotensive subjects. Based on the ROC curve analysis, BMI values of 23.35 kg/m², a WC of 81.50 and a WHR of 0.85 for men were the optimum cut-off values to discriminate an elevated blood glucose level. The optimum cut-off values to separate hypertensive men and women from their normotensive counterparts were 22.80 and 28.95 kg/ m² (BMI), 78.50 and 89.50 cm (BMI) and 0.86 (WHR). In both genders, the mean values for all three anthropometric indices (BMI, WC, and WHR) were significantly higher in subjects with elevated blood glucose than those with normal glucose levels and in subjects with elevated SBP compared to normotensive subjects.

The higher mean values of anthropometric indices observed in the present study were consistent with previous studies elsewhere (32, 33) and may have been due to the higher level of physical inactivity among adult Swazi women (10). These results imply that individuals with high general obesity and central obesity values tend to have elevated blood glucose and high blood pressure.

The waist circumference's superiority over BMI in discriminating T2DM/prediabetes risk seen in the present study has been reported in other studies (34-36). In the present study, the ability of WC to predict T2DM/prediabetes risk was greater than that of BMI and WHR in both men and women, consistent with other studies. Haregu et al. (17) studied urban slum adults in Kenya and found WC to be superior to BMI in predicting hyperglycaemia. A study in Ghana reported that WC and WHR were better obesity measures for discriminating T2DM than BMI (38). In Ethiopia, Wai et al. (39) found WC as the best predictor of CVD risk compared to BMI and other adiposity measures. However, in a pooled analysis of 32 prospective studies, Vazquez et al. (38) did not find a significant difference in WC and BMI's ability to predict T2DM. The researchers recommend further studies to understand the usefulness of the central obesity indices (WC and WHR) over BMI. Similarly, WC's superiority (compared to BMI and WHR) for predicting hypertension risk in the present study was consistent with findings in previous reports (17, 37, 38). Studies conducted in Kenya (17) and Ethiopia (37) found WC as a superior anthropometric obesity index to identify the hypertension risk.

In the present study, the anthropometric indices of central obesity (WC and WHR) performed better than BMI, a measure of general obesity. Waist circumference yielded a higher ROC curve than either WHR or BMI and had a greater predictive ability for T2DM/prediabetes. Measures of central obesity (WC and WHR) were more sensitive but less specific than BMI to discriminate elevated blood glucose levels in men, whereas waist circumference was more sensitive than either BMI or WHR in women. With respect to hypertension, WC and WHR were more sensitive than BMI. These findings supported evidence from a longitudinal study where waist circumference yielded the highest ROC curve and had the greatest ability to identify diabetes risk (35). In a study of Chinese adults (39), WC showed a stronger association with CVD risk factors such as T2DM than BMI, and similar findings were reported in Thailand (40), Iran (41), and Mexico (42). Higher energy consumption is connected to stored fat in the central part of the body (43), and excessive fat accumulation is linked to ectopic fat deposition in the liver, pancreas, and skeletal muscle, according to growing data. This ectopic fat build-up can raise the risk of diabetes, dyslipidaemia, metabolic syndrome, CVDs, and other cardiometabolic disorders (44, 45).

There is almost a unanimous agreement on the association of central obesity measures with diabetes in both sexes in the literature. The lack of a significant AUC value for WC in discriminating prediabetes/diabetes observed among women in the present study, at variance with the findings from other studies, was not expected, and was possibly due to variations in population distinctiveness and cultural dynamics. Hips, thighs, and legs contain most of the body's skeletal muscles, which are the main target for insulin and thus the main site of insulin resistance (46,47). Swazi women are known to have larger hips, thighs and legs compared to Caucasians (48).

One of the challenges of using a surrogate measure of obesity is the variation in the cut-off point. The debates on the optimal cut-point are ongoing, and it has been established that the cut-off values for the anthropometric indices of obesity in predicting T2DM, hypertension, and CVD are population-specific (17, 19). In the present study, the optimum cut-off values for all three anthropometric indices (WC, WHR, and BMI) for identifying T2DM/prediabetes risk were all lower than the standardised values (according to the WHO) (31), except for the BMI for women which was like the standardised value. In contrast, the optimum cut-off values for all three anthropometric indices estimated to predict hypertension risk were higher than the standardised values for women but lower than the standardised values in men, except for WHR. These findings agreed with previous reports (38, 49-51) which found lower cut-off values for men and women than the standardised values. Like the findings from the present study, Frank et al. (36), Bouguran et al. (50) and Crowther et al. (52) found the optimum cut-off values to be higher in women compared with men. The estimation of optimal cut-off values for anthropometric indices is still a scarcely investigated area in

SSA, so further studies are required in SSA to determine the optimal cut-off values for predicting future T2DM and hypertension.

Women were more overweight and obese than men in the present study. Overweight in women can have a significant impact on their reproductive health, particularly pregnancy and childbirth. For instance, obese women are at an increased risk of gestational diabetes and preeclampsia, and are more likely to deliver via caesarean operation (53). There is, therefore, a need for cost-effective strategies to prevent overweight and obesity in women and at-risk individuals, and for these strategies to be effective, a multi-disciplinary and multi-sectorial approach must be adopted.

In the present study, waist circumference yielded a superior predictive ability to discriminate T2DM/prediabetes (in men only) and hypertension risk. The superiority observed in the predictive ability of WC compared to BMI or WHR was expected since organisations like the National Institute of Health have advocated for the use of WC in clinical practice (54). Furthermore, studies (55, 56) have identified increased visceral tissue as the most clinically relevant body fat associated with T2DM and hypertension. Therefore, measuring WC in addition to measuring BMI may improve the ability of healthcare providers to identify T2DM and hypertension risk accurately. The waist circumference is easy to determine in busy healthcare settings and should be included in the management of cardiometabolic diseases.

Strengths and limitations of the study

The cross-sectional nature of this study may limit the causal interpretation of the findings, so future prospective studies are needed to understand the direction of the causality observed in this study. Furthermore, investigations are warranted to evaluate the usefulness of country-specific cut-off values for obesity indices to identify T2DM/prediabetes and hypertension risk in SSA. However, our study had some merit, as the use of trained clinicians in the measurement of biochemical and anthropometric measurements minimised bias.

Conclusions

Waist circumference emerged as the anthropometric index with the highest predictive value to identify T2DM/prediabetes and hypertension risk among adult outpatients in this clinical setting. The optimum WC cut-off values of 81.5 cm (in men only) but 78.5 vs 89.50, respectively for men and women predicted T2DM/prediabetes and hypertension risk better than WHR and BMI, and discriminated subjects with elevated glucose from non-diabetic (in men only), as well as subjects with a high SBP from normotensive subjects in both sexes. These findings emphasised the need to adopt WC in addition to BMI as an appropriate obesity measurement for the identification of T2DM and hypertension risk.

List of Abbreviations

BMI	Body mass index
CVD	Cardiovascular disease
HTN	Hypertension
SBP	Systolic blood pressure
SSA	Sub-Saharan Africa
T2DM	Type 2 diabetes mellitus
WC	Waist circumference
WHO	World Health Organization
WHR	Waist-to-hip ratio

Declarations

Authors' contributions

MG reviewed the literature, and made substantial contributions to the conception, design, and drafting of the manuscript. BT participated in the design of the study and/or the drafting of the manuscript. Both authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this manuscript.

Ethical considerations

The study was approved by the Biomedical Research Ethics Committee (BREC) of the University of Kwa Zulu-Natal (UKZN) (Reference: BE 385/18). Participation was voluntary and written informed consent was obtained from each participant. No participant under 18 years was included in this study. Therefore, there was no need to obtain written informed consent from participants' parents or guardians.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

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CHAPTER FIVE

SYNTHESIS/DISCUSSION

5. Introduction

This section of the thesis discusses the findings of all of the chapters in an integrated fashion to highlight the contribution of this dissertation to the existing body of knowledge and the implications of this work, to provide some recommendations, and to highlight future related research questions that still need to be addressed.

5.1 Thesis Overview

The aim of this study was to assess the prevalence and risk factors associated with type 2 diabetes mellitus among adults attending the OPD at a Tertiary Hospital in Manzini, Swaziland. The research presented in this thesis fulfilled the study objectives in examining the issue of T2DM among adult outpatients in Manzini, Swaziland. Following a review of the relevant literature, background information, and a brief overview of the general methodology (Chapter One), the prevalence of T2DM was assessed (Chapter Two). Thereafter, the risk factors associated with T2DM, pre-diabetes, hypertension (Chapter Three) and obesity and overweight (Chapter Four) were identified. Next, the anthropometric predictor and optimum cut off values were assessed.

5.2 Synthesis

This thesis combined data from four separate but interrelated papers. In this section, the main findings from the four manuscripts are summarised. These results are compared with other research findings and their importance is evaluated. Also, the limitations of this study and the implications of these findings for policy and practice are presented.

5.2.1 Prevalence of type 2 diabetes mellitus, hypertension, and obesity among adult outpatients at a Manzini Tertiary Hospital, Swaziland

Key findings:

- High burden of type 2 diabetes mellitus, hypertension, and obesity.
- Increasing prevalence of type 2 diabetes, hypertension, and obesity with advancing age.
- Significant gender disparity in the prevalence of type 2 diabetes, hypertension, and obesity.
- An alarming rate of newly detected type 2 diabetes cases.

5.2.1.1 Prevalence of abnormal glucose metabolism, T2DM and pre-diabetes

In general, the findings of this study revealed a high prevalence of AGM among patients aged 18 years and above in this public health facility (Papers I, II, III). Hyperglycaemia (AGM) was observed in 13.8% of the adult outpatients, consistent with a previous report in Swaziland (1) and elsewhere in SSA (2). The estimated prevalence of T2DM (7.3%) in the present study was higher than the 5.0% reported previously in this hospital among HIV-infected patients (3), but lower than the 14% estimated in the STEPS survey (1). This discrepancy may have been due to a lower cut-off value used in the STEPS survey and the use of different diagnostic criteria by Rabkin et al. (3); glycated haemoglobin is known to underestimate the blood glucose measurement in HIV-infected individuals (4). In Africa, the prevalence of T2DM among adults 20 – 79 years old ranged from 2.1% - 7.1% in 2019 (5). Like studies in other African countries, the prevalence

of pre-diabetes, a risk factor for T2DM, was 6.5% in the present study (Paper I). There was no comparative figure from previous studies in Swaziland because the prevalence of pre-diabetes was not assessed in the studies. Nevertheless, this finding was consistent with previous reports elsewhere in SSA (6-9). The estimated pre-diabetes prevalence in the present study was within the 2 – 16% estimated for SSA in an IDF report (10).

5.2.1.2 Prevalence of hypertension among adult outpatients in a Manzini Tertiary Hospital, Swaziland

The prevalence of hypertension was higher according to the ACC/AHA criteria (48.3%) (Paper II) than the WHO criteria (13%) (Paper III) currently used in Swaziland and in many other countries in SSA. Based on the ACC/AHA criteria, an estimated 29.4% and 18.9% of the participants were diagnosed with stage one and two hypertension, respectively (Papers I & II). The estimated hypertension prevalence (based on WHO criteria) was higher than previous estimates in this health facility, but lower than previous estimates in Swaziland (1). Based on the ACC/AHA criteria, the estimated prevalence of hypertension in the present study was higher than previously reported in Swaziland (1, 3). Few studies have used the ACC/AHA criteria to diagnose hypertension in SSA. Nevertheless, the benefit of this new guideline was echoed in an observational study (11) conducted in the USA and China. The major benefit of the new ACC/AHA guidelines is in the lowering of major cardiovascular events.

5.2.1.3 Prevalence of overweight and obesity among adult outpatients in a Manzini Hospital, Swaziland

In general, central obesity was more prevalent than general obesity among the Swazi population. The overall prevalence of central obesity by waist circumference (27.6%) was higher than the prevalence by waist-to-hip ratio (23.1%). In contrast, the prevalence of overweight by BMI (26.5%) was higher than the rate according to either WC (15.3%) or WHR (12.7%). Previous reports in Swaziland (1, 12) focused on general obesity (BMI) only, but the present study confirmed the epidemic nature of overweight and obesity in Swaziland. The prevalence of general obesity found in the present study was consistent with a previous report in Swaziland (1) but higher than that reported in Uganda (13, 14). The overall prevalence of overweight was consistent with findings elsewhere in SSA (15). Similarly, a low prevalence of underweight observed in the present study was consistent with a previous report in Swaziland (1) and elsewhere in SSA (13, 16).

5.2.1.4 Increasing prevalence of chronic diseases with advancing age

The increasing prevalence of T2DM, pre-diabetes (Paper I), hypertension (Paper II) and obesity and overweight (Paper IV) with advancing age observed in the present study was consistent with previous reports in SSA (6,17-20). A plausible explanation for the association between increasing age and the prevalence of NCD may be due to the lower levels of physical activity associated with advancing age. Also, the mean glucose concentration peaked within the age group 45-64 years old. This suggests the effect of ageing on T2DM in this setting; the age at onset of T2DM may shift to younger age groups as the T2DM epidemic matures (21).

5.2.1.5 High rate of newly diagnosed T2DM

The high rate of screen detected T2DM cases in the present study (Paper I) was consistent with previous findings in SSA (18, 22). This finding implies that current screening services are unable to detect many people with type 2 diabetes in its early stages. A study conducted at the national referral hospital in Uganda found that most of the T2DM patients presented with classical symptoms of T2DM, indicating that diagnosis occurred late (23).

5.2.1.6 Significant gender disparity in the prevalence of chronic diseases

In this clinical setting, pre-diabetes and hypertension appeared to be common among men but T2DM and obesity were more predominant in women. This observation was the same as previous evidence in SSA (24). Studies in SSA reported a higher prevalence of pre-diabetes (8, 20, 25-27) in men compared to women. The most plausible explanation is the higher prevalence of smoking among men in the present study. It is well known that smoking appears to increase the risk of impaired fasting glucose (IFG) by decreasing insulin sensitivity (28). In Kenya, however, Mohammed et al. (6) reported a lower prevalence of pre-diabetes among men compared to women. This variation between the present study findings and Mohamed et al.'s finding could be due to the observed regional variations in the sex differences in the prevalence of IFG and IGT in SSA.

The observed gender differential in the prevalence of hypertension in the present study was consistent with previous reports in SSA (6, 28-30). Like the present study, studies in SSA (29, 30) reported a higher prevalence of hypertension among men than women. However, some studies (17, 31, 32) found a higher prevalence of hypertension among women than men in SSA. Insulin resistance and insulin action may have played a role in the observed gender differential in hypertension prevalence in the present study. Insulin resistance is a key risk factor for the development of hypertension and is associated with other markers of CVD, including impaired endothelial function, and increased vascular reactivity. Prediabetes was more

common among men than women in the present study, and it was not surprising that men were more affected by hypertension, possibly due to insulin resistance.

Like the present study, previous reports from Swaziland and studies in SSA have reported a higher prevalence of T2DM (33-35) and obesity (1, 13, 36-39) among women than men. Contrarily, Bahadeka et al. (8) reported a higher prevalence of T2DM among men compared to women. Also, Adebayo et al. (40) reported a higher proportion of overweight/obesity in men than women. The sex differences in the prevalence of T2DM in the present study may have been due to the higher prevalence of central obesity among women than men. Central obesity is a stronger predictor of T2DM than general obesity (41). Similarly, a possible explanation for the high prevalence of obesity among women in the present study could be the higher prevalence of physical inactivity and a sedentary lifestyle, lower consumption of the recommended daily intake of fruit and vegetables, and higher consumption of salty processed foods in women compared to men. The next section discusses the influence of globalisation and socioeconomic status on the rising prevalence of T2DM, hypertension and obesity.

5.2.2 Globalisation/socioeconomic status and chronic diseases

Key findings:

- Influence of lifestyle factors on the prevalence of chronic diseases.
- Modifiable and non-modifiable risk factors associated with chronic diseases.
- The dynamic nature of the influence of socioeconomic status on the development of chronic diseases.

5.2.2.1 The influence of lifestyle factors on chronic diseases

The relatively high burden of NCDs found in the present study confirmed the NCD epidemic in SSA (53). The high burden of chronic NCDs (T2DM, hypertension and obesity) observed in the present study was consistent with previous reports elsewhere (53, 54). This high burden of chronic diseases is thought to be propelled by demographic, nutritional and lifestyle factors, driven mainly by urbanisation, industrialisation and globalisation (55). The traditional African diets (majorly based on legumes, whole grains and traditional vegetables) have been replaced with western diets. These foods are rich in fats and oils, sweetened beverages and low fibre (56).

The influence of westernisation manifested in the present study, considering the level of tobacco use, alcohol consumption, consumption of sweet beverages, and consumption of salty processed foods by the subjects. Findings suggested that tobacco use was common among the sample, with current smokers

accounting for 18.2% of the total sample, the majority of whom were males (Paper II). Furthermore, the prevalence of previous smoking history was unacceptably high (31.2%) among the studied participants (Paper II). This was far higher than the prevalence of 6%, 9% and 2.9% reported in the STEPs survey (1), by Rabkin et al. (3) and Masona (57), respectively. It is suspected that the patients may have been provided with the health benefits of quitting smoking. Of note is the potential influence of the Tobacco Product Control Act 2013 introduced in Swaziland. Various components of the legislation, including adequate health education, control of advertising, sale, and packaging of tobacco products may play a part in the smoking history observed. Expectedly, tobacco smoking was more prevalent among men compared to women, consistent with other observations in Swaziland (1) and elsewhere in SSA (58). In the present study smoking was an independent determinant of pre-diabetes, consistent with previous reports from SSA and elsewhere (59, 60). Individuals in the present study with a previous or current smoking history were eight times more likely to develop prediabetes, compared to non-smokers. Studies have reported a positive association between smoking and insulin resistance (61, 62).

Moderate or excessive consumption of alcohol was significantly associated with the risk of hypertension in the present study. The Stepwise Approach to Surveillance (STEPS) survey (1) in Swaziland identified alcohol as a significant risk factor for NCDs, including hypertension. Like the present study, Peer et al. (17) found an increased risk of hypertension among black Southern Africans with excessive alcohol use. Excessive consumption of alcohol is a known risk factor for hypertension, while the moderate use of alcohol has a protective effect on hypertension (63). There is thus a need to address the harmful use of alcohol in this setting.

The consumption of sweet drinks, which included sweet coffee, sweet tea, soda, and other sweetened beverages, was independently significantly associated with T2DM and pre-diabetes in the present study, consistent with previous reports elsewhere (64, 65). In a prospective study of more than 50 000 women, Schulze et al. (66) found an 83% increased risk of developing T2DM for those who consumed $\geqslant$ 1 sweet drink per day compared with those who consumed <1 sweet drink per month. Unlike the present study and that of Schulze et al., a study by Malik et al. (67) did not observe a significant association between the consumption of sweet drinks and the risk of T2DM. It is suspected that the age differential may have played a role since many of the consumers in Malik et al.'s study were young adults. More importantly, the fructose component of sugar in sweet drinks is considered a singularly harmful macronutrient and has been suggested to lead to obesity, hyperlipidaemia, and insulin resistance; key risk factors for T2DM and CVDs (68).

In the present study the consumption of salty processed foods was a significant determinant of T2DM, pre-diabetes, and hypertension. Like the present study, evidence elsewhere has shown a positive relationship

between the consumption of salty processed food and T2DM (69) and hypertension (70). In the present study, individuals who consumed salty processed foods moderately or regularly were seven times more likely to develop T2DM or pre-diabetes, and twice as likely to develop hypertension, compared to those consumers who did so rarely. A possible explanation for this is that the consumption of processed food, high in non-water-soluble fats, contributed to the weight gain observed among the participants (reflected in the obesity indices). It is well known that obesity is the most important risk factor for T2DM, pre-diabetes and hypertension (71). The influence of the consumption of salty processed foods on the NCD risk is a scarcely investigated subject in SSA, therefore more studies are needed to understand the mechanisms linking the consumption of salty processed foods to cardio metabolic diseases.

Salt use and consumption of salty processed foods were significantly associated with the risk of HTN in the present study. These findings were consistent with a previous report elsewhere (72). Salt intake has a direct relationship with high BP and the prevalence of HTN (73). Furthermore, processed foods are the main source of dietary sodium in many countries (74). It is known that a high intake of salt affects left ventricular hypertrophy directly and is an independent predictor of renal disease, proteinuria, and stroke (75, 76). Therefore, the WHO recommends a daily intake of fewer than five grams of salt to reduce the risk of stroke and IHD (77).

5.2.2.2. Modifiable and non-modifiable risk factors associated with chronic diseases

In the present study, both modifiable and non-modifiable risk factors were associated with the chronic NCDs studied. Modifiable risk factors significantly associated with abnormal glucose metabolism included diet, physical activity, smoking, alcohol, overweight and obesity. Consumption of fruits and vegetable were independently significantly associated with reduced risk of T2DM, pre-diabetes and hypertension in the present study (Paper II), in agreement with previous evidence in SSA. The protective impact of vegetable consumption on the risk of T2DM, pre-diabetes, and hypertension observed in the present study was expected, and was consistent with reports from Sub-Saharan Africa and elsewhere (78-80). Studies have shown that the adequate consumption of fruit and vegetables reduces T2DM (78, 79), hypertension and cardiovascular incidences (81) as they are high in fibre and other micronutrients, but low in glycaemic load and energy density (78, 79). Surprisingly, the inverse relationship observed between the consumption of fruits, and the risk of hypertension did not reach a level of statistical significance — the reason for this warrants further investigation.

Physical inactivity is an independent predictor of T2DM, pre-diabetes and hypertension (82). Surprisingly, physical inactivity was not significantly associated with T2DM, pre-diabetes, and raised BP in this study. This finding was consistent with findings from Nigeria (58) but differed from a report which found physical

inactivity is associated with an increased risk of HTN (83). Nevertheless, the promotion of recommendations by the WHO on physical activity for health should be sustained.

5.2.2.3. Socioeconomic status and the development of chronic diseases

Four surrogate indicators of wealth were examined as part of this study. These could be described as domestic wealth, which included acquired wealth, ownership of agricultural land and livestock, household assets, income, education, and occupation. These surrogate measures of wealth had a different influence on T2DM, hypertension, and excess adiposity. The results were dynamic, as higher levels of education resulted in a higher proportion of obesity, but a lower rate of T2DM. The effects of wealth extended into the development of chronic diseases and examination of those relationships was a novel aspect of this study. The appearance of wealth could be assumed by external indicators such as excess adiposity (84, 85); however, ownership of agricultural land and livestock and household assets appeared to have an association with excessive adiposity in this study and could be considered an indicator of tangible wealth, whereas obesity could represent pseudo-wealth (55).

Household wealth and education were the socio-economic variables independently associated with T2DM and pre-diabetes, respectively. Respondents from a lower SES household were significantly at risk of T2DM, whereas a mid-level SES was significantly associated with a reduced T2DM risk, consistent with findings elsewhere (86, 87). However, this finding was contrary to the positive association found among outpatients in Ghana (80). Recent epidemiological studies in SSA have observed an increased risk of T2DM among individuals from high SES households (89-91). Prospective studies are thus needed in SSA to understand the influence of SES on the risk of T2DM, pre-diabetes and hypertension in SSA. In a Kenyan study by Mohammed et al. (6), a primary education was inversely associated with pre-diabetes. In the present study, participants with a secondary or higher education were at a 31.5% reduced risk of developing pre-diabetes. Studies conducted in Europe have shown the beneficial influence of a formal education on the risk of diabetes (92, 93). This finding shows the importance of education in reversing pre-diabetes to prevent its progression into full T2DM.

Findings from this study indicate that the behavioural risk factors for NCDs are potentially modifiable. Nevertheless, the behavioural risk factors are influenced by social stratification in the society. Individuals from a high SES can afford the more expensive, highly refined, and energy-dense western foods (25, 43) but have little opportunities for physical activities (6). The consumption of energy-dense foods, accompanied by decreasing physical activity has been linked to the rising prevalence of overweight and obesity in SSA (55, 56). Several anthropometric measurements are used to identify individuals at risk of obesity, however it remains unclear which of the anthropometric indices is the best to identify individuals

at risk of T2DM and hypertension. The next section compares the predictive ability of the three commonly used anthropometric indices to identify T2DM and hypertension risk, and estimatesd their cut-off values.

5.2.3 Biometric predictors of health

Key findings:

- Waist circumference yielded a superior predictive ability to identify the future risk of type 2 diabetes and hypertension, compared to BMI and WHR.
- There was significant gender disparity in the predictive ability of the obesity indices. The predictive ability of BMI, WC, and WHR to predict T2DM/pre-diabetes and hypertension was higher in men than in women; but (BMI) was higher in women than men for hypertension.
- Both measures of central obesity (WC and WHR) and general obesity (BMI) were significantly associated with T2DM and hypertension.

5.2.3.1 Association of obesity with T2DM/pre-diabetes and hypertension

Findings from the present study showed that both measures of central obesity (WC and WHR) and general obesity (BMI) were significantly associated with either T2DM or hypertension (Papers II, III, IV). Also, both central obesity (WHR) and general obesity (BMI) significantly predicted T2DM and hypertension (Paper III) in this Swazi population, indicating the importance of overweight and obesity in the prevention and management of T2DM and hypertension. The observed association of obesity, measured by the surrogate anthropometric measures, T2DM and hypertension in this Swazi setting has been reported in the previous studies. Previous studies (42, 43) have documented the beneficial effect of weight reduction, in addition to lifestyle factors, in the prevention and management of T2DM and hypertension. It has been suggested (44) that the rising rate of obesity in a population is a precursor of the escalating incidence of chronic diseases, notably T2DM and hypertension. The findings of the present study affirmed the positive, independent association between obesity and T2DM and hypertension (Papers I-IV).

5.2.3.2. Predictive ability of anthropometric measurements

The superiority of waist circumference (WC) over BMI in predicting T2DM in the present study (P III) has been reported in other studies (45-47). Like the present study, previous studies in SSA (48, 49) have reported the superiority of WC over BMI or WHR in identifying future risk of hypertension. In the present study, the ability of waist circumference to predict T2DM and pre-diabetes was greater than that of BMI and WHR in both men and women, consistent with other studies. Haragu et al. (48), in their study of urban slum adults in Kenya, found WC to be superior to BMI in predicting hyperglycaemia. A study in Ghana

reported that WC and WHR were better obesity measures for discriminating T2DM compared to BMI (49). In Ethiopia, Wai et al. (49) found WC as the best predictor of CVD risk compared to BMI and other measures of adiposity. Similarly, the superiority of WC to BMI and WHR in predicting the risk of hypertension in the present study was consistent with findings in previous reports. Studies in Kenya (48) and Ethiopia (49) found WC as the superior anthropometric obesity index to identify the future risk of developing hypertension. However, in a pooled analysis of 32 prospective studies, Vazquez et al. (50) did not find a significant difference in the ability of WC and BMI to predict T2DM. The authors concluded that future research is necessary to understand the central obesity indices (WC and WHR) over BMI, despite the clinical usefulness of central obesity in identifying T2DM.

5.2.3.3. Significant gender disparity in the predictive ability of obesity indices

The significant gender disparity observed in the predictive ability of obesity indices in the present study (PIII) has been reported previously elsewhere (51). The lower predictive ability of BMI found in men in the present study may have been due to the dependency of BMI on height. Men were taller than women in the present study, so BMI in men was expected to be more affected by height. The lower predictive ability of BMI in men could also relate to their higher muscle mass compared to women. In women, the predictive ability of BMI was close to that of waist circumference. Therefore, in women, both measures of central obesity (WC and WHR) and even BMI showed similar predictive abilities.

5.2.3.4. Cut-off values for anthropometric measurements to identify T2DM/pre-diabetes and hypertension risk

In the present study, optimum cut-off values of waist circumference, 81.5 cm vs 79.0 cm and 78.5 cm vs 89.5 cm in men and women, respectively predicted T2DM and hypertension better than WHR and BMI and discriminated diabetic from non-diabetic and high SBP from normal SBP in both sexes (PIII). This is a scantily researched topic in SSA, therefore, research based on large prospective data is required in SSA to establish ethnic-specific optimum cut-off values for identifying T2DM and hypertension risk. Ethnic-specific differences in the cut-off values of WC have been reported elsewhere. For instance, optimum cut-off values of 102 cm vs 88 cm were reported for American men and women (52), and 94 cm (for men) and 80 cm (for women) were reported as the optimum cut-off values for Europeans, while among Asian men and women 90 cm was the optimum cut-off value to identify their cardiometabolic risk. It is important to note that differences in cut-off points of obesity have a profound effect on prevalence estimates. The comparative analysis of the prevalence estimates for obesity show that the WHO cut-off points underestimate general and central obesity among Swazi men, and the ROC curves underestimate the general and central obesity (except WC) among women. Using gender-specific cut-offs for WC may offer putative

markers for early detection of cardiometabolic risk factors among outpatients; therefore, being a simple and easy-to-detect measure, WC should be used in addition to BMI in the clinical management of cardiometabolic diseases in this setting.

5.3 Contributions to the Body of Knowledge

Comparing the findings from the present study with the literature, the current study:

- Confirms the negative influence of wealth and behavioural factors on the risk of chronic diseases. This was a novel aspect of this study. Overwhelming evidence suggests that household wealth, the adoption of western lifestyles (smoking, alcohol use, consumption of salty processed foods, and sweetened beverages) are potentially modifiable risk factors for T2DM. Given the limited studies from Swaziland, the present study determined the relationship between these modifiable risk factors and chronic diseases among adult outpatients in the second-largest hospital in Swaziland.
- Provides additional evidence on the prevalence of chronic diseases in Swaziland and SSA, which are increasing. This study estimated the age-adjusted prevalence of T2DM and pre-diabetes among adults attending OPD in the second largest hospital in Swaziland for the first time.
- Confirms the previous evidence of an alarming rate of newly detected T2DM cases in SSA. Evidence suggests that up to 90% of T2DM cases are screen-detected in cross-sectional studies in SSA. In the present study, 89.3% of the T2DM cases were identified during the study. These participants were previously unaware of their condition.
- Supports the evidence linking age with an increased prevalence of chronic diseases. The importance of age as a non-modifiable risk factor for chronic diseases, consistent with previous reports, was highlighted and discussed in chapter two.
- Supports the evidence linking gender with an increased prevalence of chronic diseases as an important non-modifiable risk factor for chronic diseases; discussed in chapter two.
- Supports previous findings that the use of ethnic- and sex-specific cut-off values in different populations are needed for anthropometric indices. The current WHO recommended cut-off values for obesity measures are unsuitable for assessing T2DM and hypertension risk in this Swazi population. The present study supports the use of country-specific or region-specific cut-off values for anthropometric measures to identify individuals at increased risk of T2DM and hypertension in SSA.

5.4 Strengths and Limitations

The main strength of this study is the accuracy of the biometric and anthropometric measurements by qualified and trained field staff. This may have improved the reliability of the data. Also, using social epidemiology, this study examined how globalisation and improved socioeconomic status are associated with adiposity, AGM and hypertension. This provides a new lens on the emerging health implications of social factors.

The cross-sectional nature of this study precludes making causal inferences due to the absence of temporarity between the outcomes and exposure. Also, the results may be subject to biases, particularly selection, and recall bias. The participants in the study were recruited from an OPD at a tertiary hospital and hence are not representative of the Swazi population. It is likely that the respondents may not have provided accurate information due to recall bias or due to the sensitivity of such information, especially for socially undesirable behaviours like smoking, alcohol use, unhealthy diet, and physical inactivity.

5.5 Implications of the Study Findings

These findings have many implications on health education and health service delivery. First, the high prevalence of T2DM, pre-diabetes and hypertension calls for strengthening of the secondary care of chronic diseases, including diagnosis, treatment, and follow-up. The burden of T2DM and CVD in Swaziland is likely to increase due to the improvement in the life expectancy and high burden of communicable diseases, particularly HIV/AIDS and TB. This is because the majority of the individuals affected by these conditions are not aware of their conditions. This potential increase in the burden of chronic diseases is likely to overstretch the already overburdened healthcare system. There is a need for capacity strengthening and provision of logistics for health facilities to facilitate the diagnosis, treatment and follow-up of patients and the at-risk population. The OPDs need to be redesigned to incorporate follow-ups in chronic care services. Furthermore, most patients with T2DM in the present study were newly diagnosed with the disease. This indicates that the current screening practices in this hospital are not effective. Therefore, it is suggested that a routine blood glucose test be incorporated into healthcare services at outpatient departments in the hospitals in the country.

The present study highlights that modifiable risk factors, particularly obesity, socioeconomic and lifestyle factors play an important role in the prevalence of chronic diseases in this setting. Previous studies have documented the importance of weight reduction and the adoption of healthy lifestyles in tackling the rising epidemic of T2DM, hypertension, and obesity. Findings from the present study indicate that weight gain is an important risk factor for hyperglycaemia (T2DM and prediabetes) and hypertension. Therefore, strategies to control body weight, particularly by concerned individuals, are the most effective way to

reduce the risk of NCDs in this setting. As pointed out by Manning (86), the patients and the public may not understand the association between overweight or obesity and chronic NCDs, so public health education strategies should be employed to create awareness among patients and the public in general. Chronic diseases (particularly T2DM, hypertension, and obesity) prevention policies are warranted in this setting, in Swaziland, and in SSA as a whole. Specifically, policies targeting modest weight reduction and increased physical activities should be implemented, but in order for these policies to be effective, concerted efforts will be required by the stakeholders. To this end, public health messages must be formulated and health professionals, non-governmental organisations (NGOs) and public health policymakers must collaborate to promote behaviour change for healthy lifestyles among the people.

The present study confirms the previous findings on the superiority of central obesity (measured by waist circumference) as a better predictor for T2DM and hypertension compared to general obesity (measured by BMI). It is not clear whether obesity is the sentinel event, however, these findings may have pathophysiologic implications since the presence of central obesity with hypertension and T2DM in a patient suggests the presence of the metabolic syndrome. Therefore, waist circumference, which is easy to measure in busy health care settings, must be included (in addition to BMI) in the clinical management of cardiometabolic diseases in this setting, in Swaziland, and in SSA as a whole.

The female gender was associated with obesity in the present study, consistent with previous findings. Therefore, measures to improve the socio-economic conditions of women are necessary in Swaziland to reduce the inequalities between men and women and to curb the growing burden of chronic diseases in the kingdom.

5.6 Areas for Future Studies

Future studies are needed to confirm the prevalence of T2DM and hypertension in this setting and in other regions in Swaziland. Although there is a controversy regarding the usefulness of glycated haemoglobin (HbA1c) in African populations, future studies must compare point of care glycated haemoglobin (HbA1c) levels to the standard capillary blood glucose levels to determine the usefulness and cost-effectiveness of the latter for screening purposes. Further, future research must use prospective studies to examine the anthropometric measures and cut-off points in the Swazi population.

This study examined the effect of the adoption of a western lifestyle and this was a novel exploration. This should be replicated, especially at community level. Future studies must examine caloric intake and caloric expenditure objectively; calories consumed should be measured while calories expended should also be quantified.

The current study used the ROC curve analysis to examine the strength of the anthropometric measurements (BMI, WC, WHR) and their optimum cut-off values. Future studies may consider the use of the Bayesian model and clarify which of the two approaches is better for different populations.

5.7 Conclusions

The growing burden of T2DM is a concern to public health professionals, patients with diabetes, and policymakers worldwide. Findings from the present study indicate the need to consider the three components of the global NCD strategy: surveillance, management, and control of NCDs including T2DM, hypertension, and obesity. More importantly, the high rate of newly detected T2DM cases shows that the current screening practices in this hospital are not effective. Therefore, a routine blood glucose test should be incorporated into the screening regimen in the OPD in this hospital and in other clinical settings in Swaziland.

The higher prevalence of T2DM, hypertension and obesity in this setting compared to the previous study is concerning. In a resource-limited setting such as Swaziland, these conditions can have devastating effects unless urgent measures are taken to address the growing epidemic of T2DM and other chronic diseases in Swaziland. Additional studies are required to confirm the prevalence of T2DM and HTN in this hospital as well as on other areas in Swaziland.

Modifiable risk factors played an important role in the rising prevalence of T2DM, HTN, and obesity in the present study. Particularly, the influence of westernisation is apparent among this population. The influence of globalisation is evident through the availability of energy-dense foods, frequent consumption of processed foods, and the high rate of sweet drink consumption among this population, all associated with the prevalence of T2DM, hypertension and obesity. Cost-effective and culturally acceptable interventions are needed to promote healthy lifestyles among this population and the general Swazi population. Further studies are needed to understand the implications of globalisation and culture on the burden of chronic diseases in Swaziland and in SSA.

The present study confirms the previous evidence that obesity is an important risk factor for T2DM and hypertension. This shows the importance of obesity in the prevention of T2DM and hypertension. In the present study, waist circumference is identified as the best anthropometric measure for identifying the risk of T2DM and HTN. Therefore, waist circumference should be used as a screening tool in this setting and in other clinical settings in Swaziland and SSA. Also, ethnic- and sex-specific cut-off values of waist circumference and body mass index should be considered in setting the diagnostic criteria for obesity.

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APPENDICES

Appendix 1 CONSORT diagram

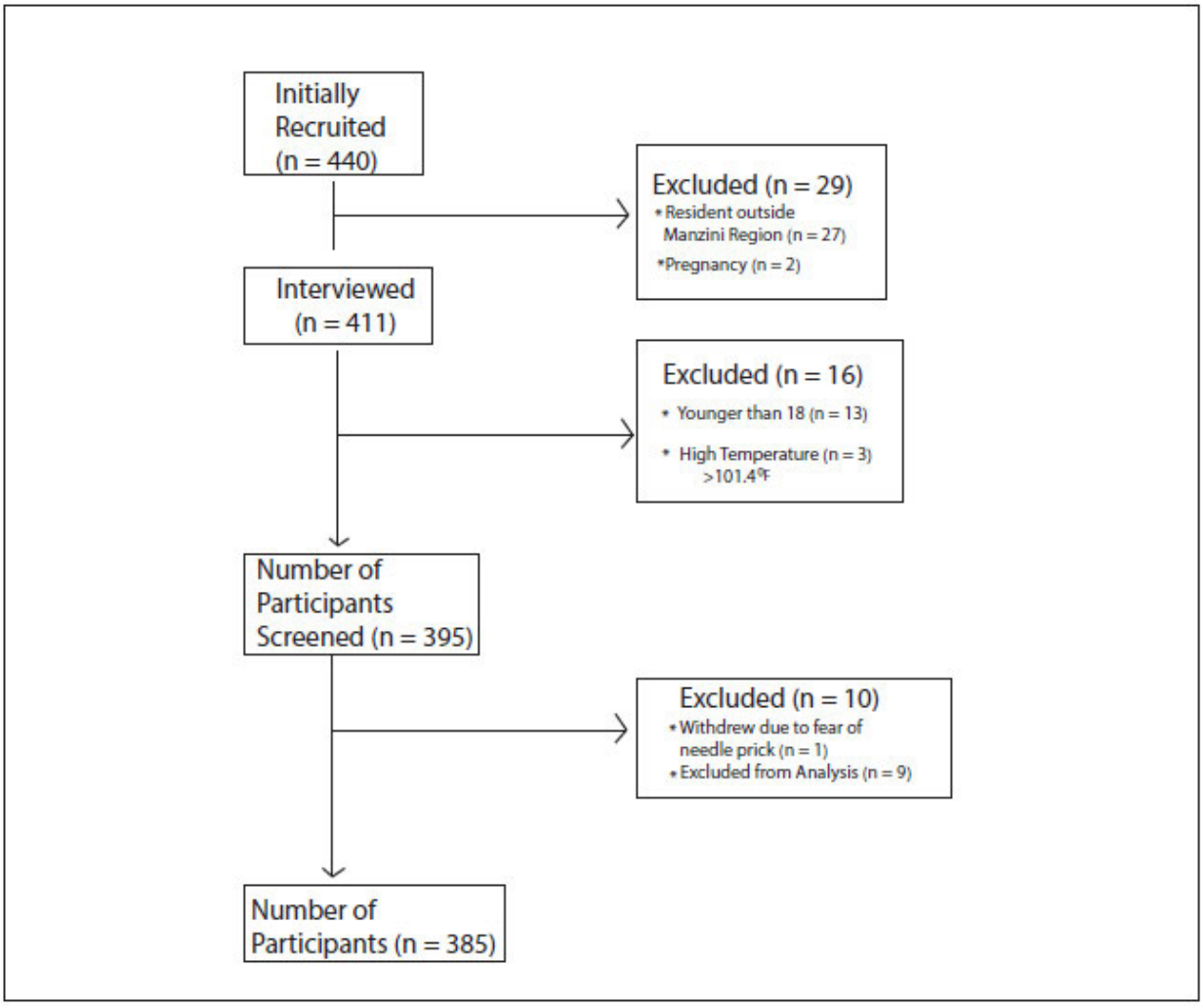
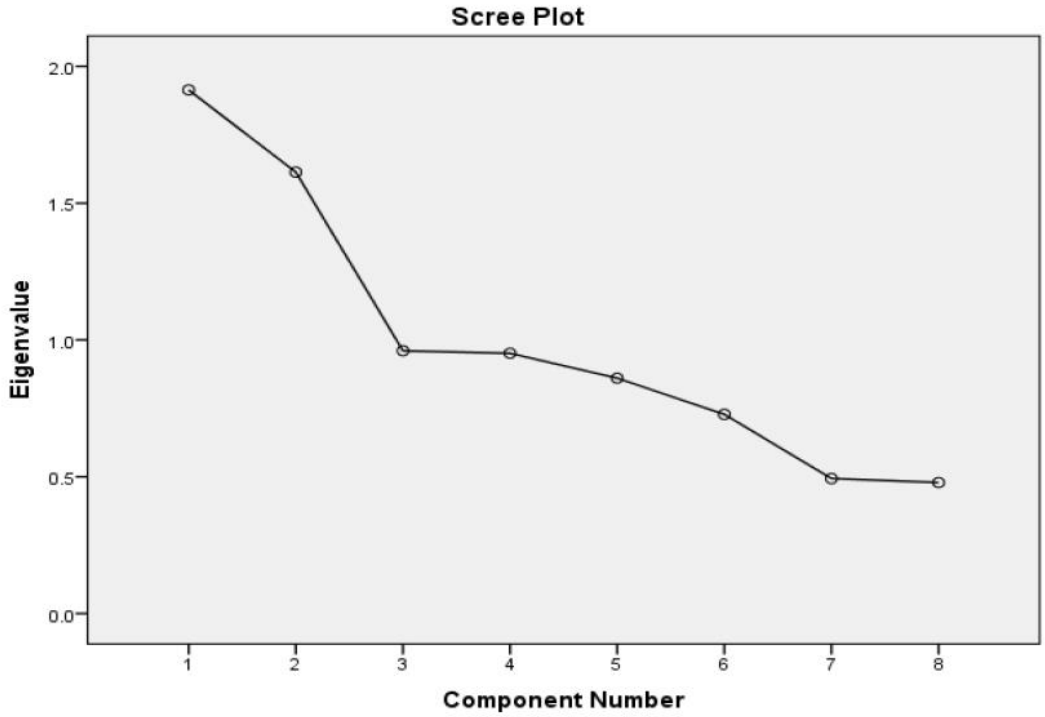


Figure 2. CONSORT diagram

Appendix 2. PCA Plot



Component Matrix[a]

	Component	
	1	2
Ownership of refrigerator	.769	.011
Ownership of TV	.728	.056
Ownershio of stove	.571	-.388
Ownership of watch/clock	.466	.050
Ownershio of Radio	.367	.273
Ownership of non-mobile phone	.328	-.120
Ownership of livestock	.027	.839
Ownership of agricultural land	.081	.815

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
Ownership of refrigerator	.765	.073
Ownership of TV	.721	.114
Ownership of stove	.600	-.341
Ownership of watch/clock	.460	.087
Ownership of Radio	.344	.301
Ownership of non-mobile phone	.337	-.094
Ownership of livestock	-.040	.838
Ownership of agricultural land	.015	.819

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Component Transformation Matrix

Component	1	2
1	.997	.080
2	-.080	.997

Extraction Method: Principal component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Figure 3. PCA Plot

Appendix 3. Study Ethical Clearance

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Amended letter

23 January 2018

Mr GM Akorede (217081323)
School of Nursing and Public Health
College of Health Sciences
gbmojeed@yahoo.com

NEW PROTOCOL TITLE: Type 2 diabetes prevalence and its associated risk factors among adults attending the outpatients departments in Manzini tertiary hospital, Swaziland. Degree: PhD
BREC Ref No: BE385/18
Previous Protocol Title: Type 2 diabetes in the Manzini region of Swaziland: Prevalence and associated risk factors.

EXPEDITED APPLICATION: APPROVAL LETTER

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received 25 June 2018.

The study was provisionally approved pending appropriate responses to queries raised. Your response received on 04 January 2019 to BREC correspondence dated 27 July 2018 has been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have been met and the study is given full ethics approval and may begin as from 23 January 2019. Please ensure that site permissions are obtained and forwarded to BREC for approval before commencing research at a site.

This approval is valid for one year from 23 January 2019. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2015), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be noted by a full Committee at its next meeting taking place on 12 February 2019.

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

[redacted]

Professor V Rambiritch
Chair: Biomedical Research Ethics Committee

cc postgraduate administrator:ramlalm@ukzn.ac.za Supervisor:Tlou@ukzn.ac.za

Biomedical Research Ethics Committee
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Website: http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx

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Appendix 4. Questionnaire

TYPE 2 DIABETES PREVALENCE AND ITS ASSOCIATED RISK FACTORS AMONG ADULTS ATTENDING THE OUTPATIENT DEPARTMENTS IN A MANZINI TERTIARY HOSPITAL, SWAZILAND

Participant Identification Number……. **Date**……

SECTION 1: DEMOGRAPHIC INFORMATION

(1.) How old are you? ……

(2.) What is your gender?

Male	Female
1	2

3. Area of residence

Rural	Urban
1	2

4. Marital status

Single	Married	Staying with partner	Widowed	Divorced
1	2	3	4	5

SECTION 2: SOCIOECONOMIC STATUS

5. What is your highest level of education you completed?

No formal education	Primary school	Secondary school	High school	College/university degree	Postgraduate degree
1	2	3	4	5	6

6. Which of the following best describe your occupation?

Student	Unemployed	Civil servant	Self-employed	Domestic worker	Shop attendant
1	2	3	4	5	6

7. What is the average monthly income for your household (in Emalangeni)?

< E500	E500 – E999	E1000 – E1999	E2000 – E2999	E3000 or more	Don't know
1	2	3	4	5	6

Please respond YES if you own the item and it is in working form. If you own the item but it is broken or not working, please respond NO

Household effects	YES	NO
8. Does your household have a radio or transistor?		
9. Does your household have a television?		
10. Does your household have a mobile phone?		
11. Does your household have a non-mobile phone?		
12. Does your household have a refrigerator?		
13. Does your household have a stove?		
14. Does your household have a watch/clock?		

Means of transportation

15. What is the means of transportation used by your household?

Bicycle	Motorcycle/ scooter	Animal/drawn cart	Tractor	Car/truck
1	2	3	4	5

Ownership of agricultural land

16. Does your household own any agricultural land? **YES** ☐ **NO** ☐

Ownership of farm animals

17. Does your household own cattle, cows, bulls, horses, mules, goats, sheep, or chicken?

YES ☐ **NO** ☐

SECTION 3: MEDICAL HISTORY

18. Have you ever been told by a medical doctor, a nurse, or any healthcare worker that you have any of the following health conditions? **YES** ☐ **NO** ☐

Sugar diabetes	High blood pressure	Stroke	Heart attack	Kidney problem
1	2	3	4	5

SECTION 4: LIFESTYLE BEHAVIOURS

SMOKING

19. Do you currently smoke any tobacco products, such as cigarette, cigars, or pipes?

Never used tobacco	**Former tobacco user**	**Current tobacco user**
1	2	3

ALCOHOL USE

20. Do you drink alcohol? YES ☐ NO ☐

21. If yes, how often?

Rarely (less than 4 drinks per month)	**1 – 2 drinks per week**	**3 – 7 drinks per week**	**8 – 14 drinks per week**	**15 or more drinks per week**
1	2	3	4	5

DIET

22. How many sweet drinks do you take per week? (sweet coffee, sweet tea, cola, fizzy drinks, etc.)

Less than 3 per week	**4 – 10 per week**	**11 – 15 per week**	**16 – 20 per week**	**21 – 25 per week**	**26 or more drinks per week**
1	2	3	4	5	6

23. In a typical week, do you eat 3 or more servings of fruits daily?

YES ☐ NO ☐ I don't eat fruits ☐

24. In a typical week, do you eat 3 or more servings of vegetables daily?

YES ☐ NO ☐ I don't eat vegetables ☐

25. How often do you add salt or a salty sauce such as soya sauce to your food right before you eat it or as you are eating it?

Always	**Sometimes**	**Often**	**Rarely**	**Never**	**I do not know**
1	2	3	4	5	6

26. How often do you eat processed food high in salt? (e.g. packaged salty snacks, canned salty food including pickles and preserves, salty food prepared at a fast food restaurant)

Always	Sometimes	Often	Rarely	Never	I do not know
1	2	3	4	5	6

27. What type of oil or fat is most often used for meal preparation in your household?

Vegetable oil	Lard or suet	Butter or ghee	Margarine	Other	None	I do not know
1	2	3	4	5	6	7

PHYSICAL ACTIVITY

Please answer these questions, even if you consider yourself physically inactive.

Work

28. Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate, like carrying or lifting heavy loads, or digging or construction?

YES ☐ NO ☐

29. In a typical week, on how many days do you do vigorous-intensity* activities as part of your work? ……..Day (s)

'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate.

30. How many hours do you spend doing vigorous-intensity activities at work in a typical week? ……Hour (s)

31. Does your work involve moderate-intensity* activity, that causes small increases in breathing or heart rate, such as brisk walking (or carrying light loads) for at least 10 minutes?

'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

YES ☐ NO ☐

32. In a typical week, on how many days do you do moderate-intensity activities as part of your work?……..Day (s)

33. How many hours do you spend doing moderate-intensity activities at work in a typical week? ……Hour (s)

Travel

The next set of questions concern the usual way in which you travel to and from places. For example to work, for shopping, to market, and to your place of worship.

34. Do you walk or use a bicycle (pedal cycle) for at least 10 minutes continuously to get to and from places? YES ☐ NO ☐

35. In a typical week, on how many days do you walk or use a bicycle for at least 10 minutes continuously to get to and from places? …….Day (s)

36. How many hours do you spend walking or bicycling for travel in a typical day?

…….Hour (s)

Recreational Activities

37. Do you do any vigorous-intensity sports, fitness or recreational (leisure) activities that cause large increases in breathing or heart rate, like running or football, for at least 10 minutes continuously?

YES ☐ NO ☐

38. In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (leisure) activities?.....Day (s)

39. How many hours do you spend doing vigorous-intensity sports, fitness, or recreational activities on a typical day?.....Hour (s)

40. Do you do any moderate-intensity sports, fitness or recreational (leisure) activities that cause a small increase in breathing or heart rate, such as brisk walking, cycling, swimming, and volleyball for at least 10 minutes continuously?

YES ☐ NO ☐

41. In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (leisure) activities?.....Day (s)

42. How many hours do you spend doing moderate-intensity sports, fitness or recreational (leisure) activities in a typical day?.....Hour (s)

Sedentary behaviour

43. How much time do you usually spend sitting or reclining on a typical day?

……Hour (s) / Minute (s)

Thank you for participating in this survey