Spatial, Demographic and Physical Risk Factors for Type 2 Diabetes Mellitus: A Retrospective Examination of Adult Screening Data for Nine Communes in Siem Reap Province, Cambodia

Vansak SOEUM

Auckland University of Technology

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Faculty of Health and Environmental Science
School of Public Health and Interdisciplinary Studies

Supervisor: Dr Ailsa Holloway
Co-Supervisor: Dr Melanie Moylan

Abstract

Diabetes is recognised as a global public health threat due to its emergence as a leading cause of death, as well as its burden on national healthcare systems and impacts on health and economic productivity. In 2017, there were nearly 425 million diabetes cases reported worldwide, with more than 60% of cases reported in Asia. By 2035, the number of type 2 diabetes mellitus (T2DM) cases in Southeast Asia is projected to exceed 123 million, with almost 95% of these being T2DM.

In Cambodia, a lower-middle-income country within Southeast Asia, diabetes is a health condition of increasing concern, with the number of T2DM cases projected to rise to more than 260,000 by 2028. Previous research on risk factors for T2DM in Cambodia has primarily focused on the effects of unhealthy lifestyles, genetic disorders, and societal risk factors for T2DM. These include the effect of an unhealthy living environment, limited diabetes awareness and access to health services, and cultural beliefs on the use of traditional medicine. Despite the absence of diabetes diagnostic and treatment centres outside Cambodia's provincial capitals, previous studies have not examined constrained geographical access to diabetes health services as a risk factor for T2DM.

This research examined physical distance from diabetes health services as a T2DM risk factor. It investigated the differences in the prevalence of T2DM in nine communes geographically situated at various distances from the province-level diabetes health services in Siem Reap province.

The study employed a quantitative research methodology, through secondary data analysis of previously collected diabetes screening data, gathered by the Cambodian Diabetes Association in 2010. It analysed de-identified data from 399 voluntary diabetes screening study participants aged 26 years and older, including anthropometric measures of body mass index, weight, height, waist circumference and hip circumference as well as blood glucose and blood pressure measurements.

Study results showed that although each commune had a different prevalence of T2DM, the total prevalence was 20.3% (81/399) 95%CI 16.7-24.5. Newly diagnosed T2DM cases were nearly double those who had been previously diagnosed, 13.3% (53/399) (95%CI: 10.3-17.0) and 7.0% (28/399) (95%CI: 4.9-10.0), respectively. This study found that distance to the Siem Reap provincial capital was a significant predictor for T2DM (*p*-value = .006). Age and hypertension were also identified as T2DM risk factors of T2DM (*p*-value = .005 and *p*-value = .028, respectively).

In conclusion, this study found increasing age, distance from diabetes health services in Siem Reap provincial capital, and hypertension were risk factors of T2DM. These findings suggest that the distance between the place of residence and province-level diabetes health services may be a risk factor for T2DM. As diabetes healthcare providers are limited in Cambodia's rural areas, these research findings have the potential to inform future planning to improve diabetes control and prevention by enhancing geographical access to diabetes health services.

Contents

List of Abbreviations

95%CI	95% Confidence Interval
AUTEC	Auckland University of Technology Ethics Committee
BMI	Body Mass Index
CDC	Chronic Diseases Clinic
CDA	Cambodian Diabetes Association
CRF	Case Report Form
DALYS	Disability-Adjusted Life Years
DBST	Double Bituminous Treatment Surface
HC	Hip Circumference
HIV/AIDs	Human Immunodeficiency Virus Infection and Acquired Immune Deficiency Syndrome
MNAR	Missing Not At Random
NDD	National Democratic Development
NCDs	Non-Communication Diseases
SPSS	Statistical Package for the Social Sciences
SD	Standard Deviation
T2DM	Type 2 Diabetes Mellitus
WC	Waist Circumference
WHR	Waist-to-Hip Ratio
WtHR	Waist-to-Height Ratio
WHO	World Health Organisation

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Vansak SOEUM

Signed: Date: 8th November 2020

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Finally, I dedicate my achievement to my home country, Cambodia, where I believe that people will have a better health condition.

Chapter 1. Introduction

1.1 Overview of diabetes

Diabetes is a non-communicable disease (NCD) of increasing global concern, especially type 2 diabetes mellitus (T2DM) (Nang et al., 2019). This specifically applies to developing countries where rapid development has changed lifestyles and dietary patterns (Nanditha et al., 2016). Cambodia is one such country where a rapid increase in T2DM is now observed (Institute for Health Metrics and Evaluation, 2020).

This chapter provides an overview of T2DM and the increasing prevalence of the disease at a global level, as well as in Asia and Cambodia. It then provides information relevant to this study about Cambodia, including its geography and demographic composition, as well as its health system. The chapter then presents the research rationale which identifies a knowledge gap concerning T2DM in Cambodia and concludes by describing this study's intention to address the question that was identified from the knowledge gap.

Diabetes is a serious, complex health condition that can affect the entire body. It is a metabolic disorder that arises when insulin is not sufficiently produced by the pancreas due to genetic disorders (type 1 diabetes mellitus (T1DM)) or when insulin cannot perform its regular function, resulting in uncontrolled blood glucose levels (T2DM), (World Health Organisation (WHO), 2020). According to WHO, T1DM tends to show symptoms more quickly than T2DM. Individuals may be asymptomatic initially, and in some cases go undiagnosed until they have severe complications. The signs of diabetic disease include extreme fatigue, frequent and excessive urination, constant hunger, intense thirst, blurred vision and a decrease in body weight (World Health Organisation, 2016b).

Prevailing research indicates that the longer a diabetes patient lives with uncontrolled high blood sugar levels, the worse his or her health consequences are likely to be (World Health Organisation, 2020). Diabetics frequently have debilitating complications due to uncontrolled hyperglycaemia. These include microvascular damage including retinopathy, nephropathy, neuropathy, as well as macrovascular disease, such as ischaemic heart disease, stroke, and other peripheral blood vessel diseases. All of these conditions increase morbidity and mortality rates (Raguenaud et al., 2009).

1.2 Diabetes: An emerging global health issue

Non-communicable diseases currently rank among the top leading causes of premature death worldwide. This in part reflects the changing patterns of health and disease due to improvements in health care and other services. McKeown (2009) explained this process as an “Epidemiological Transition” which denotes changing population patterns in terms of fertility, an increase in life expectancy, causes and risk factors of death, and population growth.

This phenomenon has resulted from improvements in global health. For example, nutritional disorders and infectious diseases such as human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDs), malaria, and tuberculosis, once considered major threats to global health, are better managed (Murray et al., 2015). These are due to the application of scientific knowledge in health strategies and services, such as universal vaccination, and improved sanitation and clean water (Yunguo & Beresford, 2017). In the thirteen years between 1990 and 2013, life expectancy increased worldwide by 6.2 years, increasing population size but also the number of older people, who are more likely to be vulnerable to NCDs (Murray et al., 2015). These changes have been compounded by increasingly unhealthy lifestyles due to unsustainable forms of economic growth (Nanditha et al., 2016), resulting in a growing global NCD “pandemic”, including T2DM.

1.2.1 Increasing diabetes prevalence especially in Asia

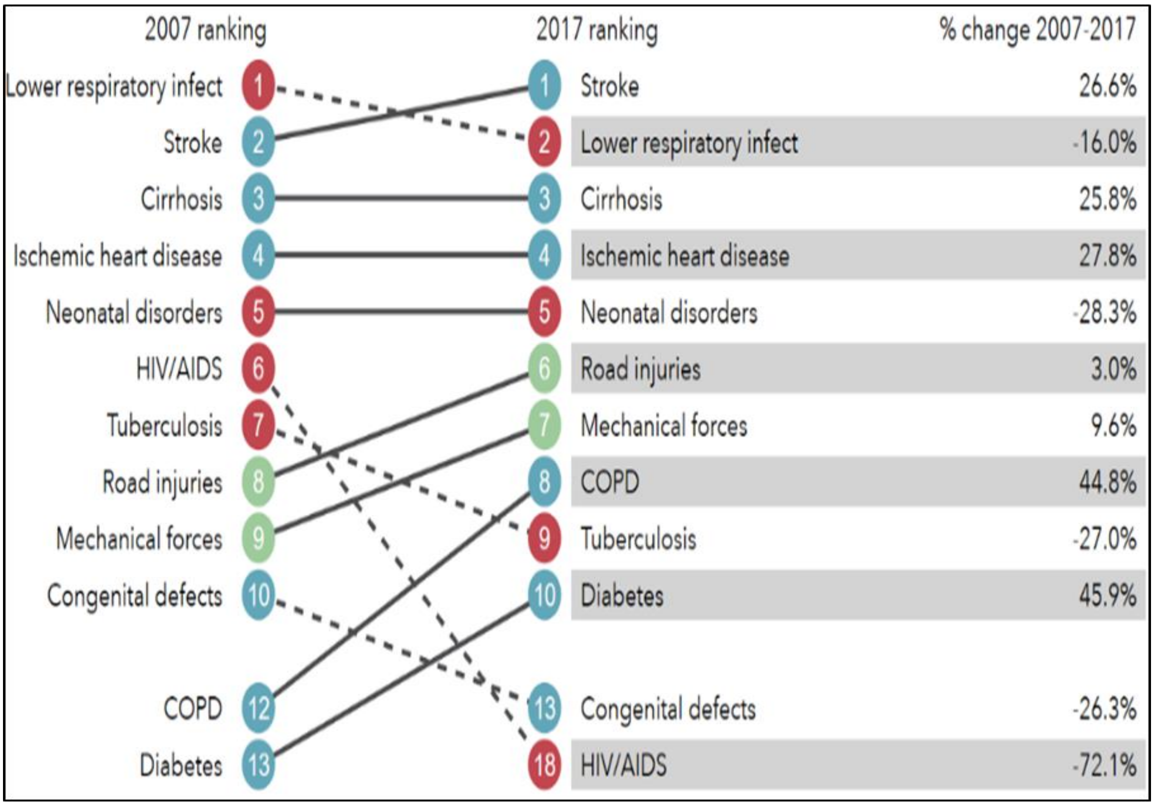
Globally, diabetes prevalence has increased alarmingly. In 2016, this NCD was ranked as the seventh leading cause of death, responsible for approximately 1.6 million deaths (World Health Organisation, 2020). In 2017, the global estimate of people with diabetes was nearly 425 million (87%-91% of these with T2DM), with projected increases to 629 million by 2045. This has resulted in diabetes becoming one of the top world health crises of the 21st century and beyond (International Diabetes Federation, 2017 as cited in Nang et al., 2019). Diabetes prevalence has risen more rapidly in developing countries with, by 2015, these countries accounting for 80% of all cases worldwide (Nanditha et al., 2016). Of these, more than 60% were from Asia, with approximately one-half from India and China, followed by the Philippines, Indonesia, Bangladesh and Pakistan (Nanditha et al., 2016). In 2013 in Southeast Asia, 72 million adults were diagnosed with diabetes, with estimates projected to exceed 123 million by 2035. Approximately 95% of the cases were T2DM (Ramachandran et al., 2014).

1.2.2 Diabetes: A current public health issue in Cambodia

Cambodia is a country identified as experiencing the epidemiological transition with an emerging prominence of NCDs. In 1990, infectious diseases were the leading cause of deaths; fortunately, the collaboration between international aid programmes and the Cambodian government has been key in controlling communicable diseases such as diarrhoea, tetanus, malaria, measles and HIV/AIDS (Institute for Health Metrics and Evaluation, n.d). As a result, between 1990 and 2017, life expectancy for males increased from 55.3 years to 66.8 years and for females from 59.8 years to 72.7 years (Institute for Health Metrics and Evaluation, 2020). However, since 2007, NCDs including ischaemic heart disease, stroke, and diabetes are now ranked as Cambodia's top 13 leading causes of death or premature mortality (Figure1) (Institute for Health Metrics and Evaluation, 2020). The reason for this could be due to an increase in life expectancy combined with unhealthy behaviours due to current economic growth (Wagner et al., 2018; Yunguo & Beresford, 2017).

Figure 1

Leading Causes of Death in Cambodia (2007-2017)



Note. Ranking of the leading causes of death in Cambodia in 2007 and 2017. Reprinted from *Cambodia* ("What Causes the Most Deaths?"), by Institute for Health Metrics and Evaluation, 2020, http://www.healthdata.org/cambodia. Copyright 2020 by University of Washington.

In Cambodia, non-communicable diseases, principally chronic respiratory diseases cancer, cardiovascular diseases, and, diabetes, pose a major threat to public health and the country's development (World Health Organisation, 2019a). These four NCD groups accounted for 48% of all deaths in 2008 (Ministry of Health, 2013) and 52% in 2014 (Yunguo & Beresford, 2017).

The rising prevalence of T2DM in Cambodia has been highlighted by successive studies. In 2005, a study of 2,246 participants aged 25 and older found the prevalence rate of 11% T2DM in semi-urban areas and 5% in rural settings (King et al., 2005). In 2008, all types of diabetes were responsible for 3,122 deaths in Cambodia, along with a loss of 39,000 disability-adjusted life years (DALYs) (World Health Organisation, 2011, as cited in Flessa & Zembok, 2014).

In 2010, a national survey of 5,643 participants reported a T2DM prevalence of 2.9%, with more than half not receiving treatment (Oum et al., 2010). The same survey highlighted differences between urban and rural populations. For example, Oum et al. (2010) found that the urban prevalence of T2DM was 5.6% compared with 2.3% in rural participants. However, Oum et al. (2010) and Wagner et al. (2018) found that even though urban dwellers had a higher rate of T2DM, rural residents were more likely to be undiagnosed. By 2014, the national prevalence of diabetes in Cambodia had reached approximately 5.9% (World Health Organisation, 2016a), with the number of people affected by T2DM projected to rise from 145,000 in 2008 to 264, 000 by 2028 **(**Flessa & Zembok, 2014).

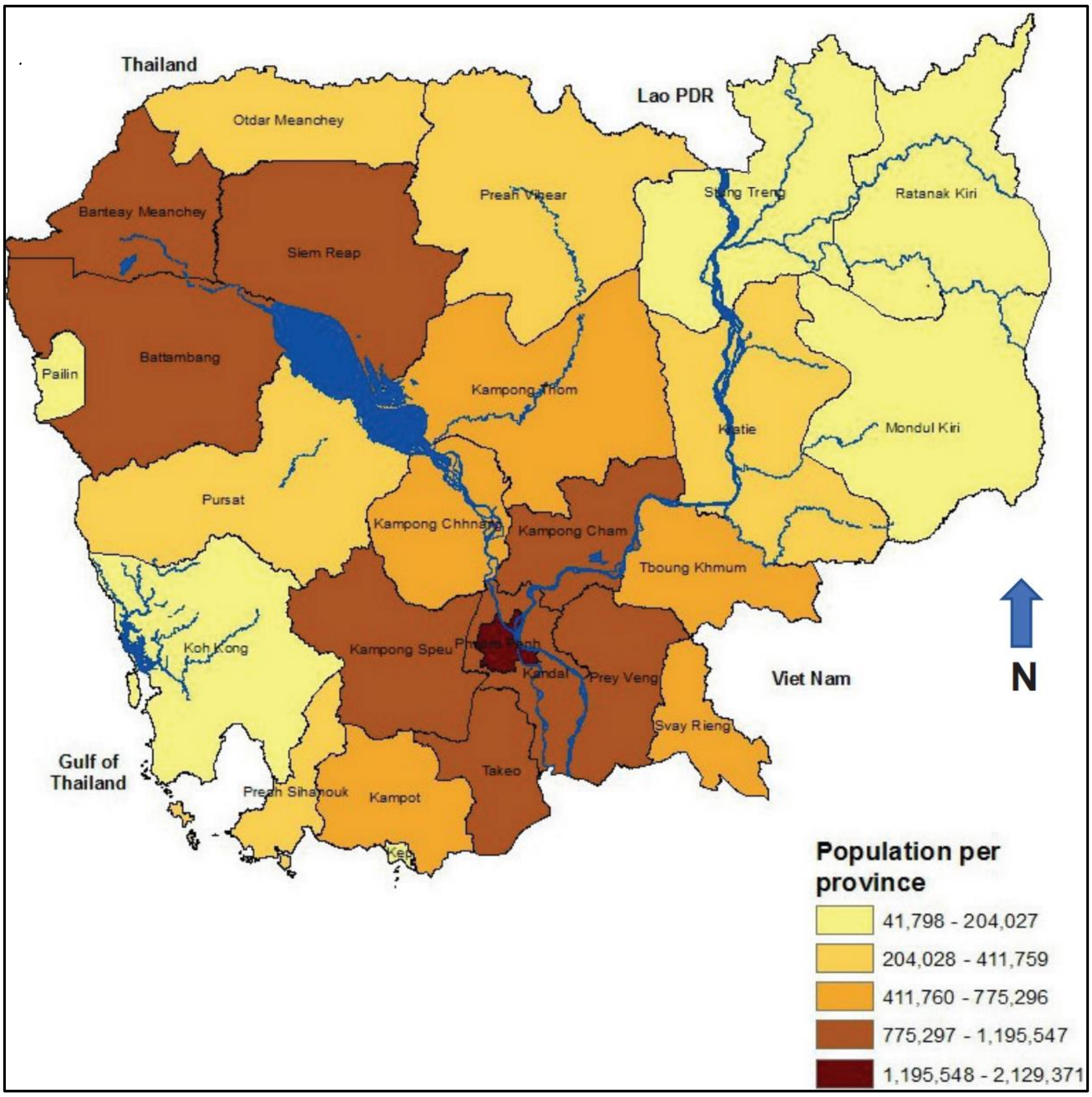
1.3 Research context

1.3.1 Overview of Cambodia

The changing pattern of T2DM within Cambodia reflects the country's rapid development during the past two decades and Cambodia's emergence as a low-middle-income country (World Health Organisation, 2016c). Officially known as "the Kingdom of Cambodia", Cambodia is located in Southeast Asia and has a total landmass of 181,035 square kilometres (Royal Government of Cambodia, 2014). The northwest and the west of the country are bordered by Thailand, whereas Cambodia's southwest is located along the Gulf of Thailand. Vietnam is situated to the east and southeast while the Lao People's Democratic Republic is in the northeast (Figure 2).

Figure 2

Map of Cambodia

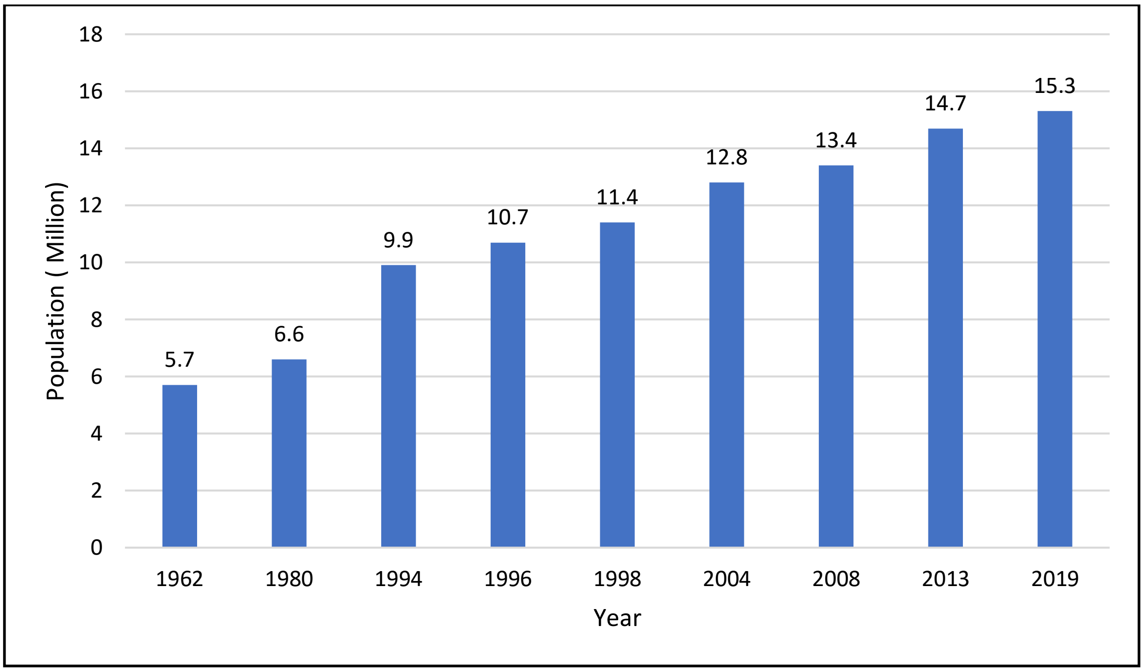


Note. Map of Cambodia with the density of population by province. Reprinted from *General Population Census of the Kingdom of Cambodia 2019* ("Population by Province and Sex, 2019"), by National Institute of Statistics, 2019, http://www.nis.gov.kh/nis/Census2019/Provisional%20Population%20Census%202019English_FINAL.pdf. Copyright 2019 by National Institute of Statistics.

The Cambodia population has increased significantly since 1962. Data from 2019 showed that the Cambodia population stood at 15.3 million (Figure 3); with a male population of 7.4 million (48.5%) and a female population of 7.9 million (51.5%) (National Institute of Statistics, 2019). From 2008 to 2019, the average household size was stable at 4.6 persons. In 2015, the number of people aged over 60 years was approximately 1.3 million (8.3%). As Cambodia's working-age population is larger than both its older and younger age groups, it will take time before the countries older population increases. This resulting "demographic dividend" will continue to accelerate economic growth in Cambodia for the next few decades (World Health Organisation, 2016c).

Figure 3

Population of Cambodia (1962-2019)



Note. Cambodia population in millions from 1962 to 2019. Reprinted from *General Population Census of the Kingdom of Cambodia 2019* ("The Cambodian Total Population in Millions, Trend 1962-2019"), by National Institute of Statistics, 2019, http://www.nis.gov.kh/nis/Census2019/Provisional%20Population%20Census%202019English_FINAL.pdf. Copyright 2019 by National Institute of Statistics.

The Cambodian health sector comprises of both public and private healthcare services. The unregulated private health market dominates the health service sector and accounts for 61% of all care providers (World Health Organisation, 2016c). The private sector consists mainly of nursing homes which are operated by nurses, and clinics that are owned by doctors, but who also work for the public hospitals. The private sector also includes unregulated traditional healers, and a large number of pharmacies which are predominantly managed by unqualified practitioners (Jacobs et al., 2017).

1.3.2 Introduction to Siem Reap province and communes surveyed

Cambodia is divided into one capital city and 24 provinces that are administratively composed of districts. Districts are made up of communes which are further divided into villages (Wagner et al., 2018). Siem Reap is the third-largest province, located in the north-western part of the country (National Institute of Statistics, 2002). It is ranked fourth out of the 25 provinces and cities in population size with approximately 1 million residents and has 12 districts with 100 communes and 882 villages (National Institute of Statistics, 2019). The province is also known for its world-famous and largest religious temple, Angkor Wat. This has resulted in the province having the highest number of tourists nationwide, and the most developed service sectors, especially in the provincial capital (Wagner et al., 2018). Despite this, rural villages have a higher proportion of the provincial population compared to urban areas (Wagner et al., 2018). This is reflected in the main occupation in Siem Reap province which is agriculture, which accounts for 81% of employment (Wagner et al., 2015). Given that much of the population resides in rural areas, there is unequal access to services; for example, up to 56% of the population use unclean drinking water during the dry season (the National Committee for Sub-National Democratic Development, 2012 as cited in Wagner et al., 2015).

While Siem Reap province has 100 communes, this study focused on T2DM testing results from nine of these. Altogether, in 2010 the combined population of the nine communes was 107,160, representing 11.3 % of Siem Reap Province’s population of 946,656. These communes range from 9,490 people in Svey Leu to 15,837 in Dom Daek (Table 1) (National Committee for Sub-National Democratic Development, 2010).

The nine communes are geographically situated at different distances from the Siem Reap provincial capital. Despite these communes having an unequal number of villages (9 to 16 villages) and a varied population size, in 2010, each commune had only one health centre (Table 1) (National Committee for Sub-National Democratic Development, 2010).

Table 1.Overall population and distance between the Siem Reap provincial capital and the nine communes surveyed.

Commune Name	Distance from the Provincial Capital	Population Size	Village
	Km	N	N
Dom Daek	34.74km	15,837	13
Dan Run	36.24km	12,215	13
Kien Sangkae	36.75km	10,787	12
Samraong	40.48km	9,950	9
Kampong Khleang	49.6km	10,849	10
Kampong Kdei	61.75km	12,280	16
Anlong Samnar	65.95km	12,673	16
Svey Leu	72.45km	9,490	11
Khvav	97.43km	13,079	9
Total		**107,160**	**109**

The nine communes are located in the eastern part of the province and were randomly selected as they represented rural communes where health services were limited. They were considered as rural settings, based on the following criteria; (1) long-distances and travel times to the referral hospital in the capital Siem Reap, (2) number of households involved in agriculture per commune, and (3) absence of paved road access (Wagner et al., 2018), according to criteria measured by the Ministry of Planning (National Committee for Sub-National Democratic Development, 2010). Although Dom Daek and Samraong are the closest communes to the provincial capital (Table 1), these were still considered as "rural" due to their poor economic conditions, inadequate sanitation and limited electricity. (King et al., 2005), (Table 2). The other seven communes that were geographically more distant, had lower socio-economic conditions, including education, income, and infrastructure (National Committee for Sub-National Democratic Development, 2010) (Table 2).

Table 2. 2010 socio-economic indicators for the nine communes surveyed.

Commune	Distance from Health centre	Pharmacies	Clinics	Houses with electricity	Good road (DBST Road*)	Occupation in agriculture	Unsafe water sources	Food shop businesses	Cars	Illiterate population aged 25-60 years
	Km	N	N	**%**	Km	**%**	**%**	N	N	**%**
Dom Daek	1.77km	9	8	39.0%	1.5km	66.0%	23.9%	425	102	3.62%
Dan Run	3.85km	1	0	0.0%	0km	75.3%	34.3%	150	2	23.13%
Kien Sangkae	3.21km	0	0	8.5%	0km	90.1%	96.3%	83	5	12.67%
Samraong	1.39km	3	2	23.8%	0.41km	92.5%	25.8%	107	10	3.46%
Kampong Khleang	1.01km	2	0	36.3%	0.50km	93.7%	80.5%	95	9	9.21%
Kampong Kdei	2.03km	1	1	42.1%	0km	82.0%	59.3%	50	44	18.50%
Anlong Samnar	4.49km	0	0	16.2%	0km	94.0%	80.0%	1	18	17.87%
Svey Leu	6.45km	0	0	22.7%	0km	90.0%	61.1%	20	30	32.38%
Khvav	6.78km	0	0	0.0%	0km	96.2%	64.6%	1	6	28.49%

* DBST Road= Double Bituminous Treatment Surface Road (National Committee for Sub-National Democratic Development, 2010).

Kampong Khleang differs from the other communes in terms of its location and livelihood profile. It is a floating commune which is located in the northern part of the Tonle Sap (Lau-Bignon, 2015). The houses in this commune are built on stilts, and adapt to the different water levels. Additionally, in 2010, 88.73% of families were fishermen (National Committee for Sub-National Democratic Development, 2010). Kampong Khleang is a remote area that is geographically isolated from the other communes and has limited healthcare services. Mobile clinics provide primary health services in Kampong Khleang, for example, the Lake Clinic (Merali et al., 2014).

1.4 Research rationale

While international aid programmes have helped to control infectious diseases including malaria, HIV/AIDs, diarrhoea, and tuberculosis in Cambodia since 2007 NCDs such as stroke, ischaemic heart disease, and diabetes have been ranked among the leading causes of death (Institute for Health Metrics and Evaluation, 2020). T2DM is becoming one of the major burdens to public health and is predicted to rise significantly in the future (Flessa & Zembok, 2014).

There is an established body of knowledge on the behavioural and the biophysical risk factors for diabetes in Cambodia. National research conducted in 2010 found that participants had sedentary lifestyles, high consumption of sugary beverages, alcohol, and sweet foods, and less fruit and vegetable consumption (Oum et al., 2010). Biophysical risk factors have also been identified that increase susceptibility to diabetes. These are due to genetic transformations which are a consequence of famine during Cambodia’s civil war that occurred from 1970 to 1979 (King et al., 2005).

Besides these two leading causes of diabetes, there is another cluster of societal risk factors which reflect the social determinants of health. For example, research in Cambodia has found a strong correlation between diabetes and the geographical distribution of environmental and social determinants, including an obesogenic environment in more urban areas (Wagner et al., 2018), limited diabetes awareness (Nang et al., 2019), cultural beliefs related to traditional medicine (Jacobs et al., 2017) and socio-economic and educational status (Nang et al., 2019).

One specific social determinant related to diabetes in Cambodia is accessibility to healthcare services (Idei & Kato, 2019). While access to health care is a wide-ranging concept, most studies have primarily focused on the limited availability of NCDs care, which are often unaffordable, as well as unacceptable services (Idei & Kato, 2019; Flessa & Zembok, 2014). However, the role of limited geographical access as a risk factor for T2DM has not been examined in Cambodia, specifically as this applies to the distance between the place of residence and province-level diabetes health services.

1.5 Research aims

Therefore, this research sought to explore geographical access to province-level diabetes health services in relation to T2DM. It aimed to achieve this by investigating the differences in the prevalence of both newly and previously diagnosed T2DM in study participants who lived in nine selected communes at different distances from the Siem Reap provincial capital. In this context, the research probed to see whether the distance between the place of residence and province-level diabetes health services was a risk factor for T2DM in Siem Reap Province, Cambodia.

Research questions

- What was the prevalence of T2DM in the nine selected communes?
- Were there differences in the rates of T2DM in communes situated at different distances from the provincial capital?
- What were the risk factors for adults with T2DM in Siem Reap Province, Cambodia, and how did these findings align with those for developing countries in the published literature?

Hypothesis

- The null hypothesis was that there is no difference in the prevalence of T2DM in communes situated at different distances from diabetes health services in the provincial capital.
- The alternative hypothesis was that there are differences in the prevalence of T2DM in communes situated at different distances from diabetes health services in the provincial capital.

1.6 Chapter summary

Chapter 1 has presented the research questions. It has described how T2DM is becoming a growing health burden, especially in developing countries due to the epidemiological transition and increased diabetes risk factors. While there are many studies on the behavioural and biophysical risk factors, societal risk factors have only recently received attention with limited research in Cambodia. Therefore, this study examined whether geographical access, a recognised social determinant of health, was a risk factor for T2DM in the communes studied.

Chapter 2. Literature review

2.1 Introduction

Diabetes is steadily increasing globally, with the greatest prevalence predominantly in developing nations, particularly in the Western Pacific and South-East Asia Regions (World Health Organisation, 2016b).

This chapter provides a global view of diabetes, including the means of measurement and risk factors. It also outlines important social determinants of health as they relate to diabetes, with specific attention paid to the role of accessibility to diabetic healthcare services. The chapter continues by focusing on diabetes as a public health condition of concern in Cambodia. This includes challenges faced in measuring the burden of diabetes nationwide and a more detailed focus on risk factors in Cambodia. It describes the challenges of access and affordability, as well as the limited availability of public healthcare resources for those in need.

2.2 Global perspectives on diabetes

Diabetes and its complications have dire consequences on the economics of families and whole nations. At the global level, medical care of and lower productivity due to diabetes is expected to increase expenditure from $490 billion in 2010 to $893 billion in 2030 (Zimmet et al., 2014).

WHO actively promotes its “Best Buy” programme to reduce NCDs. Despite this, in lower-middle-income countries, such policies lacked funding and implementation funding (World Health Organisation, 2016b). Tuangratananon et al. (2018) were able to evaluate “Best Buy” interventions in several Asian countries and found that there were many unsatisfactory outcomes for NCDs prevention and control.

Responding to the diabetes pandemic not only requires the strengthening of “Best Buy” interventions, but also understanding of the burden of diabetes by gathering and monitoring reliable data. Diabetes is usually confirmed by measuring a fasting plasma glucose level or using the 2-hour 75g oral glucose tolerance test. Alternatively, diabetes can also be confirmed by measuring glycated haemoglobin (HbA1c) which can reflect the average of blood glucose concentration over weeks/months, although this test is more costly (World Health Organisation, 2016b). The reliability and validity of using fasting blood glucose ≥ 126 mg/dl and random glucose ≥ 200 mg/dl to indicate the presence of diabetes has been established by WHO (World Health Organisation, 2016b).

Additional measuring approaches are also used as markers of T2DM. First, body mass index (BMI) which is an indicator of obesity, has also been recognised as a predictor for T2DM. Although BMI ≥ 25.0 kg/m^2 is considered to increase T2DM risks (World Health Organisation, 2011), an Asian BMI cut-off which has proved to be appropriate for T2DM risk factors is lower at ≥ 23.0 kg/m^2 (An et al., 2013).

Waist circumference (WC), which is a marker of central obesity, is viewed as a better indicator more closely associated with T2DM risk (Luo et al., 2019). The WC cut-off values for Europeans that are associated with increased T2DM risk are ≥ 94 cm or ≥ 80 cm (World Health Organisation, 2011). For Asian populations, risk values are ≥ 80.0 cm for women and ≥ 90.0 cm for men (An et al., 2013). However, Son et al. (2016) explained that as WC does not take height difference into account, which could lead to underestimation or overestimation of the risk for short and tall individuals, respectively.

The World Health Organisation (2011) has also reported that the waist-to-hip ratio (WHR) is a risk marker of metabolic disease at values of 0.80 for Asian men and 0.90 for Asian women. However, WHR may be imprecise in individuals who have a decrease in body weight because the ratio of waist over hip circumference sometimes changes very little if their waist and hip circumference decreases proportionately.

One measurement for central obesity is waist-to-height ratio (WtHR) which is also argued to be a good predictor of T2DM (Hou et al., 2019). A study in Korea also found that WtHR was a significant predictor of T2DM at the cut-off value of 0.5. Not only was this consistent across different genders, ethnicities, and ages, but also less expensive and easier to measure than other indicators (Son et al., 2016).

Hypertension, defined as systolic blood pressure ≥ 140 mmHg and diastolic blood pressure ≥ 90 mmHg (World Health Organisation, 2019b) is also strongly associated with T2DM. Prospective observational studies with 285,664 individuals found that a 10 mmHg higher diastolic blood pressure over 90mmHg increased the risk of developing diabetes by 52%, a 20 mmHg higher systolic blood pressure increased the risk by 58% (Emdin et al.,2015).

2.3 Identified risk factors and social determinants of diabetes

Many studies have explored diabetes risk factors. There are behavioural risk factors, including low levels of physical activity, unhealthy diets, excessive alcohol consumption, and smoking (World Health Organisation, 2016b). There are also bio-physiological factors such as genetic disorders among some ethnic groups due to famine during foetal development or gestational diabetes (Hu, 2011; Henry et al., 2008; Ramachandran et al., 2012). Other major risk factors of NCDs including diabetes are societal origin, referred to as social determinants of health, including inequalities in education, poverty, environment, and culture. All of these shape the distribution of the risk of developing NCDs which include diabetes before birth and then during the lifespan of the individual. (Marmot & Bell, 2019).

2.3.1 Behavioural risk factors

The association between unhealthy living and diabetes has been extensively investigated. Poor diet and physical inactivity are linked directly to diabetes, which can first result in excess body fat which is the strongest marker for the disease (World Health Organisation, 2016b).

Excessive consumption of alcohol and tobacco are other behavioural risk factors for diabetes. With regards to smoking, 45% of tobacco consumers were found to be at risk of diabetes due to the development of insulin resistance and central obesity (Willi et al., 2007). However, despite efforts to counter global alcohol consumption and smoking, many countries in Asia have failed to implement their national action plans to eliminate exposure to second-hand smoke, advertising, sponsorship or physical availability of alcohol and smoking products (Tuangratananon et al., 2018).

2.3.2 Biophysiological risk factors: Genetic disorders

One genetic risk factor for diabetes described by Ling and Groop (2009) is reflected in a change in the DNA around genes when pregnant women are exposed to starvation, stress, and violence which results in the foetus adapting to food shortages. After childbirth, the baby continues to sparingly consume energy and later if the child consumes excess dietary energy, it is at risk of overnutrition. This increases the likelihood of developing diabetes, hypertension, and heart disease. Ramachandran et al. (2012) concluded that a high prevalence of insulin resistance, obesity, and diabetes among Asian Indians may be attributed to genetic transformation although Asians are less overweight and have a lower level of obesity rate than Europeans.

2.3.3 Societal risk factors: the influence of social determinants of health on diabetes

Societal risk factors also play a crucial role in diabetes. Societal risk factors may include an unhealthy environment, and socio-economic deprivation, as well as low levels of educational attainment and health literacy (Power et al., 2020). Other research has also highlighted the role of social determinants of health including household status, income level, and transportation infrastructure, in shaping societal risk factors that improve or deter access to diabetes prevention and control (Limi et al., 2015 as cited in Idei & Kato, 2019).

During the last decade, unsustainable economic growth has influenced major lifestyle changes associated with an increasing burden of NCDs, such as diabetes. The impact of socio-economic and urbanisation transitions has increased the level of unhealthy eating and more sedentary lifestyles, driving diabetes rates higher (Nanditha et al., 2016). For example, rising urbanisation, especially in China, India, Korea, Malaysia, and the Philippines and associated sedentary behaviour has increased body adiposity (Ramachandran et al., 2012), escalating diabetes risk. Development in Asia has also brought changes in dietary patterns with Asians consuming more refined carbohydrates, sugary drinks, meat, and animal fats (Hu, 2011).

Such changes indicate a need for improved education on diabetes and its prevention. However, a recent review on diabetes awareness found that participants in each of the studies had limited understanding of diabetes prevention and management, especially in developing countries. It also noted the role education played as an important factor influencing diabetes knowledge (Thomas, 2019). Poor health literacy was strongly associated with lower educational attainment and poor socio-economic circumstances, which increase the risk of diabetes (Power et al., 2020; Liu et al., 2015). This is due to the weakened interpretation of health information (Cotugno et al., 2015 as cited in Power et al., 2020), and the reduced ability to access health services. Individuals with lower educational levels also have difficulty in communicating with health professionals, low medication adherence, poor diet and exercise, and glycaemic control (White et al., 2016).

2.4 Accessibility to health care influence on diabetes

2.4.1 Access to health care as a social determinant

While access to health care is a key social determinant of health, a global survey found that in low-income countries, the basic technology and necessary policies to advance diabetes prevention and management were inaccessible (World Health Organisation, 2016b). For example, the majority of low-income countries reported poor availability of insulin and oral hypoglycaemic agents. They also reported limited availability of other essential medicines for lowering blood pressure and lipid levels to control diabetes and it's complications. In addition to these factors, health service provision in many rural areas, especially in developing countries is often limited, and access to quality healthcare services is usually expensive, time-consuming, and requires individuals to travel a long distance (Idei & Kato, 2019).

A recent study suggested that one possible way to address inequalities in diabetes prevalence involved focusing on geographical areas, going beyond socio-economic information such as ethnic diversity and social inequalities to also include issues related to healthcare access (Power et al., 2020). Nguyen et al. (2016) argued that making interventions available for diabetes prevention, screening, diagnosis, and treatment for resource-constrained communities would improve accessibility. They added that such measures would also strengthen the relationship between healthcare professionals and the general population.

2.4.2 Geographical accessibility to healthcare services associated with diabetes

Healthcare service accessibility is crucially important for diabetes management and prevention. There are four dimensions of accessibility to health care, including geographical access, availability, affordability, and acceptability (Peters et al., 2008). *Geographic access* is understood as the physical distance or duration of travel to the healthcare delivery setting, which is an essential aspect of obtaining health care (Peters et al., 2008). The four identified elements that influence geographic access are the configuration of facilities, distance from health services, transportation infrastructure, and the economic status of the population (Delamater et al., 2012). Low- and middle-income countries are more likely to face difficulties associated with geographical accessibility because of low distribution in the number of healthcare facilities, high travel-related costs, long travel distances, lack of available transport, and poor road conditions, which prevent people from delivering and receiving health information, diagnosis and treatment, especially in remote areas (Peters et al., 2008; Idei & Kato, 2019).

Road conditions and travel distances also influence attendance rates at healthcare facilities. While good roads enable people to attend health education events, roads in poor condition prevent the dissemination of health information, as well as providing or receiving healthcare (Idei & Kato, 2019). Measures that reduce travel time to and from diabetes care services through road-building or improving public transport systems are important for promoting quality of life for diabetes patients (Konerding et al., 2017).

Also, it has been shown that the distance from the place of residence to a healthcare facility is one of the risk factors that can have a significant influence on geographical access to health services, which in turn increases diabetes prevalence (Powell, 2017). These findings are similar to those reported by Biswas and Kabir (2017) who found that in Bangladesh, the distance from home to healthcare facilities, and numbers of qualified doctors and pharmacies, influenced diabetes prevalence, specifically due to early diagnosis and medication compliance.

2.5 Diabetes as a public health condition of concern in Cambodia

As described in Chapter 1, diabetes is one of the major public health issues of national concern in Cambodia, with an estimated prevalence in 2014 of 5.9% (World Health Organisation, 2016a). With continuing changes in development, the number of cases is expected to rise, with some projections estimating 264,000 cases by 2028 (Flessa & Zembok, 2014). Unfortunately, it is still not possible to assess the exact burden of diabetes in Cambodia, as Cambodia has no accurate data source for deaths or NCDs (Ministry of Health, 2013).

Past surveys may have applied anthropometric cut-off and thresholds inappropriately for the Cambodia population. For example, An et al. (2013) found that the 2010 Cambodian national STEP survey may have underestimated the prevalence of being overweight and central obesity when it applied BMI and WC standards recommended by WHO. They concluded that the Asian BMI cut-offs were more appropriate in a Cambodian context; i.e. BMI ≥ 23.0 kg/m^2 being overweight and BMI ≥ 28.0 kg/m^2 being obese with WC of ≥ 90cm for men and ≥ 80cm for women for central obesity (An et al., 2013). If these standards had been applied in the 2010 STEP survey, the prevalence of being overweight would have nearly doubled (13.5 % to 25.5%) and central obesity would have increased from 16.9% in women and 11.8% in men to 20% in both sexes.

The high prevalence of diabetes is not just a major burden on the healthcare sector but also to society and the Cambodian economy and its national development goals. Firstly, diabetes directly reduces the quality of living. Nang et al. (2019) found that most participants in their study in Cambodia were symptomatic for a duration of months to years before seeking medical help. Individuals often sought medical help due to diabetic complications such as eye disease, renal dysfunction, and foot ulcers rather than diabetes. Another important feature reported by MoPoTsyo (n.d) was that the average life expectancy of 500 Cambodian diabetes patients studied was only four years after diagnosis, and only one out of ten patients living longer than ten years following diagnosis. Such results reflect the negative impact of unaffordable or delayed diagnosis and care. It also highlights how premature deaths due to diabetes can deprive households of their main financial providers. Therefore, when diabetes is rising in countries with poor healthcare infrastructure such as Cambodia, this can result in numerous premature deaths (Wagner et al., 2015).

MoPoTsyo (n.d) also reported that diabetes drains Cambodian households of their assets and financial resources, leaving poor households in debt due to unaffordable costs of long-term treatment and forcing parents to make their children drop out of school. Similarly, diabetes patients, especially those in poor families, risk losing their income, land, livestock, and savings. Productivity is lost due to diabetes-related disabilities, their quality of life deteriorates and there is a heavy financial burden due to the cost of long-term care (Yunguo & Beresford, 2017; Jacobs et al., 2017).

2.5.1 Identified diabetes risk factors in Cambodia

2.5.1.1 Behavioural risk factors

Consistent with observations globally, there are numerous risk factors for diabetes seen in Cambodia. These include behavioural risk factors, as well as those of genetic and societal concerns. Many Cambodians now consume unhealthier food than previously, including nutrient-poor, energy-dense foods with inadequate fruit and vegetable uptake and high rates of alcohol consumption. In 2017, dietary risks, tobacco, and alcohol use were ranked in the top six risk factors driving to disability-adjusted life years (DALYs) in Cambodia as demonstrated in Figure 4 (Institute for Health Metrics and Evaluation, 2020).

Figure 4

Risk Factors for Deaths and Disability in Cambodia

Note. Ranking of risk factors that drive combined deaths and disability in Cambodia 2007 and 2017 compared. Reprinted from Cambodia ("What Risk Factors Drive the Most Death and Disability Combined?"), by Institute for Health Metrics and Evaluation, 2020, http://www.healthdata.org/cambodia. Copyright 2020 by University of Washington.

According to the 2010 national survey, more than eight out of ten Cambodian adults were exposed to two or more diabetes risk factors. These included a diet rich in saturated fats and salts, alcohol and/or smoking. Up to 84.3% of the participants also reported consuming less than five servings of vegetables and fruit daily (Oum et al., 2010). For many Cambodians, eating sufficient quantities of fruit and vegetables is not always possible due to lack of availability and/or low income (Ministry of Health, 2013).

In recent years, the presence of unhealthy fast-food chains and sugar-sweetened beverages has steadily increased, specifically targeting young adults (Cheng & Spengler, 2016) through unrestricted advertising, ease of accessibility, and convenience (Pries et al., 2016). Culturally, most Cambodians routinely consume large amounts of white rice that has high sugar levels (Sar & Marks, 2015), and more recently the World Health Organisation (2019a) reported that daily salt consumption is almost double that of the recommended daily intake.

Additionally, alcohol and tobacco are not only risk factors of diabetes, but they disproportionately affect the Cambodia population by reducing their ability to spend on health care, education, and healthy food. According to the 2010 national STEP survey, 29.4% of the participants' aged 25-64 smoked tobacco while 53.5 % of adult participants reported drinking alcohol in the past 30 days with only 26.5 % lifetime alcohol abstainers (Oum et al., 2010). Kheam et al. (2011) also reported that most of the poorer households spend more than 10% of their income on cigarettes and spend less on education, clothing, and food.

Oum et al. (2010) also found that 63% of adults aged 25-64 were not engaged in any vigorous physical activity and many young Cambodians had moved to the cities for more sedentary jobs rather than undertaking agricultural work in their rural hometowns (Cheng & Spengler, 2016).

2.5.1.2 Genetic disorders as risk factors for diabetes

Diabetes in Cambodia may also be linked to a historical exposure of starvation leading to genetic disorders (Wagner et al., 2015). Pregnant women who endured famine during the 1975-1979 Cambodia civil war experienced adverse health conditions that negatively influenced foetal genetic conditions. These increased susceptibilities to glucose intolerance and genetic transformation, which have been associated with diabetes and other NCDs in later life (King et al., 2005). Such findings are consistent with those of the Ministry of Health (2013) that reported that cardiovascular disease and diabetes may result from undernutrition during foetal development and childhood. The high prevalence of reported maternal and child undernutrition suggests that many Cambodians are born with a higher risk of developing NCDs.

2.6 Societal risk factors for diabetes in Cambodia

2.6.1 Unhealthy environment due to unsustainable economic growth

While there are several important societal risk factors for diabetes in Cambodia, recent studies have highlighted the roles that urban markets and urban lifestyles play in relation to this.

Although economic growth has been pronounced in the last few decades, this increase has been accompanied by air pollution and unhealthy lifestyles (Yunguo & Beresford, 2017). For instance, from 1990 to 2010, O'Leary (2015) reported that the percentage of people living in urban areas had increased from 16% to 27%. It was also noted that this was expected to exceed 50% of the population by 2050. Outside of the capital city, Wagner et al. (2018) also observed that urban areas were expanding. For example, Siem Reap province has, in recent years, adopted a more Western, industrial, and modern lifestyle leading to increased NCD cases.

Urbanisation influences a wide range of behavioural risk factors for diabetes. It makes items such as unhealthy foods and tobacco, as well as alcohol, readily available across Cambodia. It also increases the likelihood of sedentary lifestyles as urban residents are half as active compared to rural dwellers (Ministry of Health, 2013). Wagner et al. (2016) found that in recent years, there has been a gradual change from using bicycles to motorbikes, a transition toward agricultural industrialisation, and a change to service-related employment rather than agriculture work, all decreasing physical activity for many Cambodians.

2.6.2 Cultural barriers

Cambodian cultural beliefs and traditional practices are another challenge for early diabetes diagnosis and long-term management. Jacobs et al. (2017) reported that some individuals experienced diabetic symptoms for long periods or sometimes until severe complications appeared before being diagnosed. This was often due to individuals assuming their symptoms, especially fatigue or weight loss were due to other causes such as having offended local spirits.

Similarly, the use of traditional medicine for diabetes treatment is highly practised in Cambodia. Jacobs et al. (2017) showed that in their study only half of the patients received conventional diabetes medicine, while the other half chose traditional medicine or no treatment at all. This was mainly due to patients' beliefs in the possibility of a cure through traditional remedies. These remedies were also cheaper when compared to western medicine and the belief in the synergistic effect of combining traditional with western treatment (Nang et al., 2019). Even in developed countries, Cambodians retained considerable confidence in traditional medicine. For example, Renfrew et al. (2013) demonstrated that despite poor glycaemic control, Cambodian refugees in the US often replaced or combined western diabetic medicines with traditional medicine.

2.6.3 Educational barriers

Limited diabetes literacy in terms of diet control and long-terms management is another obstacle (Nang et al., 2019). Jacobs et al. (2017) noted that some patients had found it challenging to follow the guidelines for long-term diabetes care after being discharged from the hospital. The authors showed that when newly diagnosed diabetes patients received episodic care, they did not adhere to long-term care after their health improved. However, if the long-term health consequences were negative, patients would repeatedly shift to new treatments. This pattern of self-treatment and 'shopping' around for diabetic treatment limits adherence to long-term care, reduces the effectiveness of treatment and increases out-of-pocket expenditure (Bigdeli et al., 2016).

2.6.4 Gender inequality

Cambodian women are affected slightly more by diabetes than men. In respect to the role played by gender in increasing diabetes risk, Kautzky-Willer et al. (2016) showed that these differences are reflected in biological and physiological differences in body composition, hormones, fat and glucose metabolism, and some pathophysiology, which may result in different rates of diabetes. Also, gender differences between men and women are associated with different behaviours, as well as levels of stress, education, income, and the lifestyle that influence the risk of developing diabetes (Kautzky-Willer et al., 2016). It has been shown that Cambodian women were twice as likely to be overweight than men, a known risk factor of diabetes (Oum et al., 2010). The World Health Organisation (2019b) found that one in five women were not physically active. In addition, a 2011 national survey on tobacco consumption found that while more adult males (42.5%) used tobacco, women appeared to be equally exposed to second-hand smoke (Kheam et al., 2011). Men et al. (2011) also found that as the burden of care falls mostly on Cambodian women and girls, this reduced their ability to access health care, education, and social welfare.

2.7 Issues of accessibility as a risk factor for diabetes prevention and control in Cambodia

2.7.1 Introduction

In addition to the wide range of behavioural, genetic, and societal risk factors, accessibility to healthcare services including those for diabetes, remain challenging in Cambodia. Through its health strategic plans for 2003-2007 and again for 2008-2015, the Cambodian government has made considerable effort to improve healthcare delivery, quality, and quantity of healthcare resources to improve accessibility (Annear et al., 2015). In the latest plan for 2016-2020, there has been a focus on the universal health coverage to assure equitable access to quality healthcare services for all (World Health Organisation, 2016c).

However, there is limited and unequal access to quality health care, especially those living in poverty despite past efforts on expanding access (Asante et al., 2019; Liverani et al., 2017). To date, Cambodia has not yet focused on improving access to NCDs prevention and control. Effective operational strategies and action plans are still lacking on a large scale to cope with the ever-increasing diabetes rates and very limited interventions or policies to assure success in reaching the goal of reducing premature deaths by 2030 (Yunguo & Beresford, 2017). There has been very limited critical attention to NCD management, largely because most of the health funding is directed to infectious diseases such as human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDs), malaria, and tuberculosis (Wagner et al., 2015). These reports are consistent with those of another study which indicated that limited strategies for diabetes management continue to face funding shortages, with none of the district health administrations reported having budgets for NCD management (Jacobs et al., 2015). For this reason, access to quality care in Cambodia remains problematic, especially for diabetes care. This is described in more detail in relation to the dimension of affordability, availability, acceptability, and geographic access.

2.7.2 Unaffordable diabetes care and structural inequality

Diabetes care is unaffordable for low-income groups. Generally, out-of-pocket spending for NCD care costs an average of five U.S dollars, which is equivalent to one day's wage for an unskilled worker in Cambodia (Bigdeli et al., 2016). People in poverty encounter poor access or long queues for very limited services in public hospitals (Ministry of Health, 2013). Conversely, wealthy groups can pay for treatment in private clinics or treatment in neighbouring countries such as Vietnam, Thailand, or Singapore offering better quality facilities (Jacobs et al., 2017).

For diabetes treatment in a public hospital, patients reported an average expenditure of US$30 to $50 (Nang et al., 2019). This amount doubled for treatment in the private sector while the average monthly household income was around US$116 (Nang et al., 2019). Even though there are financial schemes to promote equal access to public health care, especially for low-income families, these do not prioritise NCD care (Flessa & Zembok, 2014). This has resulted in a large number of Cambodians initiating treatment with out of pocket payments in the private sector (Asante et al., 2019).

2.7.3 Unavailable resources for diabetes care

While access to affordable diabetes care is beyond the financial reach of many Cambodians, physical availability to diabetes services is also a barrier. This is due to limited healthcare workers and an absence of diabetes management at community health centres (Nang et al., 2019).

First, the shortage of human healthcare resources creates considerable difficulties in managing an increasing diabetic population, combined with high population growth (National Institute of Statistics, 2019). Despite evidence of rising demands, the number of healthcare professionals remain insufficient. Data from 2008 indicated the density of health workers was only one per 1,000 people, which was less than the Millennium Development Goals recommendation of 2.3 health workers per 1,000 population (Henderson & Tulloch,2008). This critical shortage of healthcare workers and inequalities in the distribution of health services remains an issue given the current growing population, especially in rural communities (Liverani et al., 2017). Other research has shown that in rural areas, only 20% of healthcare services were delivered by public providers and 29% by qualified private healthcare providers. In contrast, up to 50% were delivered by non-medical providers (Jacobs et al., 2015). An added concern was that there were no qualified health professionals responsible for NCD management at health centres (Jacobs et al., 2015).

Additionally, public hospitals in Cambodia are inadequately equipped to address diabetes. Diabetes prevention, diagnosis, and treatment are not yet incorporated in the basic package of healthcare provision in health centres due to limitations in both financial and human resources (Flessa & Zembok, 2014). For example, at the community level, there are only nurses or midwives who provide basic healthcare and do not support NCDs. The alternative is for individuals to travel to referral hospitals in the provincial capital for more substantial healthcare needs including surgery, emergency, and more severe medical conditions (Idei & Kato, 2019; World Health Organisation, 2016c). Limited diabetes care is only available in Cambodia at the national and provincial referral hospital level, and diabetes complications management is only available at the national level in Phnom Penh city (Nang et al., 2019).

Availability issues of health resources also apply to medication. The World Health Organisation (2016a) suggests that diabetes management requires regular blood glucose control, appropriate medication, as well as physical activity and a healthy diet. The provision of essential drugs and diabetes education are priorities for coping with the diabetes emergency in Cambodia, as medication costs represent such a high proportion of medical costs (Bigdeli et al., 2016). However, the World Health Organisation (2016b) has shown that in Cambodia's public hospitals, diabetes-related medications and clinical procedures, as well as basic technologies, are not readily available. Medication stocked for NCDs is only able to fulfil five to seven diabetes patients' treatment requirements per quarter and is not available in all public healthcare facilities (Jacobs et al., 2015) and a patient is only prescribed medication for one to two weeks per hospital visit (Nang et al., 2019). More importantly, insulin is not available at public hospitals across all of Cambodia for the majority of patients, although it is recognised as one of the major priority treatments (Flessa & Zembok, 2014; Nang et al., 2019). As a consequence, diabetes patients requiring insulin have to use private healthcare services, as well as purchase the medication, neither of which are affordable for the majority of individuals. Furthermore, most hospitals reported a lack of laboratory equipment to test for glycated haemoglobin A1C which monitors blood glucose levels. (Nang et al., 2019).

2.7.4 Unacceptable diabetes care

The degree to which diabetes care is acceptable to the public also influences accessibility. Currently, in Cambodia, geographical access to public diabetic services is only possible at the province-level and in several chronic diseases clinics (CDC). In the case of the CDC, diabetes-specific services were first initiated with donor funding. Unfortunately, when the funding ended, the services for diabetes care became less efficient (Ministry of Health, 2013). The CDCs were organised through international aid as integrated clinics for HIV/AIDs patients, hypertension, and diabetes, where patients could go for a consultation, receive medication, as well as laboratory testing (Ministry of

Health, 2013). There were ten CDCs set up in Cambodia, located at referral hospitals in seven provinces. One study reported that during a three-month period 34% of diabetic patients from the CDCs were lost to follow-up (Raguenaud et al., 2009). Van Olmen et al. (2016) explained this loss to follow-up was due to several reasons, including inadequate funding, increased levels of self-payment by 39% for diabetes services, limited provision of medication, long travel distances, and distrust of the public health services.

Additionally, many diabetes patients often expressed fear and hopelessness after a diabetes diagnosis. This was due to having heard about other experiences of diabetes complications such as death or amputation, which reflected the number of improper diabetes consultations (Nang et al., 2019).

2.8 Challenges in geographical access to diabetes care

In Cambodia, the public healthcare network is divided into three levels, to include national, provincial, and then community healthcare centres. At the national level, there are the central ministry and national hospitals, located in Phnom Penh city, while in each of the 24 provinces there are the provincial health offices with one referral hospital (Jacobs et al., 2017) that provide a complimentary package of services to the health centres such as major surgery (Bigdeli et al., 2016). At the district level, there are healthcare centres that offer only preventative services and basic curative care which mainly covers maternal, newborn child, and reproductive health (Jacobs et al., 2017). As a result, there is a low utilisation of public health services. For example, a World Bank study determined that only 15% of patients commenced care in rural communities using public health services, while 50% sought private care from unqualified providers (World Bank, 2013, as cited in Jacobs et al. 2017).

These challenges in rural areas illustrate some of the potential difficulties in geographical access to healthcare services in Cambodia. Poor road infrastructure in rural areas and long travel times to healthcare facilities are obstacles for many people residing in rural areas. Idei and Kato (2019) conducted a study in three rural Cambodia provinces that showed people only visited healthcare centres for preventative care but not for treatment due to the absence of a doctor and curative services. As a result, people in rural communities were left with little option but to consult private providers who were often unqualified and overpriced. The authors concluded that limited vehicle ownership, poor road conditions, and the location of healthcare facilities influenced health service choices and discouraged rural participants from travelling to receive health care at a referral hospital. Similarly, Nang et al. (2019) noted that patients complained about transportation expenses, as well as the time it took to reach diabetic centres. They also reported that many patients were left untreated or faced interruptions to their diabetes treatment due to poor geographical access as well as financial issues, lack of skills and knowledge on diabetes management.

2.9 Chapter summary

This chapter has described how diabetes reduces the quality of life and exacerbates poverty for individuals with diabetes living in Cambodia. It has also examined a wide range of behavioural, genetic, and societal risk factors that increase the likelihood of diabetes. The chapter has presented the importance of accessibility of healthcare services for diabetes prevention and control and identified studies that have shown how the impact of poor road conditions, travel times, poverty, and meagre healthcare services discourage patient access to diabetes care, especially in rural areas. This study focuses specifically on the prevalence of T2DM in Siem Reap province to better understand the role of access to province-level diabetes health services in the diagnosis and detection of T2DM.

Chapter 3 Methodology

3.1 Introduction

The overarching aim of this research was to better understand the role of physical distance between rural communes and diabetes health services in the provincial capital on type 2 diabetes mellitus (T2DM) in Siem Reap Province, Cambodia.

In one study, the relationship between geographical access to health services and T2DM conducted in Bangladesh, Biswas and Kabir (2017) found that distance to diabetes healthcare services influenced T2DM prevalence. This was due to distance having an adverse effect on early T2DM diagnosis, access to treatment and preventative measures. In Cambodia, rural areas face similar difficulties in geographical access to diabetes healthcare services (Nang et al., 2019; Idei & Kato, 2019). This is due to poor road infrastructure, long travel times, and financial constraints. It is also due to the limited provision of diabetes health services that are located primarily in provincial capitals (Jacobs et al., 2015).

Therefore, this study sought to investigate whether the distance between the place of residence and diabetes health services in the Siem Reap provincial capital was a risk factor for undiagnosed T2DM. This was done by addressing three specific research questions:

- What was the prevalence of T2DM in the nine different communes investigated?
- Were there differences in the prevalence of T2DM in communes situated at different distances from the provincial capital?
- What were the risk factors for adults with T2DM in Siem Reap Province, Cambodia, and how did these findings align with those for developing countries in the published literature?

This chapter presents the research methodology used to address these questions. It begins by introducing and describing the rationale for using a secondary dataset, including evaluation of its quality and appropriateness for secondary research. The chapter then outlines the statistical methods used for data analysis and steps taken to ensure compliance with research ethics requirements.

3.2 Rationale for using the Cambodian Diabetes Association (CDA) dataset

There are advantages in the use of a secondary dataset. Johnston (2017) notes that these can include cost-effectiveness and an expedited research process, as the development of measures and data collection steps have already been completed. Hakim (1982) also noted that secondary datasets provide opportunities for emerging or unfunded researchers to build their research capacity (Johnston, 2017).

However, there are also limitations in using secondary data. These include a mismatch between the original study's purpose and the aims and objectives of the new research (Johnston, 2017; Boslaugh, 2007). A further drawback in the use of secondary data is due to limited first-hand knowledge of how the original study was carried out (Johnston, 2017).

Due to time and resource constraints for primary data-gathering in Cambodia, a robust secondary dataset relevant to the research topic of T2DM was deemed appropriate. However, careful and systematic steps needed to be taken to determine the quality of the original research process and its appropriateness for application to the new research question. As this research sought to use a secondary dataset collected by the CDA, careful examination of the original data-gathering process was conducted. A review of the following was required; alignment of the aims of both studies, scientific reputation of the primary researchers, clarity of the information collected and its timing, methods used in the original data collection, and management of the primary data (Johnston, 2017).

3.3 Evaluation of the CDA dataset

3.3.1 Alignment between the aims of the 2010 CDA screening survey and this research

In 2010, the CDA ran mobile screening clinics in nine geographically distinct communes in Siem Reap province, including; Dom Daek, Dan Run, Kien Sangkae, Samraong, Kampong Khleang, Kampong Kdei, Anlong Samnar, Svay Leu and Khvav. This screening survey represented a feasibility study whose aim was to test the scope for T2DM screening at-scale across the entire province (Eldridge et al., 2016). It was followed in 2012 by a much larger screening survey across Siem Reap province that reached 13,997 people aged 25 years and older (Wagner et al., 2018).

While the original research only aimed to conduct a feasibility study that collected data without analysis, it captured detailed demographic and anthropometric data (body mass index, waist circumference, hip circumference, weight, and height) across nine geographically distinct communes. These unanalysed data were directly relevant to the new research aim to examine T2DM prevalence in the rural areas of Siem Reap.

3.3.2 The scientific reputation of the primary researchers

The 2010 primary data were collected by the Cambodian Diabetes Association. This organisation was founded in 2000 to combat the growing prevalence of diabetes in Cambodia through diabetes education, prevention, and management (Cambodian Diabetes Association, n.d). The CDA is internationally recognised and is a highly reputable research institution with professional performance and research integrity. The well-trained researchers have established research profiles in diabetes and have published in peer-reviewed journals. Their publications include a survey on T2DM and associated disorders in Cambodia (King et al., 2005) and T2DM and cardiometabolic risk factors in Cambodia (Wagner et al., 2018). CDA has demonstrated expertise in diabetes research and provides confidence in the academic rigour of the 2010 survey data collected.

As this research analysed the secondary data from the 2010 CDA screening survey, it was necessary to examine and verify the data-gathering instruments. An example of the case report form (CRF) was made available for this research (Appendix 1). The dataset was provided by the CDA in excel format with no access to the original CRFs to verify any of the raw values. The CDA's principal investigator explained the procedures, measures, and protocols applied in the original survey. These have been used repeatedly in CDA's screening surveys, for example, in the 2018 publication by Wagner et al. (2018).

The data from the original 2010 CDA screening survey were still considered valid for this research as the secondary research sought to examine factors that had remained constant over the past ten years. Specifically, the research sought to investigate the relationship between the geographical distance of participants' places of residence and the provincial capital as a risk factor for T2DM.

3.3.3 Methods used in the original study

A key requirement for evaluating the appropriateness and quality of a secondary dataset involved knowledge of the primary data collection methods used (Johnston, 2017) to ensure that this study would comply with the New Zealand Ethical Standards for Health and Disability Research and Quality Improvement (National Ethics Advisory Committee, 2019). The reliability and validity of the measurements in the 2010 screening survey and the measurement methods used were also explored.

To comply with ethical requirements informed consent from the participants in the original study was required from participants. The 2010 screening survey was conducted as a feasibility study; therefore, convenience sampling was utilised not just because it was convenient and less expensive but also it offered basic data and trends without complications of using a randomized sample. Etikan (2016) explained that convenience sampling is a non-random sampling methodology that is used when the sample subjects are easy to access, readily available to recruit, and affordable. Residents of nine communes in Siem Reap were invited to respond to a public health invitation to be screened for T2DM. CDA researchers explained to the prospective participants the research study and the procedures that would take place. In total, 481 adults gave consent to be screened.

For the validity and reliability of the indicators used and measurement methods, a data dictionary was compiled (Appendix 2) to ensure alignment with internationally recognised measurement criteria. For example, a *HemoCue® blood* glucose analyser was used to measure glucose. The outcome variable of "having diabetes" was defined as a measurement of "fasting glucose ≥ 126 mg/dL or random/postprandial glucose ≥ 200 mg/dL" (World Health Organisation, 2016b).

As a confirmation measure, *random blood sugar* was also used if participants had low fasting glucose but had T2DM symptoms or high fasting glucose without T2DM symptoms which would suggest that the participant ate breakfast before testing. Participants who self-reported doctor-diagnosed T2DM or reported taking T2DM medication were also coded as positive for T2DM (classified as previously diagnosed T2DM).

Trained research assistants conducted the measurements and collected the data. Weight was measured using an electronic body scale without footwear at the time of screening. Waist, hip, and height measurements were taken twice by a tailor's measuring tape measure and then averaged. Body mass index was later determined by dividing participants' weight in kilograms by height in metres squared (Wagner et al., 2018). Blood pressure measurement was taken twice in the sitting position using the left arm with an automatic digital blood pressure instrument. Participants who were taking antihypertensive medication were also classified as hypertensive cases.

3.3.4 Determining adequacy for sample size

Altogether, 481 participants met the inclusion criteria. To determine the sample size that would be adequate to determine the prevalence of a disease in a population, Arya et al. (2012) suggested the equation below to calculate the sample size:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

The ***Z statistic*** represents the number of standard deviations from the population mean. For this study, the desired level of confidence was 95%; giving a Z value of 1.96 (Arya et al., 2012). Additionally, ***Expected Prevalence*** *(P)* was 0.05 (5%). This value was obtained from the prior studies of King et al. (2005) and Wagner et al. (2018), who found that the prevalence of T2DM in rural communes in Siem Reap was 5%. The ***Margin of error*** (d) referred to the maximum risk estimate acceptable in the sample size and for the study $d = \frac{P}{2}$ = 0.025 (Arya et al., 2012). Therefore, the minimum sample size for this research required 292 subjects.

The sample size also met the minimum requirement for the logistic regression analysis planned in this study. It is recommended that there are at least 15 participants for each variable to obtain a reliable equation from logistic regression (Stevens, 1996 as cited in Pallant, 2011). The formula N > 50 + 8m was used to calculate the total number of participants for independent variables (where m is the number of independent variables) (Tabachnick & Fidell, 2001 as cited in Pallant, 2011). In this study, the regression analysis had eight independent variables: distance from the Siem Reap provincial capital, age, gender, body mass index (BMI), hip circumference (HC), waist-to-height ratio (WtHR), waist-to-hip ratio (WHR) and hypertension. Therefore, the number of cases needed was 114 to establish any associations between predictors variables and T2DM.

3.4 Research methodology

3.4.1 Procedure

This study analysed the relationship between independent variables and T2DM. It also examined the detailed demographic, development, and socio-economic information for each of the communes being investigated by drawing on an open-access 2010 database for all communes in Cambodia (National Committee for Sub-National Democratic Development, 2010). This offered critical information about societal risk factors of the communes survey that influenced T2DM prevalence.

3.4.2 Variable measurements

Two additional variables were calculated. The waist-to-height ratio value was calculated by dividing WC and height and the waist-to-hip ratio results from WC divided by the HC as described in the data dictionary (Appendix 2). Distance from the Siem Reap provincial capital was defined by the number of kilometres from the provincial capital to each commune. This was determined using the 2010 online database from Sub-National Democratic Development (NDD) (Table 3).

Table 3.Distance between the nine communes surveyed and the Siem Reap provincial capital.

N	Commune	Distance from the Provincial Capital
1	Dom Daek	34.74km
2	Dan Run	36.24 km
3	Kien Sangkae	36.75km
4	Samraong	40.48km
5	Kampong Khleang	49.6km
6	Kampong Kdei	61.75km
7	Anlong Samnar	65.95km
8	Svey Leu	72.45km
9	Khvav	97.43km

3.4.3 Data treatment and analysis

The data were exported electronically from Excel into IBM SPSS Statistics for Windows, Version 25.0. for analysis. Data cleaning and checking were conducted. Descriptive statistics followed by statistical analysis were conducted to respond to the research questions previously described in this chapter.

3.4.3.1 Missing data

In the original dataset, seven participants had variables with one or more missing values. During data cleaning, there were 75 participants with unresolvable measurements as the individual records were inaccessible to verify the errors or abnormal values.

The number of participant records with a complete dataset available for analysis was 399. As the original study was prospective, missing data were not expected. Because the individual records could not be accessed to verify the missing data, they were considered to be missing not at random (MNAR). For this study, *complete-case analysis* was used (399 participants). Although the number of participants dropped from 481 to 399 cases, the cases available were still adequate to meet the minimum sample size required (292).

3.4.3.2 Checking for Outliers

Outliers were checked to avoid sensitivity in the analysis. Histograms were generated (Appendix 3) to view the distribution of values for continuous variables and Boxplots were used (Appendix 3) to visualise values which might have fallen out-of-range. No extreme values were noted. The *Descriptive Statistics* technique (Appendix 4) offered descriptive information such as mean, 5% trimmed mean, standard deviation, maximum, and minimum for continuous variables, the *Frequencies* technique (Appendix 5) verified the number of cases for categorical variables.

3.4.3.3 Coding technique

The dichotomous dependent variable (T2DM) was divided into three groups which were new T2DM, previously diagnosed T2DM and total T2DM (Table 4). The responses were coded as 0 for non T2DM and 1 for T2DM or 1 for new T2DM or 1 for previously diagnosed T2DM cases. Among the eight continuous independent variables, there were two categorical variables (gender and hypertension) and five continuous variables to be analysed, including distance from the Siem Reap provincial capital, age, BMI, WtHR, HC, and WHR.

Table 4.Variable labels and coding in SPSS software.

Variable Type	Variable name	Variable label	Coding Instruction
Dependent variables	NT2DM	New T2DM cases	0= no, 1= NT2DM
	PT2DM	Previously diagnosed T2DM cases	0= no, 1= PT2DM
	T2DM	Type 2 diabetes mellitus	0= no, 1= T2DM
Independent variables	Distance	Distance	Distance in Km
	Age	Age	Age in years
	Sex	Sex	0= female,1= male
	BMI	Body Mass Index	BMI in cm
	WtHR	Waist-to-height ratio	Value of ratios
	WHR	Waist-to-hip ratio	Value of ratios
	Hypertension	Hypertension	0= no, 1= yes

3.5 Ethical considerations

The study obtained PGR1 research approval on 7 February 2020 (Appendix 6) and written authorisation from the director of the Cambodian Diabetes Association, Dr Lim Keuky, on 17 February 2020 for the access and use of these survey data for the purpose of this research (Appendix 7). Ethics approval from the Auckland University of Technology Ethics Committee (AUTEC) was received on 2 April 2020 (Appendix 8).

3.6 Chapter summary

Chapter 3 has presented the rationale for using the 2010 CDA dataset. It has concluded that the processes, measures, and protocols of secondary data collection were valid and reliable for the research aim. The research methodology for the initial research and the secondary data analysis has also been described.

Chapter 4 Findings

4.1 Introduction

This chapter reports the results of the analyses that were conducted to answer the research questions. It provides prevalence data for type 2 diabetes mellitus (T2DM) derived for each commune and baseline characteristics (mean (m), standard deviation (SD), percentages (%) and 95% Confidence Intervals (95%CI)). The chapter also reports on the significant predictors of T2DM that have been identified for this dataset.

4.2 T2DM prevalence across the screening sample in nine communes

Tables and scatterplots (Appendix 9) have been used to present the T2DM data. Prevalence data are presented in the tables based on the number of total participants (Table 5) and by gender (Table 6).

Of the 399 participants, there were 81/399 (20.3%) (95%CI: 16.7-24.5) T2DM cases 53/399. Fifty-three (13.3%) (95%CI: 10.3-17.0) cases were diagnosed as part of the 2010 screening programme. Only 28/399 (7.0%) (95%CI: 4.9-10.0) T2DM cases were previously diagnosed (Table 5). The results showed that Dom Daek, which was the closest distance from the Siem Reap provincial capital (34.74km), had the lowest prevalence of 8.3% (4/48) (95%CI: 3.3-19.6).

The highest T2DM prevalence was 30% (12/40) (95%CI: 18.1-45.4) recorded in Kampong Kdei commune (61.75km), with a similar prevalence of 28.3% (15/53) (95%CI: 18.0-41.6) in the furthest commune from Khvav (97.43km). The greatest percentage of previously diagnosed T2DM prevalence was in Kampong Khleang of 18.6% (11/59) (95%CI: 10.7-30.4) (49.6km). There were no previously diagnosed T2DM cases in Kien Sangkae and Samraong.

Table 5.Prevalence of new T2DM, previously diagnosed T2DM, and total T2DM cases in the nine communes surveyed

Commune	Participants	New T2DM cases			Previously diagnosed T2DM cases			Prevalence of sample of T2DM		
	N	N	%	95%CI	N	%	95%CI	N	%	95%CI
Dom Daek	48	3	6.3%	2.2-16.8	1	2.1%	0.4-10.9	4	8.3%	3.3-19.6
Dan Run	74	8	10.8%	5.6-19.9	5	6.8%	2.9-14.9	13	17.6%	10.6-27.8
Kien Sangkae	36	8	22.2%	11.7-38.1	0	0.0%	0.0-9.6	8	22.2%	11.7-38.1
Samraong	11	3	27.3%	9.8-56.6	0	0.0%	0.0-25.9	3	27.3%	9.8-56.6
Kampong Khleang	59	4	6.8%	2.7-16.2	11	18.6%	10.7-30.4	15	25.4%	16.1-37.8
Kampong Kdei	40	9	22.5%	12.3-37.5	3	7.5%	2.6-19.9	12	30.0%	18.1-45.4
Anlong Samnar	49	4	8.2%	3.2-19.2	1	2.0%	0.4-10.7	5	10.2%	4.5-21.8
Svey Leu	29	2	6.9%	1.9-22.0	4	13.8%	5.5-30.7	6	20.7%	9.9-38.4
Khvav	53	12	22.6%	13.5-35.5	3	5.7%	1.9-15.4	15	28.3%	18.0-41.6
Total	**399**	**53**	**13.3%**	**10.3-17.0**	**28**	**7.0%**	**4.9-10.0**	**81**	**20.3%**	**16.7-24.5**

For female participants (Table 6), the total prevalence of T2DM was 21.5% (59/275). Dom Daek, the closest commune to the provincial capital, had only 1 (3.6%) female participant who tested positive for T2DM out of 28 participants. The largest cluster of newly diagnosed female T2DM cases was in Kien Sangkae with 5/19 participants (26.3%). In Kvav, situated at 97 km from the capital city, 10/41 (24.4%) women had a new diagnosis of T2DM. Additionally, 10 out of 20 females had previously been diagnosed with T2DM from Kampong Khleang, located 49.6km from the Siem Reap centre. This was the largest cluster of previously diagnosed female T2DM cases for any of the communes studied. There were no previously diagnosed female T2DM cases recorded in three of the communes namely, Dom Daek, Kien Sangkae, and Samraong.

For male participants (Table 6), the total prevalence of T2DM was 17.7% (22/124). The number of both new and previously diagnosed males with T2DM were less than 3 cases per commune. Samraong had 2/2 (100.0%) male participants who tested positive for T2DM. In Anlong Samnar, only 5 males who participated, with no previously diagnosed cases, and no newly diagnosed cases of T2DM. In both Kien Sangkae and Samraong communes, no previously diagnosed male cases of T2DM were recorded, along with two further communes, Kampong Khleang and Svey Leu.

Table 6. New and previously diagnosed female T2DM cases in the nine communes surveyed

	Female Participants							Male Participants						
Commune		**New T2DM Cases**		**Previously diagnosed T2DM cases**		**Prevalence of T2DM**			**New T2DM cases**		**Previously diagnosed T2DM cases**		**Prevalence of T2DM**	
	N	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**N**	**%**	**N**	**%**	**N**	**%**
Dom Daek	28	1	3.6%	0	0.0%	1	3.6%	20	2	10.0%	1	5.0%	3	15.0%
Dan Run	47	5	10.6%	3	6.4%	8	17.0%	27	3	11.1%	2	7.4%	5	18.5%
Kien Sangkae	19	5	26.3%	0	0.0%	5	26.3%	17	3	17.6%	0	0.0%	3	17.6%
Samraong	9	1	11.1%	0	0.0%	1	11.1%	2	2	100.0%	0	0.0%	2	100.0%
Kampong Khleang	41	4	9.8%	10	24.4%	14	34.1%	18	0	0.0%	1	5.6%	1	5.6%
Kampong Kdei	29	7	24.1%	2	6.9%	9	31.0%	11	2	18.2%	1	9.1%	3	27.3%
Anlong Samnar	44	4	9.1%	1	2.3%	5	11.4%	5	0	0.0%	0	0.0%	0	0.0%
Svey Leu	17	2	11.8%	2	11.8%	4	23.5%	12	0	0.0%	2	16.7%	2	16.7%
Khvav	41	10	24.4%	2	4.9%	12	29.3%	12	2	16.7%	1	8.3%	3	25.0%
Total	**275**	**39**	**14.2%**	**20**	**7.3%**	**59**	**21.5%**	**124**	**14**	**11.3%**	**8**	**6.5%**	**22**	**17.7%**

4.3 Baseline characteristics

This study also computed descriptive statistics using the *Sample Compare Means* technique. The purpose of using the compare means procedure was to summarise and to compare the differences of general baseline characteristics between female and male participants across continuous variables by T2DM. The baseline characteristics were illustrated by comparing means, standard deviation, and counts between male and female participants (Table 7).

For the female T2DM cases, the mean distance was 60.8 (SD±21.7) km, and age was 58 (SD±9.6) years. The mean of body mass index (BMI) and waist circumference (WC) were 23.8 (SD±4.1) kg/m^2 and 80.2 (SD±9.8) cm, respectively. Additionally, the average WtHR for female T2DM cases was 0.5 (SD±0.1), the average HC was 93.9 (SD±8.1) cm and that of WHR was 0.9 (SD±0.1). In contrast, the mean values of the same variables for non T2DM female cases were lower. For example, the average BMI was only 22.3 (SD±4.5) kg/m^2, and WC was only 74.9 (SD±9.7) cm.

For the male T2DM cases, the mean distance was 52.2 (SD±22.3) km, and age was 62.3(SD±12.2) years. The means of BMI and WC were 22.2 (SD±3.7) kg/m^2 and 78.1 (SD±11.2) cm, respectively. The average HC was 87.9 (SD±7.5) cm. The means of these five variables were higher than those of the non T2DM male cases. Additionally, the average WtHR for male T2DM cases was 0.5 (SD±0.1) and WHR was 0.9 (SD±0.1). The means of these two variables were similar to those of male non T2DM cases.

Table 7. Mean value of each variable for male and female participants differentiated by T2DM and non T2DM status

	New T2DM cases			Previously diagnosed T2DM cases			Total T2DM cases			Non T2DM cases		
	N	Mean	SD (±)	N	Mean	SD (±)	N	Mean	SD (±)	N	Mean	SD (±)
Females												
Distance from province-level diabetes health services (km)	39	62.9	23.6	20	56.7	17.3	59	60.8	21.7	216	56.0	20.9
Age (years)	39	57.1	8.9	20	59.7	10.9	59	58.0	9.6	216	53.4	11.8
BMI (kg/m^2)	39	23.6	4.0	20	24.2	4.4	59	23.8	4.1	216	22.3	4.5
WC (cm)	39	79.6	9.8	20	81.2	10.2	59	80.2	9.8	216	74.9	9.7
WtHR	39	0.5	0.1	20	0.5	0.1	59	0.5	0.1	216	0.5	0.1
HC (cm)	39	93.1	8.1	20	95.5	8.1	59	93.9	8.1	216	90.4	8.7
WHR	39	0.9	0.1	20	0.8	0.1	59	0.9	0.1	216	0.9	0.1
Males												
Distance from province-level diabetes health services (km)	14	49.1	22.4	8	57.6	22.5	22	52.2	22.3	102	50.7	19.5
Age (years)	14	60.1	11.0	8	66.0	13.9	22	62.3	12.2	102	55.3	9.7
BMI (kg/m^2)	14	22.4	3.2	8	21.7	4.7	22	22.2	3.7	102	21.8	3.4
WC (cm)	14	79.8	11.0	8	75.3	11.8	22	78.1	11.2	102	76.1	9.6
WtHR	14	0.5	0.1	8	0.5	0.1	22	0.5	0.1	102	0.5	0.1
HC (cm)	14	88.2	6.2	8	87.3	9.8	22	87.9	7.5	102	88.6	7.1
WHR	14	0.9	0.1	8	0.9	0.1	22	0.9	0.1	102	0.9	0.1

4.4 Logistic regression analyses

The association between each variable as a risk factor for T2DM was estimated by *binary logistic regression* analysis which calculated the level of significance (*p*-value). In this study, the level of significance < .05 was considered to be statistically significant.

The dependent variable of interest was T2DM, whereas the independent variables were a mix of categorical (gender and hypertension) and continuous variables (distance from province-level diabetes health services in Siem Reap, and BMI, WC, HC, WHR, WtHR, and age). Statistical analysis using logistic regression was used for assessing the association between the predictor variables and T2DM by determining the OR and 95%CI (Pallant, 2011).

Logistic regression also assessed how well independent variables such as BMI, WC, HC, WHR, WtHR, age, gender, hypertension, and distance from the Siem Reap provincial capital predicted the risk of T2DM development.

4.4.1 Multicollinearity

For logistic regression analysis, predictors that have strong inter-correlation were removed as they have a negative influence on a logistic regression model. The WC variable was removed as it was highly correlated with WtHR. WtHR is believed to be a better predictor of T2DM (Son et al., 2016) (Appendix 10). The relationship between distance from province-level diabetes health services in Siem Reap, and age, sex, BMI, HC, WtHR, WHR, and hypertension were analysed with respect to T2DM diagnosis.

Table 8 shows the OR and level of significance for each of the predictor variables. In this study, distance from the Siem Reap provincial capital and age, and hypertension were identified as significant predictors for T2DM with *p*-values of .006, .005, and .028 respectively, and positive β-values.

New T2DM cases had two significant variables, distance from the Siem Reap provincial capital (*p*-value = .009) and hy*p*ertension (*p*-value = .002) compared to previously diagnosed cases which had only one significant variable which was age (*p*-value = .004).

Table 8. Predictor variables for T2DM

	New T2DM cases		Previously diagnosed T2DM cases		Total T2DM cases	
Variables	**β-values**	***p*-values**	**β-values**	***p*-values**	**β-values**	***p*-values**
Distance from province-level diabetes health services (km)	0.02	.009	0.01	.425	0.02	.006
Age (years)	0.02	.280	0.06	.004	0.04	.005
Sex	0.36	.421	-0.31	.574	0.09	.812
BMI (kg/m^2)	-.08	.925	-0.03	.785	-0.02	.769
WtHR	-2.77	.753	13.40	.199	5.52	.452
HC (cm)	0.03	.586	0.00	.947	0.01	.731
WHR	8.95	.105	-6.10	.361	3.18	.485
Hypertension	1.05	.002	-0.30	.512	0.62	.028

4.5 Chapter summary

This chapter has reported the results of the analysis that was conducted to address the research questions identified in Chapter 3. The analysis found that the mean distance, age, and anthropometric indices such as BMI, WC, and HC for female T2DM cases were higher than those of male T2DM. The results showed that the prevalence of T2DM was 20.3% in the 399 participants studied, of which 13.3 % were new cases and 7.0% were previously diagnosed cases. This chapter also reported that increasing age, distance from the Siem Reap provincial capital, and hypertension were the significant predictors of T2DM.

Chapter 5. Discussion and Conclusion

5.1 Introduction

The overarching aim of this research was to explore the relationship between geographic access to province-level diabetes health services and T2DM in nine rural communes within Siem Reap province, Cambodia. The study probed the relationship between distance and T2DM by determining the prevalence of T2DM in the nine selected communes and investigating differences in rates of T2DM for communes situated at different distances from province-level healthcare services. It also examined risk factors for adults with T2DM in the selected communes to establish whether these aligned with the results of previous studies.

This chapter discusses the study findings in relation to its research objectives. It concludes by describing the study's strengths and limitations as well as its implication for future research.

5.2 Prevalence of T2DM in the nine communes surveyed

Results showed 20.3% (81/399) prevalence of T2DM across all nine communes in this study (see Table 5). It also showed that only 7.0% (28/399) of all T2DM cases had been previously diagnosed, while 13.3% (53/399) were newly diagnosed cases. The prevalence of T2DM varied slightly by gender, with a prevalence of T2DM of 21.5% (59/275) and 17.7% (22/124) for females and males, respectively. These results differ to those of the 2012 diabetes screening survey which reported only 5% T2DM in rural Siem Reap, Cambodia (Wagner et al., 2018).

These differences are possibly explained by the larger sample size in the 2012 study. Another difference was the older age profile of survey participants in this study. Eighty-two per cent (329/399) of the participants were ≥ 45 years old compared with 66% of participants in the 2012 survey (Wagner et al., 2018). The older age probe of the 2010 participants may explain the higher prevalence rates seen in this dataset.

The variation could also be explained by the prevalence of hypertension seen among those surveyed. The number of hypertensive participants in the 2010 screening survey was also higher than that in 2012, with a prevalence of 36% (144/399) and 27.9% (39.49/14,155), respectively (Wagner et al., 2018).

The high prevalence of T2DM in the 2010 screening survey may also be explained by the low socio-economic status of the communes surveyed (National Committee for Sub-National Democratic Development, 2010) and their constrained access to diabetic diagnostic and treatment centres located only in the provincial capital. This is due to societal risk factors, including low socio-economic conditions and access to diabetic services, increasing the risk of developing T2DM (Power et al., 2020; Idei & Kato, 2019).

These findings reinforce those of Nang et al. (2019) who found that Cambodia people in rural areas encountered difficulties in receiving diabetes care due to lack of knowledge regarding diabetes prevention and control, limited diabetes diagnostics, poor access to diabetes services, and financial issues. In a similar case, in Australia, Power et al. (2020) conducted a geographical study in an area located 50km from the central business district in New South Wales. The study showed that the area faced difficulty in implementing diabetes prevention and control due to a high level of poverty, and illiteracy, combined with limited access to healthcare services.

5.3 Differences in T2DM prevalence in the nine communes surveyed

The nine communes surveyed are located at different distances from the provincial capital ranging from 34.74km (Dom Daek) to 97.43km (Khvav) and had unequal socio-economic status (National Committee for Sub-National Democratic Development, 2010).

Dom Daek had the lowest study prevalence of T2DM (8.3%). This may be due to Dom Daek being the closest commune to the provincial capital with more favourable socio-economic conditions than the other communes. In 2010, Dom Daek had the highest number of clinics (eight) and pharmacies (nine). It had the longest road of all the provinces in good condition with the highest number of vehicles. Dom Daek also had the lowest percentage of farmers and the highest literacy levels. Dom Daek's proximity to the provincial capital (Siem Reap) enabled residents to access province-level health care. This reduced the reliance of mobile diabetes clinic screening services for early diabetes detection.

In contrast, higher rates of T2DM were observed in the other communes located further from the provincial capital with poorer socio-economic situations. For example, Kampong Kdei had the highest sample prevalence of T2DM of 30% (12/40), followed by the furthest commune, Khvav with a similar prevalence of 28.3% (15/53). While Samraong had an unexpectedly high prevalence of 27.3% of T2DM (3/11), given its proximity to the provincial capital, this may be due to the effect of removing cases (49) due to incomplete and inaccurate records. Kampong Khleang, whose T2DM prevalence was 25.4% (15/59), is an isolated floating commune with difficult geographical access to health facilities (Merali et al., 2014). Anlong Samnar (65.95km) had only 10.2% (5/ 49) of T2DM but had only one food shop business. Kien Sangkae and Svey Leu had similar levels of T2DM of 22.20% (8/36) and 20.70% (6/29), respectively. This may be due to the population being made up of approximately 90% of farmers with neither commune having any private pharmacies or clinics, and was further compounded by poor road access. It would be expected that Dan Run, which is located in a closer proximity to the provincial capital would have a low prevalence of T2DM. However, this commune had no private clinic, no electricity and poor access, along with the lowest number of vehicles (only two cars), resulting in a relatively high prevalence of T2DM of 17.60% (13/74).

5.3.1 The minimum prevalence of T2DM in each commune

In the 2012 screening survey, 13,997 participants were screened in 197 locations in urban, semi-urban, and rural settings. This study reported only 5% of the total prevalence of T2DM for rural areas in Siem Reap (Wagner et al., 2018). However, the numbers of participants from these rural areas were not reported.

In contrast, this study reported the number of cases of T2DM in the nine communes surveyed, and also on gender differences. There was a sampling bias in the 2010 screening survey; hence, the prevalence data is unlikely to be representative of the overall prevalence for the total population or the populations for each commune. This study then estimated a minimum prevalence of T2DM for each commune surveyed. This is also unlikely to be representative of the population, however, if the numbers of T2DM cases found in this study were all the T2DM cases within each commune, the prevalence for each commune is given in Table 9. To calculate the minimum prevalence, the 2010 database which recorded the number of people aged ≥ 18 for each commune and the 2008 census which reported the prevalence of rural residents aged between 18-25 in Siem Reap province (National Institute of Statistics, 2008) was used.

There were a total of 50,278 people aged ≥ 25 (Table 9). If there were 81 T2DM cases in the 2010 screening survey, the minimum prevalence of T2DM would be 0.16% (81/50,278) (95%CI: 0.12-0.20). Therefore the lowest prevalence of T2DM in Dom Daek would be 0.05% (4/7,977) (95%CI: 0.019-0.12), which is the closest commune to province-level diabetes health services. The highest prevalence of T2DM would be in Khvav of 0.30% (15/5,435) (95%CI: 0.15-0.45), which was the furthest commune to the Siem Reap provincial capital.

Table 9. Minimum prevalence of new T2DM, previously diagnosed T2DM, and total T2DM cases in the nine communes surveyed

Commune	Population	New T2DM cases			Previously diagnosed T2DM cases			Prevalence of T2DM in sample		
	N	N	%	95%CI	N	%	95%CI	N	%	95%CI
Dom Daek	7,977	3	0.04%	0.012-0.11	1	0.01%	0.002-0.07	4	0.05%	0.019-0.12
Dan Run	6,237	8	0.13%	0.06-0.25	5	0.08%	0.03-0.18	13	0.21%	0.12-0.35
Kien Sangkae	5,311	8	0.15%	0.07-0.30	0	0.00%	0.00-0.03	8	0.15%	0.07-0.30
Samraong	5,086	3	0.06%	0.02-0.17	0	0.00%	0.00-0.07	3	0.06%	0.02-0.17
Kampong Khleang	5,435	4	0.07%	0.02-0.19	11	0.20%	0.11-0.36	15	0.28%	0.17-0.45
Kampong Kdei	5,608	9	0.16%	0.08-0.30	3	0.05%	0.018-0.16	12	0.21%	0.12-0.37
Anlong Samnar	5,990	4	0.07%	0.03-0.17	1	0.02%	0.003-0.09	5	0.08%	0.04-0.20
Svey Leu	3,647	2	0.05%	0.015-0.20	4	0.11%	0.04-0.30	6	0.16%	0.03-0.30
Khvav	4,987	12	0.24%	0.13-0.42	3	0.06%	0.02-0.18	15	0.30%	0.15-0.45
Total	**50,278**	**53**	**0.11%**	**0.08-0.13**	**28**	**0.06%**	**0.03-0.08**	**81**	**0.16%**	**0.12-0.20**

5.4 Risk factors identified for T2DM

5.4.1 Overview

In this study, gender, body mass index (BMI), hip circumference (HC), waist-to-height ratio (WtHR), and waist-to-hip ratio (WHR) were not significantly associated with T2DM.

Age, hypertension, and distance from diabetes health services in the Siem Reap provincial capital were the only three significant predictors for T2DM. Regression analysis showed a positive direction (positive β-values) in the relationship between these variables, which showed that increasing age, distance from the province-level diabetes health services and having hypertension were associated with a greater risk of T2DM (Table 8). Although these three variables (age, hypertension, and distance from province-level diabetes health services) were predictors for T2DM, they were not uniformly significant for both new T2DM and previously diagnosed T2DM cases.

Distance from the province-level diabetes health services was more strongly associated with a new diagnosis of T2DM, but not with previously diagnosed T2DM (*p*-value = .425). One of the possible reasons might be that nearly half of all previously diagnosed T2DM cases were located in Kampong Khleang (11/28 cases), located at 49.6km from the provincial capital. Since 2008, and in contrast with other communes, Kampong Khleang had access to customised health services provided by an international non-governmental organisation (Merali et al., 2014).

Hypertension was also not a significant predictor for previously diagnosed T2DM cases (*p*-value = .512). This could be because hypertensive cases were found to be more highly correlated with new T2DM cases (ratio of 33:114) more than with previously diagnosed T2DM cases (ratio of 12:114).

Conversely, age was significant for people who had been previously diagnosed T2DM, but not for new T2DM cases (*p*-value = .280). Overall, the new T2DM patients in this study were younger than the previously diagnosed T2DM patients. These differences may have resulted from sampling bias due to the convenience sampling methodology used in the 2010 screening survey. Additionally, there was a likelihood that older participants had other age-related comorbidities that resulted in a previous referral to the provincial hospital and subsequent diagnosis of T2DM as part of that healthcare process.

5.4.2 Distance from province-level diabetes health services and increased risk of T2DM

The analysis found that the distance variable was a significant predictor of total T2DM cases with a *p*-value of .006 and for new T2DM cases with a *p*-value of .009. These findings are consistent with those of Oum et al. (2010) and Wagner et al. (2018). Both researchers found that rural residents in Cambodia were more likely to be undiagnosed. This study also found a high prevalence of undiagnosed T2DM in rural areas (13.3%).

Even though each commune had an accessible health centre within several kilometres, this did not appear to influence a diabetes diagnosis as rural health centres only focus on basic health care for reproductive, maternal, and newborn health (Jacobs et al., 2017), and not for non-communicable diseases, including diabetes (Idei & Kato, 2019; World Health Organisation, 2016c). Idei and Kato (2019) also found that Cambodian rural residents had difficulty with geographical access to healthcare providers due to limited transport options, the long distance from higher quality healthcare facilities, and poor road conditions. They concluded that rural dwellers were less likely to receive the same quality of health advice and T2DM diagnosis from their healthcare practitioners compared to their urban counterparts.

Results from this study suggest that distance from province-level diabetes services constitutes a barrier to access for diabetes on prevention, diagnosis, and treatment. It highlights the need for efforts to expand diabetes outreach screening and diagnosis in rural areas.

5.4.3 Hypertension and increased risk of T2DM

The analysis also showed an association between hypertension and T2DM. For all T2DM *p*-value = .028 and .002 for newly diagnosed T2DM cases, respectively. These results are possibly because hypertensive patients with poorly controlled blood pressure have a high probability of developing T2DM (Kim et al., 2015), since high blood pressure causes microvascular dysfunction which may increase the risk of developing diabetes (Nguyen, 2008), and the hypertensive effect in inducing endothelial dysfunction, which is associated with insulin resistance (Meigs et al., 2004).

5.4.4 Age and increased risk of T2DM

The study results also showed that age was a significant risk factor of T2DM. For all T2DM *p*-value = .005 and .004 for previously diagnosed T2DM cases, respectively. Previous studies which explain the mechanism of T2DM show that it is closely associated with the ageing process. First, as we age, we increase in central body fat that causes insulin resistance (Suastika et al., 2012). Second, ageing decreases beta-cell functional mass and, functions that impact insulin production (Meneilly & Elliott, 1999, as cited in Suastika et al., 2012). Third, ageing reduces mitochondrial function that leads to insulin resistance (Petersen, 2003, as cited in Suastika et al., 2012). In 2015, the number of Cambodians aged over 60 years was approximately 1.3 million (8.3% of the total population). By 2050, the number of older people is expected to increase to five million (Zimmer & Khim, 2013). Therefore, the number of T2DM is expected to rise.

5.5 Factors not found to be significant

Gender as a risk factor was not found to be significant in this study (*p*-value = .812) (Table 8). The study's results suggest that women were only slightly more likely to develop diabetes than men, with results showing a sample prevalence of 21.5% (59/275) and 17.7% (22/124), respectively. These results are in agreement with those obtained by the national survey in 2014; that women were slightly more affected by diabetes than men at the prevalence of 6.1% and 5.7 %, respectively (World Health Organisation, 2016a). The mean age, BMI, waist circumference, and hip circumference of female participants were also greater than those of males. Similarly, Oum et al. (2010) found that Cambodian women were twice as likely to be overweight, with lower levels of physical activity compared to men (World Health Organisation, 2019a). It has also shown that Cambodian women had less ability to access healthcare services, as well as other social support services (Men et al., 2011).

This study also found that BMI and hip circumference were not good predictors for T2DM (Table 8). These findings have been seen in other studies. An et al. (2013) suggested that BMI was not a strong predictor for T2DM among Asian populations, and Son et al. (2016) found that BMI was not significant for T2DM among Korean patients and Jafari-Koshki et al. (2016) showed that hip circumference (HR) was not significant in relation to T2DM.

Waist-to-height ratio (WtHR) and waist-to-hip ratio (WHR) also showed no significant association with T2DM for both newly, previously and all diagnosed cases) (Table 8). These findings are in contrast with those of Jafari-Koshki et al. (2016) and Son et al. (2016) who demonstrated that the two variables were T2DM predictors. There are several potential explanations for this. First, this study recognised the limitations of using secondary data, including constraints in verifying any irregular values that were identified in the dataset. The accuracy of the measurement and recording processes of some of the anthropometric variables led to the removal of cases (n=75) with irregular anthropometric values from the analysis and the removal of incomplete cases (n=7), which may have an impact on the results. Second, other important risk factors of T2DM recorded in the original case report forms were not accessible for this study. These included smoking, alcohol use, and family history of T2DM. Key societal risk factors for T2DM were also not recorded, including the level of education and socio-economic status.

5.6 Conclusion

5.6.1 Revisiting research aim and objectives

Diabetes is becoming one of the leading causes of death, with 80% of cases found in developing countries (Nanditha et al., 2016). The high prevalence of T2DM in middle- and low-income countries may be due to an increasing life expectancy, unhealthy lifestyles, genetic disorders and societal risk factors. In Cambodia, the prevalence of T2DM is increasing (Oum et al., 2010; World Health Organisation, 2016a). This is possibly due to societal and behavioural risk factors. It is also associated with genetic disorders resulting from maternal starvation during the 1975-1979 Cambodia civil war that increased susceptibility to the development of T2DM and others NCDs in later life (King et al., 2005).

With the prevalence of diabetes rising in Cambodia, alongside the country's poverty, limited diabetes awareness, especially in rural communities, and an underdeveloped healthcare system, including a critical shortage of healthcare workers there are significant challenges for diabetes prevention and management.

This study sought to examine the prevalence of T2DM in nine communes surveyed within Siem Reap province and the role of distance from province-level diabetes health services in the diagnosis of T2DM. It found that in the sample surveyed, the prevalence of T2DM was high at 20.3% (81/399), of which 7.0% (28/399) constituted new cases, and 13.3% (53/399) were previously diagnosed T2DM cases. These findings indicate that distance from the Siem Reap provincial capital, ageing, and hypertension were predictors for developing T2DM. However, from our data, BMI, HC, WtHR, and WHR were not significantly associated with T2DM.

5.6.2 Strengths and limitations

This study has several strengths. The research used secondary data that had not previously been analysed to establish new knowledge about T2DM in rural Cambodian communities. It is also the first research that examined the relationship between the distance between the place of residence and province-level diabetes health services as a risk factor for T2DM in Cambodia. Additionally, the 2010 socio-economic information of the nine communes surveyed provided additional information about the social determinants of health that helped examine T2DM prevalence rates in the nine communes. This study also highlighted the utility of geospatial data in public health to guide health service planning and public health interventions.

This study also has limitations.This research used secondary data captured by CDA for the purpose of a feasibility study only. This limited the scope for assessing the quality and accuracy of the original surveyed processes. Fortunately, the measures, protocols, and procedures of the 2010 CDA screening survey were explained by CDA's principal investigator and were repeatedly referred to the CDA research publications. Second, the 2010 screening survey used the convenience sampling technique from which there was a selection bias, specifically *a sampling bias* type. This bias occurred because not all eligible residents of the nine communes were surveyed, and the target participants were in favour of those with T2DM symptoms. It could then be argued that the prevalence was overestimated due to the study bias when only participants who believed they had T2DM symptoms came for assessment. It could also be counter-argued that participants only enrolled in the study if they were confident they did not have T2DM. Hence, the sample participants selected cannot be used to represent the overall population; as a consequence, research results do not reflect the commune-wide prevalence of T2DM in the site surveyed. Third, individual records for participants could not be accessed to verify and complete missing values for the 481 participants. Despite this, the number of remaining cases were sufficient for analysis.

5.6.3 Research implications

This research proposes that long distances between residence and province-level diabetes health services is a risk factor for type 2 diabetes mellitus (T2DM). This finding adds a potentially new societal risk factor for T2DM, specifically “geographical access to diabetes health services.” In Cambodia, diabetes healthcare services are limited, especially in rural communities.

Therefore, these findings may help inform future service planning to improve diabetes control and prevention by enhancing geographical access to diabetes health services. Road improvement and enhancing public transport are likely to provide a benefit in delivering T2DM services. These findings are similar to that of Idei and Kato (2019). They concluded that poor road infrastructure and limited vehicle ownership are the two obstacles of geographical access in rural communes in Cambodia. Geographic access to diabetes services could also be improved through financial policies that co-fund transport costs to province-level services for those in remote areas.

Furthermore, diabetes services in remote areas should be made available. This could be achieved by increasing the number of mobile clinics to rural communities or expanding the skills and capacity of healthcare workers working in rural health centres. If these health care providers were equipped with non-communicable disease management, they would be able to make diabetes services more feasible and affordable to rural communes.

References

An, Y., Yi, S., Fitzpatrick, A., Gupta, V., Prak, P. R., Oum, S., & LoGerfo, J. P. (2013). Appropriate body mass index and waist circumference cutoff for overweight and central obesity among adults in Cambodia. *PLoS One*, *8*(10), e77897. https://doi.org/10.1371/journal.pone.0077897

Annear, P. L., Jacobs, B., & Nachtnebel, M. (Eds.). (2015*). The Kingdom of Cambodia health system review.* World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/208213/9789290616917_eng.pdf

Arya, R., Antonisamy, B., & Kumar, S. (2012). Sample size estimation in prevalence studies. *The Indian Journal of Pediatrics*, *79*(11), 1482-1488. https://doi.org/doi.org/10.1007/s12098-012-0763-3

Asante, A. D., Ir, P., Jacobs, B., Supon, L., Liverani, M., Hayen, A., ... & Wiseman, V. (2019). Who benefits from healthcare spending in Cambodia? Evidence for a universal health coverage policy. *Health policy and planning*, *34*(Supplement_1), i4-i13. https://doi.org/10.1093/heapol/czaa03

Bigdeli, M., Jacobs, B., Men, C. R., Nilsen, K., Van Damme, W., & Dujardin, B. (2016). Access to treatment for diabetes and hypertension in rural Cambodia: performance of existing social health protection schemes. *PloS one*, *11*(1), e0146147. https://doi.org/10.1371/journal.pone.0146147

Biswas, R. K., & Kabir, E. (2017). Influence of distance between residence and health facilities on non-communicable diseases: An assessment over hypertension and diabetes in Bangladesh. *PloS one*, *12*(5), e0177027. https://doi.org/10.1371/journal.pone.0177027

Boslaugh, S. (2007). An introduction to secondary data analysis. *Secondary data sources for public health: A practical guide*, 2-10.

Cambodian Diabetes Association. (n.d). *cda-siemreap.org*. https://www.cda-siemreap.org/links-and-resources.html

Cheng, M & Spengler, M. (2016). *How (un)healthy and (un)safe is food in Cambodia.* Konrad-Adenauer-Foundation Cambodia in cooperation with Politikoffee. https://www.kas.de/c/document_library/get_file?uuid=49714e0a-071d-3e3a-ffb4-f2351af7da40&groupId=252038

Delamater, P. L., Messina, J. P., Shortridge, A. M., & Grady, S. C. (2012). Measuring geographic access to health care: raster and network-based methods. *International journal of health geographics*, *11*(1), 15. https://doi.org/10.1186/1476-072X-11-15

Eldridge, S. M., Lancaster, G. A., Campbell, M. J., Thabane, L., Hopewell, S., Coleman, C. L., & Bond, C. M. (2016). Defining feasibility and pilot studies in preparation for randomised controlled trials: development of a conceptual framework. *PloS one*, *11*(3), e0150205. https://doi.org/10.1371/journal.pone.0150205

Emdin, C. A., Anderson, S. G., Woodward, M., & Rahimi, K. (2015). Usual blood pressure and risk of new-onset diabetes: evidence from 4.1 million adults and a meta-analysis of prospective studies. *Journal of the American College of Cardiology*, *66*(14), 1552-1562. https://doi.org/10.1016/j.jacc.2015.07.059

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, *5*(1), 1-4. https://doi.org/10.11648/j.ajtas.20160501.11

Flessa, S., & Zembok, A. (2014). Costing of diabetes mellitus type II in Cambodia. *Health economics review*, *4*(1), 24. https://doi.org/10.1186/s13561-014-0024-4

Henderson, L. N., & Tulloch, J. (2008). Incentives for retaining and motivating health workers in Pacific and Asian countries. *Human resources for health*, *6*(1), 18. https://doi.org/10.1186/1478-4491-6-18

Henry, C. J. K., Lightowler, H. J., Newens, K., Sudha, V., Radhika, G., Sathya, R. M., & Mohan, V. (2008). Glycaemic index of common foods tested in the UK and India. *British journal of nutrition*, *99*(4), 840-845. https://doi.org /10.1017/S0007114507831801

Hou, X., Chen, S., Hu, G., Chen, P., Wu, J., Ma, X., ... & Jia, W. (2019). Stronger associations of waist circumference and waist-to-height ratio with diabetes than BMI in Chinese adults. *Diabetes research and clinical practice*, *147*, 9-18. https://doi.org/10.1016/j.diabres.2018.07.029

Hu, F. B. (2011). Globalisation of diabetes: the role of diet, lifestyle, and genes. *Diabetes care*, *34*(6), 1249-1257. https://doi.org/10.2337/dc11-0442

Idei, R., & Kato, H. (2019). Medical-purposed travel behaviors in rural areas in developing countries: a case study in rural Cambodia. *Transportation*, 1-24. https://doi.org/10.1007/s11116-018-9971-7

Institute for Health Metrics and Evaluation. (2020). *Cambodia.* University of Washington. http://www.healthdata.org/cambodia

Institute for Health Metrics and Evaluation. (n.d.). *GBD PROFILE: CAMBODIA Cambodia.* University of Washington. http://www.healthdata.org/sites/default/files/files/country_profiles/GBD/ihme_gbd_country_report_cambodia.pdf

Jacobs, B., Hill, P., Bigdeli, M., & Men, C. (2015). Managing non-communicable diseases at health district level in Cambodia: a systems analysis and suggestions for improvement. *BMC health services research*, *16*(1), 32. https://doi.org /10.1186/s12913-016-1286-9

Jacobs, B., Men, C., Bigdeli, M., & Hill, P. S. (2017). Limited understanding, limited services, limited resources: patients' experiences with managing hypertension and diabetes in Cambodia. *BMJ global health*, *2*(Suppl 3), e000235. https://doi.org /10.1136/bmjgh-2016-000235

Jafari-Koshki, T., Mansourian, M., Hosseini, S. M., & Amini, M. (2016). Association of waist and hip circumference and waist-hip ratio with type 2 diabetes risk in first-degree relatives. *Journal of Diabetes and its Complications*, *30*(6), 1050-1055.

Johnston, M. P. (2017). Secondary data analysis: A method of which the time has come. *Qualitative and quantitative methods in libraries*, *3*(3), 619-626.

Kautzky-Willer, A., Harreiter, J., & Pacini, G. (2016). Sex and gender differences in risk, pathophysiology and complications of type 2 diabetes mellitus. *Endocrine reviews*, *37*(3), 278-316. https://doi.org/10.1210/er.2015-1137

Kheam, T., Yel, D., & Singh, P. N. (2011). National Adult Tobacco Survey of Cambodia (NATSC, 2011) Monograph. *National Institute of Statistics (Ministry of Planning, Cambodia): Phnom Penh, Cambodia*. https://www.who.int/fctc/reporting/Cambodiaannexone.pdf

Kim, M. J., Lim, N. K., Choi, S. J., & Park, H. Y. (2015). Hypertension is an independent risk factor for type 2 diabetes: the Korean genome and epidemiology study. *Hypertension Research*, *38*(11), 783. https://doi-org/10.1038/hr.2015.72

King, H., Keuky, L., Seng, S., Khun, T., Roglic, G., & Pinget, M. (2005). Diabetes and associated disorders in Cambodia: two epidemiological surveys. *The Lancet*, *366*(9497), 1633-1639. https://doi.org/10.1016/S0140-6736(05)67662-3

Konerding, U., Bowen, T., Elkhuizen, S. G., Faubel, R., Forte, P., Karampli, E., ... & Torkki, P. (2017). The impact of travel distance, travel time and waiting time on health-related quality of life of diabetes patients: An investigation in six European countries. *Diabetes Research and Clinical Practice*, *126*, 16-24. https://doi.org/10.1016/j.diabres.2017.01.014

Lau-Bignon, A. W. (2015). The Tonle Sap Lake, a birthplace of civilizations. *LEspace geographique*, *44*(1), 81-88.

Ling, C., & Groop, L. (2009). Epigenetics: a molecular link between environmental factors and type 2 diabetes. *Diabetes*, *58*(12), 2718-2725. https://doi.org/10.2337/db09-1003

Liu, S. Y., Walter, S., Marden, J., Rehkopf, D. H., Kubzansky, L. D., Nguyen, T., & Glymour, M. M. (2015). Genetic vulnerability to diabetes and obesity: does education offset the risk?. *Social science & medicine*, *127*, 150-158. https://doi.org/10.1016/j.socscimed.2014.09.009

Liverani, M., Nguon, C., Sok, R., Kim, D., Nou, P., Nguon, S., & Yeung, S. (2017). Improving access to health care amongst vulnerable populations: a qualitative study of village malaria workers in Kampot, Cambodia. *BMC health services research*, *17*(1), 335. https://doi-org/10.1186/s12913-017-2282-4

Luo, J., Hendryx, M., Laddu, D., Phillips, L. S., Chlebowski, R., LeBlanc, E. S., ... & Stefanick, M. L. (2019). Racial and ethnic differences in anthropometric measures as risk factors for diabetes. *Diabetes Care*, *42*(1), 126-133. https://doi.org/10.2337/dc18-1413

Marmot, M., & Bell, R. (2019). Social determinants and non-communicable diseases: time for integrated action. *Bmj*, *364*, l251.https://doi.org/10.1136/bmj.l251

McKeown, R. E. (2009). The epidemiologic transition: changing patterns of mortality and population dynamics. *American journal of lifestyle medicine*, *3*(1_suppl), 19S-26S. https://doi.org/10.1177/1559827609335350

Meigs, J. B., Hu, F. B., Rifai, N., & Manson, J. E. (2004). Biomarkers of endothelial dysfunction and risk of type 2 diabetes mellitus. *Jama*, *291*(16), 1978-1986. https://doi.org/10. 1001/jama.291.16.1978

Men, C. R., Frieson, K., Socheat, C., Nirmita, H., & Mony, C. (2011, October). *Gender as a social determinant of health: Gender analysis of the health sector ender analysis of the health sector ender analysis of the health sector in Cambodia*. In *World conference on social determinants of health* (pp. 19-21).https://www.who.int/sdhconference/resources/draft_background_paper15_cambodia.pdf

Merali, H., Morgan, J., Uk, S., Phlan, S., Wang, L. T., & Korng, S. (2014). The Lake Clinic-providing primary care to isolated floating villages on the Tonle Sap Lake, Cambodia.

Ministry of Health. (2013). *National Strategic Plan for the Prevention and Control of Noncommunicable Diseases*: https://www.iccp-portal.org/system/files/plans/KHM_B3_NSP-NCD%202013-2020_Final%20approved.pdf

MoPoTsyo. (n.d). *Diabetes in Cambodia:* https://www.mopotsyo.org/diabetes-in-cambodia/

Murray, C. J., Barber, R. M., Foreman, K. J., Ozgoren, A. A., Abd-Allah, F., Abera, S. F., ... & Abu-Rmeileh, N. M. (2015). Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. *The Lancet*, *386*(10009), 2145-2191. https://doi.org/10.1016/S0140-6736(15)61340-X

Nanditha, A., Ma, R. C., Ramachandran, A., Snehalatha, C., Chan, J. C., Chia, K. S., ... & Zimmet, P. Z. (2016). Diabetes in Asia and the Pacific: implications for the global epidemic. *Diabetes care*, *39*(3), 472-485. https://doi.org/10.2337/dc15-1536

Nang, E. E. K., Dary, C., Hsu, L. Y., Sor, S., Saphonn, V., & Evdokimov, K. (2019). Patients' and healthcare providers' perspectives of diabetes management in Cambodia: a qualitative study. *BMJ open*, *9*(11). http://dx.doi.org/10.1136/bmjopen-2019-032578

National Ethics Advisory Committee. (2019). National Ethical Standards for Health and Disability Research and Quality Improvement. *Wellington: Ministry of Health*.

National Committee for Sub-National Democratic Development. (2010). *Commune Database Online.* http://db.ncdd.gov.kh/cdbonline/home/index.castle

National Institute of Statistics. (2002). *General Population Census of Cambodia 1998. http://nis.gov.kh/nis/uploadFile/pdf/CensusResult98.pdf*

National Institute of Statistics. (2008). *General Population Census of Cambodia 2008.* http://www.stat.go.jp/english/info/meetings/cambodia/pdf/pre_rep1.pdf

National Institute of Statistics. (2019). *General Population Census the Kingdom of Cambodia 2019:* http://www.nis.gov.kh/nis/Census2019/Provisional%20Population%20Census%202019_English_FINAL.pdf

Nguyen, H. D., Chitturi, S., & Maple-Brown, L. J. (2016). Management of diabetes in Indigenous communities: lessons from the Australian Aboriginal population. *Internal medicine journal*, *46*(11), 1252-1259. https://doi-org/10.1111/imj.13123

Nguyen, T. T., Wang, J. J., Islam, F. A., Mitchell, P., Tapp, R. J., Zimmet, P. Z., ... & Wong, T. Y. (2008). Retinal arteriolar narrowing predicts incidence of diabetes: the Australian Diabetes, Obesity and Lifestyle (AusDiab) Study. *Diabetes*, *57*(3), 536-539. https://doi.org/10.2337/db07-1376

O'Leary, D. (2015, November 5). *Urbanisation in Cambodia, Past, Present & Future Trends, Influencing Factors and Challenges.* Cambodian Institute for Urban Studies.https://www.academia.edu/18836917/Urbanisation_in_Cambodia_Past_Present_and_Future_Trends_Influencing_Factors_and_Challenges

Oum, S., Prak, P., Khuon, E., Mey, V., Aim, S., Bounchan, Y., & Cin, S. (2010). *Prevalence of Non Communicable Disease Risk Factors in Cambodia. Steps Survey Country Report*. University of Health Sciences & Ministry of Health. https://www.who.int/ncds/surveillance/steps/2010_STEPS_Report_Cambodia.pdf

Pallant, J. (2011). Survival manual. *A step by step guide to data analysis using SPSS*. Maidenhead : Open University Press/McGraw-Hill.

Peters, D. H., Garg, A., Bloom, G., Walker, D. G., Brieger, W. R., & Hafizur Rahman, M. (2008). Poverty and access to health care in developing countries. *Annals of the New York Academy of Sciences*, *1136*(1), 161-171. https://doi-org/10.1196/annals.1425.011

Powell, A. (2017). Accessing Health: Examining Racial and Geographic Disparities in Diabetes Prevalence as a Result of the Built Environment.

Power, T., Kelly, R., Usher, K., East, L., Travaglia, J., Robertson, H., ... & Jackson, D. (2020). Living with diabetes and disadvantage: A qualitative, geographical case study. *Journal of Clinical Nursing*, *29*(13-14), 2710-2722.https://doi-org/10.1111/jocn.15295

Pries, A. M., Huffman, S. L., Mengkheang, K., Kroeun, H., Champeny, M., Roberts, M., & Zehner, E. (2016). High use of commercial food products among infants and young children and promotions for these products in Cambodia. *Maternal & Child Nutrition*, *12*, 52-63. https://doi.org/10.1111/mcn.12270

Raguenaud, M. E., Isaakidis, P., Reid, T., Chy, S., Keuky, L., Arellano, G., & Van Damme, W. (2009). Treating 4,000 diabetic patients in Cambodia, a high-prevalence but resource-limited setting: a 5-year study. *BMC medicine*, *7*(1), 33. https://doi.org/10.1186/1741-7015-7-33

Ramachandran, A., Snehalatha, C., & Ma, R. C. W. (2014). Diabetes in south-east Asia: An update. *Diabetes research and clinical practice*, *103*(2), 231-237. https://doi.org/10.1016/j.diabres.2013.11.011

Ramachandran, A., Snehalatha, C., Shetty, A. S., & Nanditha, A. (2012). Trends in prevalence of diabetes in Asian countries. *World journal of diabetes*, *3*(6), 110. https://doi.org/10.4239/wjd.v3.i6.110

Royal Government of Cambodia. (2014). *National Strategic Development Plan 2014 - 2018.*http://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---sro-bangkok/documents/genericdocument/wcms_364549.pdf

Sar, S., & Marks, G. C. (2015). Estimated effects of white rice consumption and rice variety selection on incidence of type 2 diabetes in Cambodia. *Public health nutrition*, *18*(14), 2592-2599. https://doi.org/10.1017/S1368980014003280

Son, Y. J., Kim, J., Park, H. J., Park, S. E., Park, C. Y., Lee, W. Y., ... & Rhee, E. J. (2016). Association of waist-to-height ratio with diabetes risk: a 4-year longitudinal retrospective study. *Endocrinology and Metabolism*, *31*(1), 127-133. https://doi.org/10.3803/EnM.2016.31.1.127

Suastika, K., Dwipayana, P., Semadi, M. S., & Kuswardhani, R. T. (2012). Age is an important risk factor for type 2 diabetes mellitus and cardiovascular diseases. *Glucose Tolerance*, 67-80. https://doi.org/10.5772/52397

Thomas, S. (2019). Knowledge and Awareness about Diabetes Mellitus and Gestational Diabetes Mellitus-Review. *Artha-Journal of Social Sciences*, *18*(1), 31-44. https://doi.org/10.12724/ajss.48.4

Tuangratananon, T., Wangmo, S., Widanapathirana, N., Pongutta, S., Viriyathorn, S., Patcharanarumol, W., ... & Puyat-Murga, M. E. (2018). Implementation of national action plans on noncommunicable diseases, Bhutan, Cambodia, Indonesia, Philippines, Sri Lanka, Thailand and Viet Nam. *Indicator*, *97*(2). https://doi.org/10.2471/BLT.18.220483

Van Olmen, J., Eggermont, N., van Pelt, M., Hen, H., de Man, J., Schellevis, F., ... & Bigdeli, M. (2016). Patient-centred innovation to ensure access to diabetes care in Cambodia: the case of MoPoTsyo. *Journal of pharmaceutical policy and practice*, *9*(1), 1.https://doi.org/10.1186/s40545-016-0050-1

Wagner, J., Keuky, L., Fraser-King, L., Kuoch, T., & Scully, M. (2015). Diabetes Prevention through Village Health Support Guides in Cambodia: A Qualitative Investigation of Opportunities and Challenges. *J Community Med Health Educ*, *5*(347), 2161-0711. https://doi.org/10.4172/2161-0711.1000347

Wagner, J., Keuky, L., Fraser-King, L., Kuoch, T., & Scully, M. (2016). Training Cambodian village health support guides in diabetes prevention: effects on guides' knowledge and teaching activities over 6 months. *International journal of behavioral medicine*, *23*(2), 162-167. https://doi.org/10.1007/s12529-015-9515-x

Wagner, J., Keuky, L., Lampert, R., Fraser-King, L., Feinn, R., Kuoch, T., & Scully, M. (2015). Socioeconomic status, waist-to-hip ratio, and short-term heart rate variability in Cambodians with type 2 diabetes. *International journal of behavioral medicine*, *22*(6), 786-791. https://doi.org/10.1007/s12529-015-9468-0

Wagner, J., Naranjo, D., Khun, T., Seng, S., Horn, I. S., Suttiratana, S. C., & Keuky, L. (2018). Diabetes and cardiometabolic risk factors in Cambodia: Results from two screening studies: 柬埔寨糖尿病与心血管代谢的危险因素: 来自两项筛查研究的结果. *Journal of diabetes*, *10*(2), 148-157.https://doi-org/10.1111/1753-0407.12570

White, R. O., Chakkalakal, R. J., Presley, C. A., Bian, A., Schildcrout, J. S., Wallston, K. A., ... & Rothman, R. (2016). Perceptions of provider communication among vulnerable patients with diabetes: influences of medical mistrust and health literacy. *Journal of health communication*, *21*(sup2), 127-134.https://doi-org/10.1080/10810730.2016.1207116

Willi, C., Bodenmann, P., Ghali, W. A., Faris, P. D., & Cornuz, J. (2007). Active smoking and the risk of type 2 diabetes: a systematic review and meta-analysis. *Jama*, *298*(22), 2654-2664. https://doi.org/10.1001/jama.298.22.2654

World Health Organisation. (2011). Waist circumference and waist-to-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008.

World Health Organisation. (2016a). *Cambodia*.https://www.who.int/diabetes/country-profiles/khm_en.pdf

World Health Organisation. (2016b). *Global report on diabetes*.https://apps.who.int/iris/bitstream/handle/10665/204871/9789241565257_eng.pdf;jsessionid=484DA8D5E7516748626AFC2438505D61?sequence=1

World Health Organisation. (2016c). *CAMBODIA–WHO Country Cooperation Strategy 2016–2020*. https://iris.wpro.who.int/bitstream/handle/10665.1/13372/WPRO_2016_DPM_004_eng.pdf

World Health Organisation.(2019a, October). *Addressing noncommunicable diseases in Cambodia can save lives and sustain economic growth*. https://www.who.int/nmh/ncd-cambodia/en/

World Health Organization. (2019b). *Hypertension*.https://www.who.int/news-room/fact-sheets/detail/hypertension

World Health Organization. (2020). *Diabetes*.https://www.who.int/news-room/fact-sheets/detail/diabetes

Yunguo, L., & Beresford, N. (2017, August). *Prevention of noncommunicable diseases in Cambodia*. United Nations Development Programme https://www.kh.undp.org/content/cambodia/en/home/presscenter/articles/2017/08/07/prevention-of-noncommunicable-diseases-in-cambodia.html

Zimmer, Z., & Khim, F. (2013). *Ageing and Migration in Cambodia. A CRUMP Series Report.* Ministry of Planning. http://mop.gov.kh/DocumentKH/Ageing%20&%20Migration%20in-Cambodia.pdf

Zimmet, P. Z., Magliano, D. J., Herman, W. H., & Shaw, J. E. (2014). Diabetes: a 21st century challenge. *The lancet Diabetes & endocrinology*, *2*(1), 56-64. https://doi.org/10.1016/S2213-8587(13)70112-8

Appendix 1. Example of the case report form used in the original study

PATIENT FILE

Height :

Weight :

Research Code :					

Village :

Site Code:

Patient's tel. no.:

Registration number:

PATIENT IDENTIFICATION

Name				
Age/Sex				
Village				
Commune				
District				
Profession				
Habits	Smoke		Alcohol	
	Yes	No	Yes	No

Doctor's suggestion

Appoint DATE	Visit DATE

GENERAL SYMPTOMS

Questionnaire	Yes	No	D/k
D1-Have you recently lost weight?	☐	☐	☐
D2-Do you drink a lot of water?	☐	☐	☐
D3-Do you often feel hungry?	☐	☐	☐
D4-Do you have polyuria?	☐	☐	☐
D5-Do you often feel itchy?	☐	☐	☐
H1-Do you often get headaches?	☐	☐	☐
H2-Do you often get neck pain?	☐	☐	☐
H3-Do you sometimes feel dizzy?	☐	☐	☐
H4-In general do you feel healthy?	☐	☐	☐
H5-Do you suffer from muscle ache?	☐	☐	☐
H6-Do you duffer from chest pain?	☐	☐	☐
A1-Have you ever been diagnosed with diabetes?	☐	☐	☐
A2-Have you ever been diagnosed with high blood pressure?	☐	☐	☐
Other :			

Base line

Glycemia Test	Blood Pressure
FPG:	BP max:
RPG:	BP min:
2HRPG	5'BPmax:
Glucose urine:	5'BPmin:
Albumin:	Pulse: /
IGT IFG DM	HBP: 1 2 3 4

Chest pain, Swelling, Alb+
HBP & DM not control

Note: Send patient to CDA, SRB

Contact phone 097 48 43 519
063 63 01 719

Date: / /

Triglyceride:
Cholesterol:
Creatinine:
HA1C:

MONITORING FILES

Essential parameter monitoring responsibility of Nurse						
Visit date						
FPG						
RPG						
Blood Pressure						
Pulse						
HA1C						

Prescription / Responsibility of Doctor						
Drug name	Dose/Quantity	Dose/Quantity	Dose/Quantity	Dose/Quantity	Dose/Quantity	Dose/Quantity
Please write: qd(1time a day) bid(2time a day) tid(3time a day) . Ex: 1qd/30 (1 x 1), 2qd/60 (2 x 1), 1bid/60 (1 x 1)						
Sign/ Doctor						

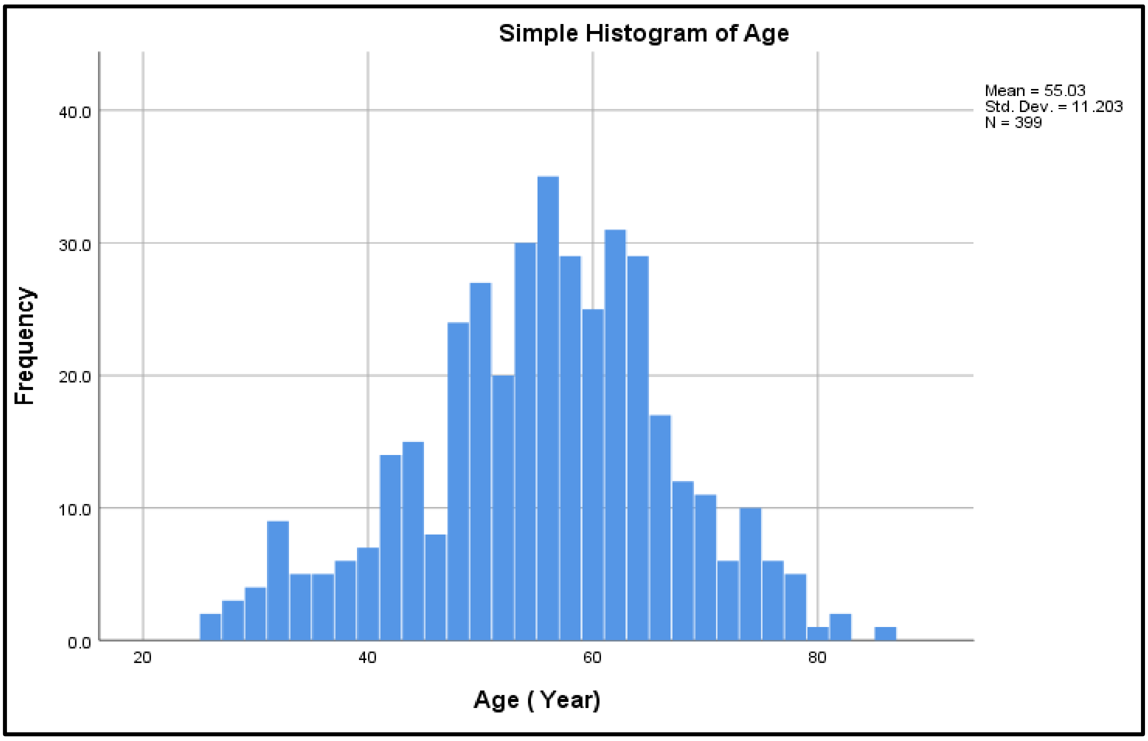
Clinical Monitoring (Please record the problem finding by date of visit)

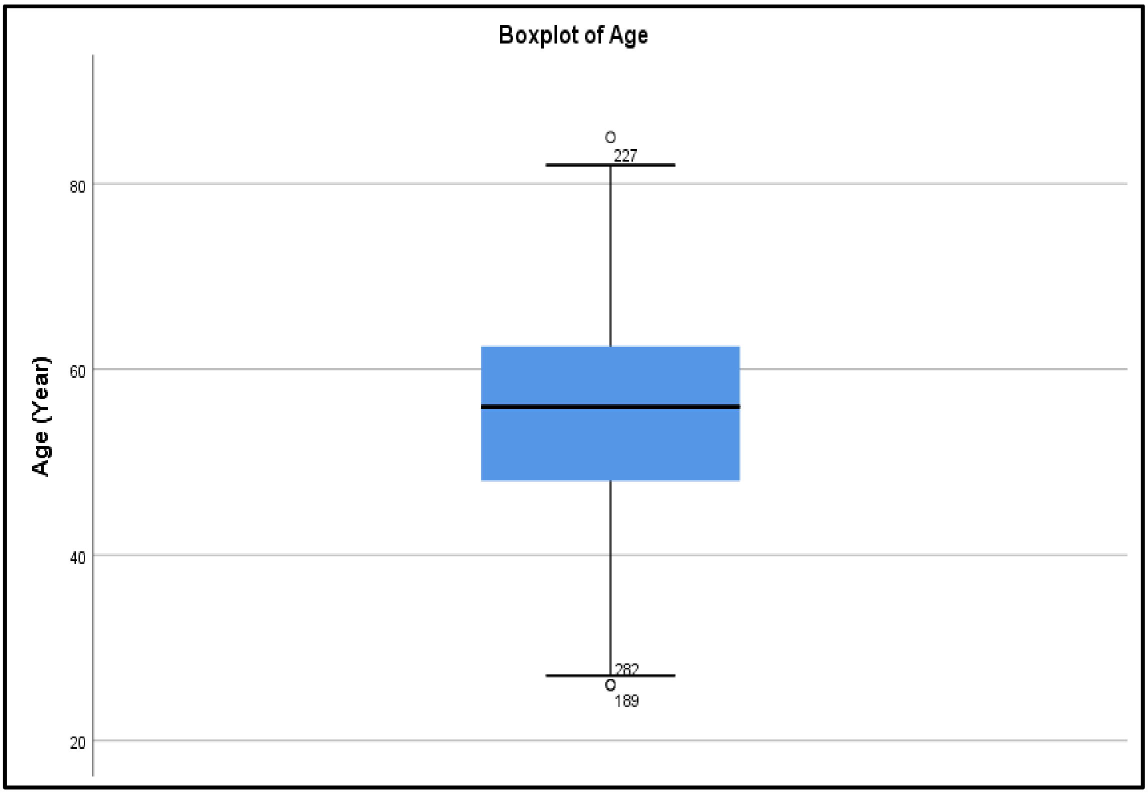
Appendix 2. Data dictionary showing how the study variables were measured

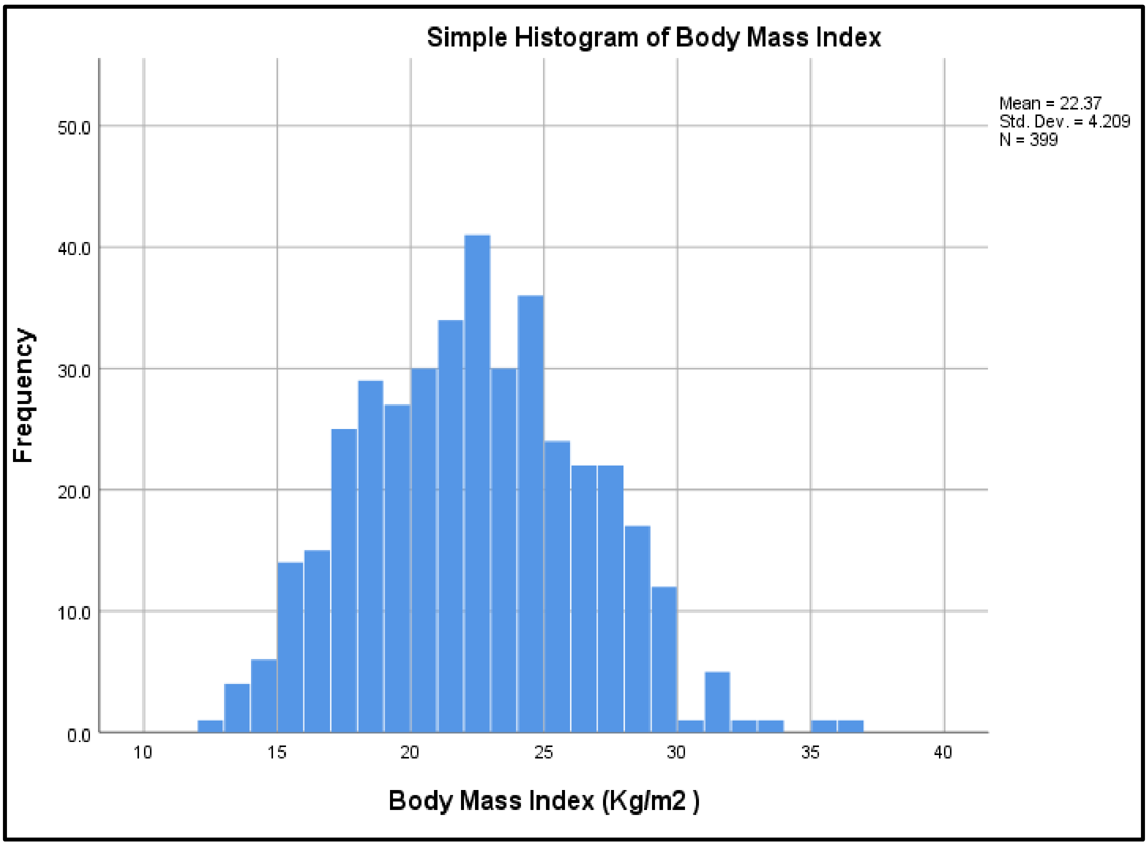
Variables	Description	How determined/measured?
Village/ Commune/ District	Location of residence	Mobile clinic to the nine communes Check their ID card Asked to confirm
Age	≥ 25 Age provided in years.	Checked the ID card and asked to verify
Sex	Biological gender	Appearance and ID
Height	Participant measured height at the time of the survey	In cm
Weight	Participants were measured weight at the time of the survey	In kg
BMI	Calculated Body Mass Index (BMI) using height and weight variables	Formula: BMI=Weight/ $(Height)^2$ in Kg/m^2
Waist circumference	Participant measured waist circumference at the time of the survey	It was measured in cm at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest. Tape measure placed around the bare stomach just above the upper bone
Hip circumference	Participants were measured hip circumference at the time of the survey	Measured by tape measure in cm on the widest portion of the buttocks when feet were together.
T2DM diagnosis by fasting blood glucose	Yes/No	HbA1C (Concentration of glucose in the blood) Reference: ≥ 126 mg/dL (World Health Organisation, 2016b)
T2DM diagnosis by random blood glucose	Yes/No	HA1C (Concentration of glucose in the blood)

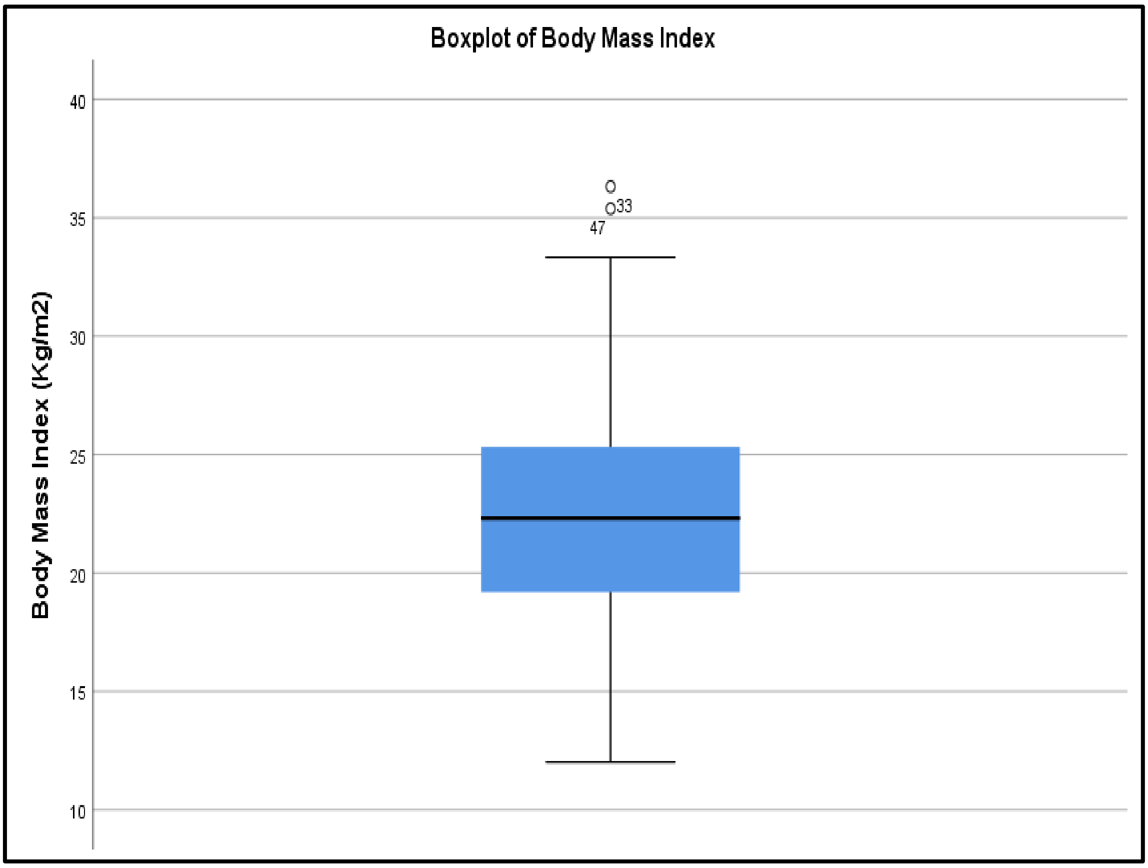
		Reference: ≥ 200 mg/dL (World Health Organisation, 2016b)
Previously diagnosed T2DM	Yes/No	Participants currently taking medication for diabetes are to be classified as being diabetic, and those reporting a previous diagnosis of diabetes. By self-reported and diabetes symptom through questionnaire plus random blood glucose test
Commune prevalence of diabetes	Number of diabetes patients in the population	Calculated by the number of diagnosed diabetics in the commune population
Blood Pressure measurement	mmHg	Electronic measuring device
Pulse	Beats/minute	Electronic measuring device

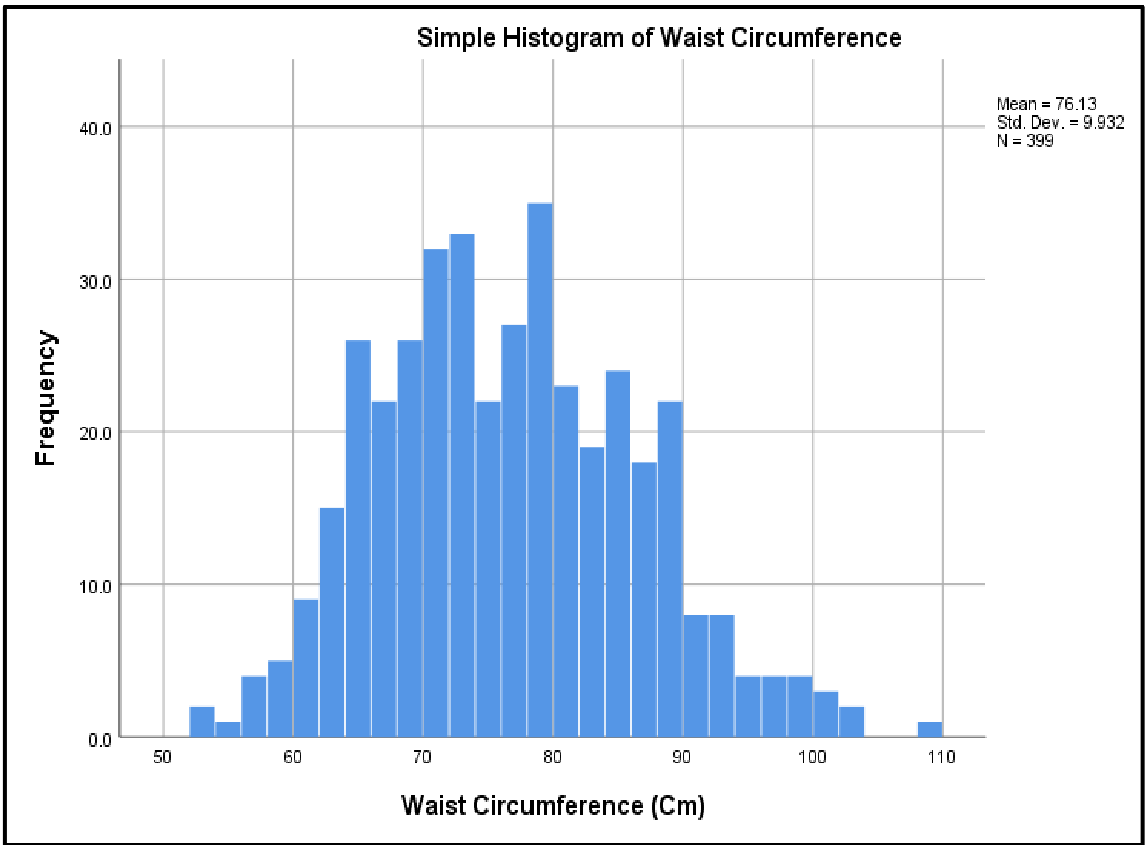
Appendix 3. Histograms and Boxplots illustrating the basic descriptive statistics and the missing cases for each variable

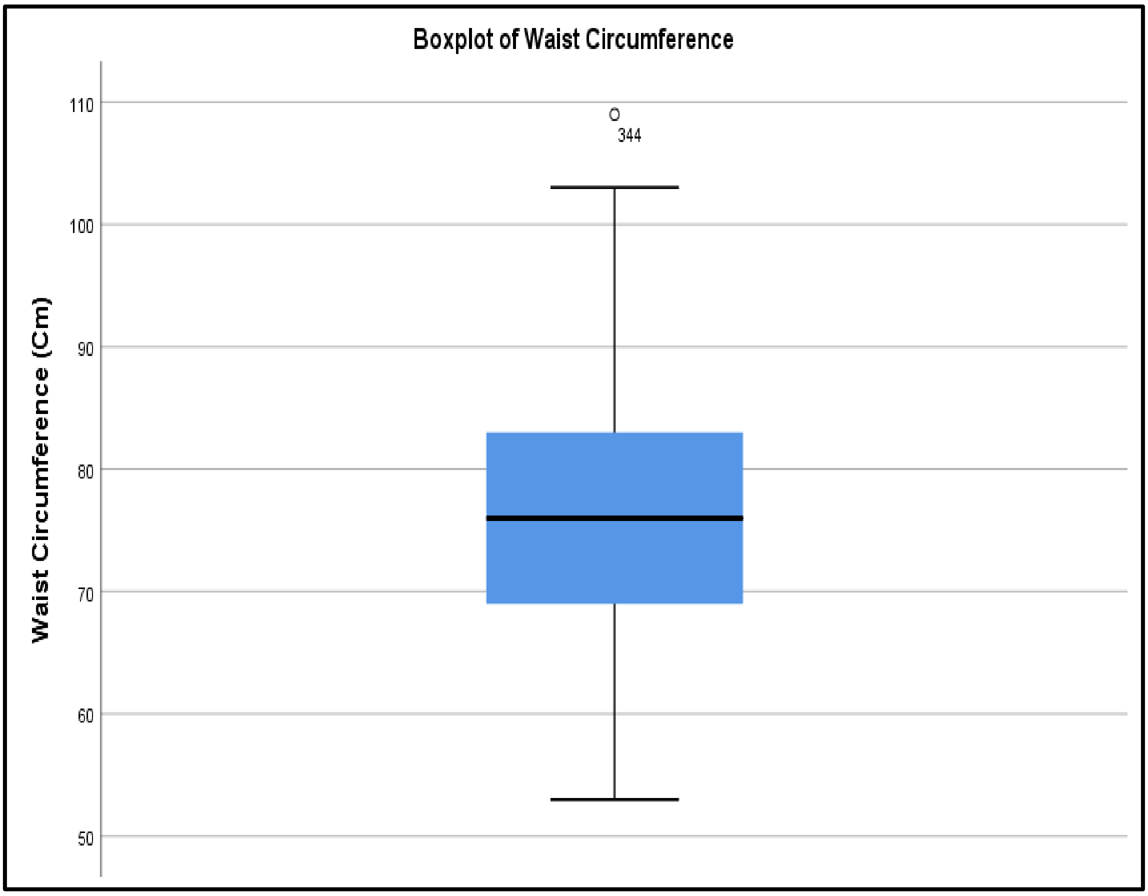


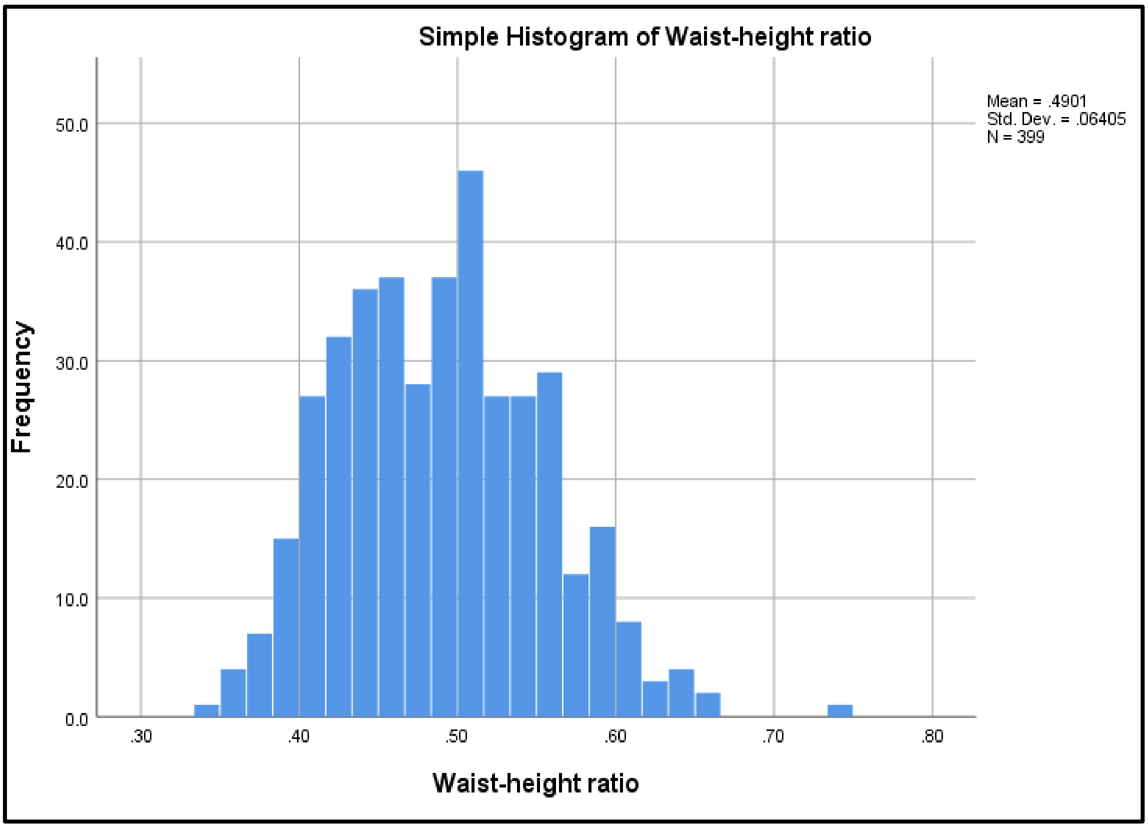


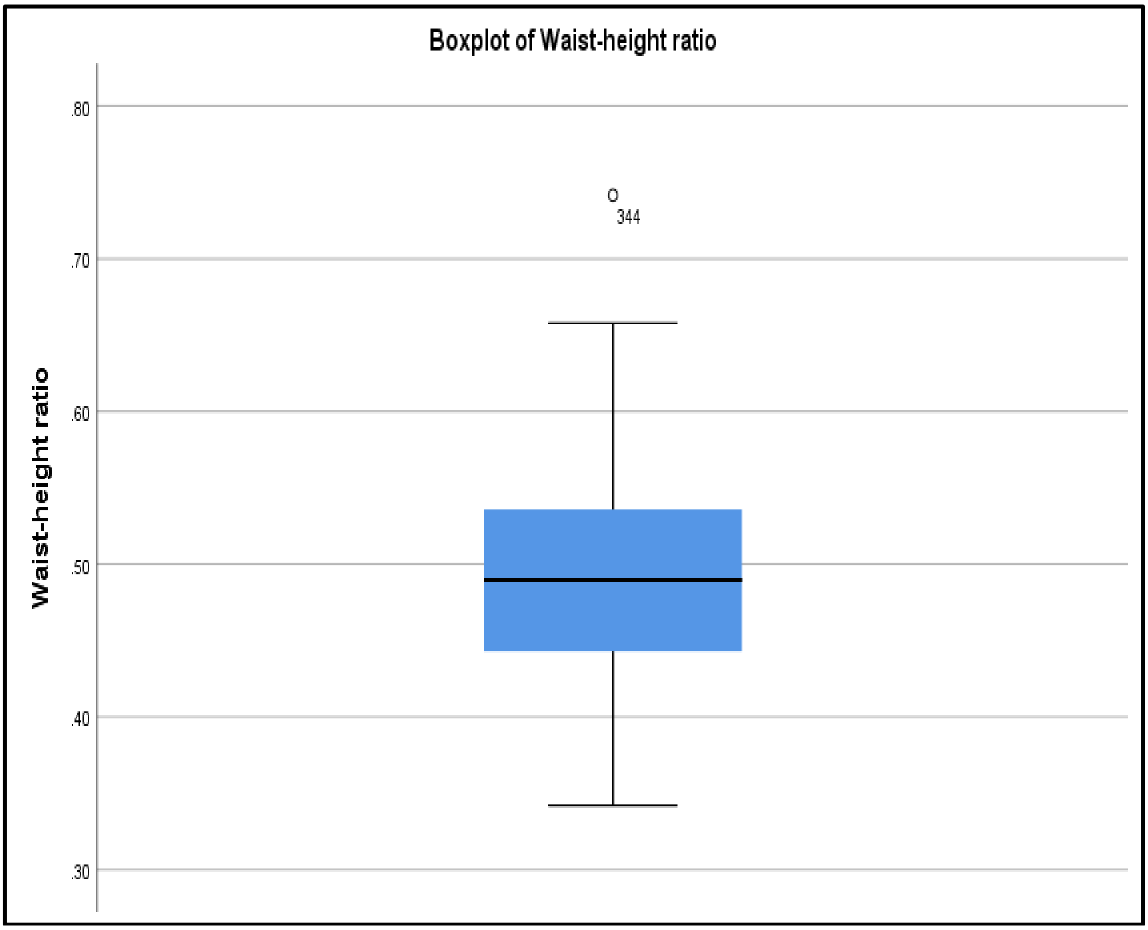

Simple Histogram of Body Mass Index
Mean = 22.37
Std. Dev. = 4.209
N = 399
Frequency
50.0
40.0
30.0
20.0
10.0
0.0
10
15
20
25
30
35
40
Body Mass Index (Kg/m2)

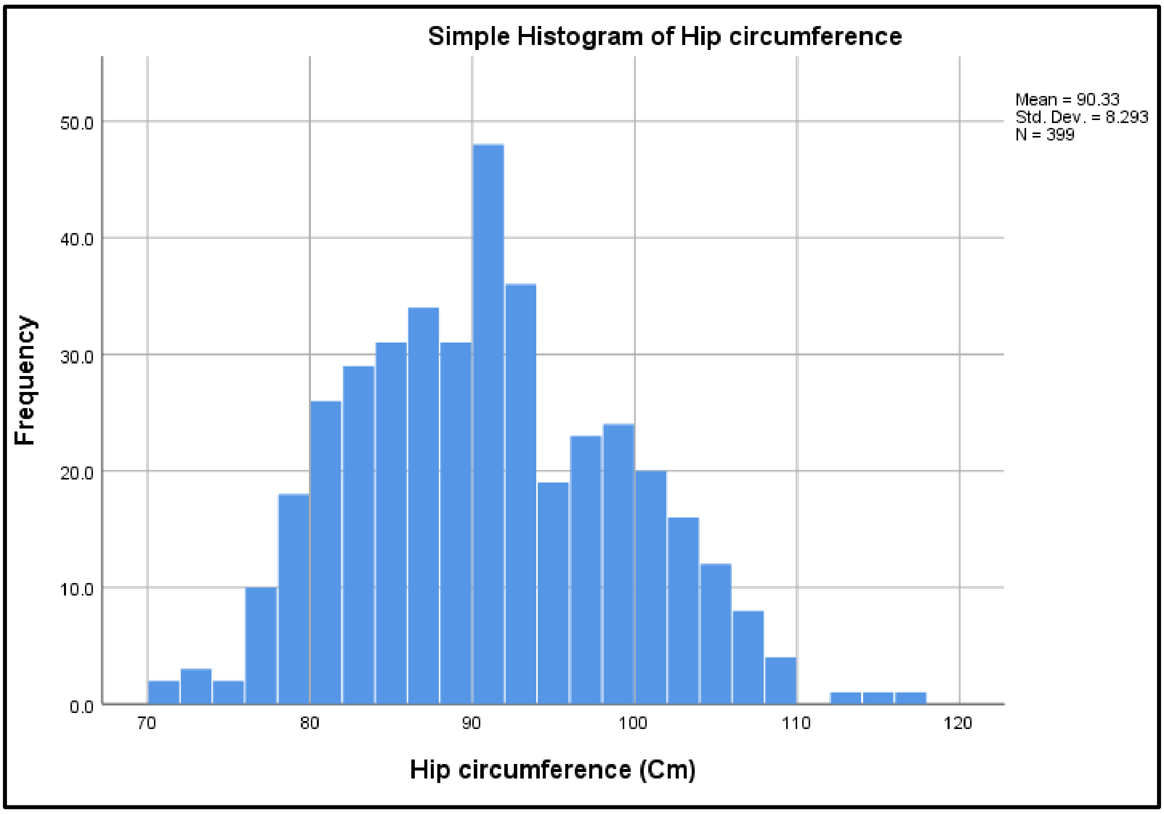

Boxplot of Body Mass Index
Body Mass Index (Kg/m2)
40
35
30
25
20
15
10
33
47

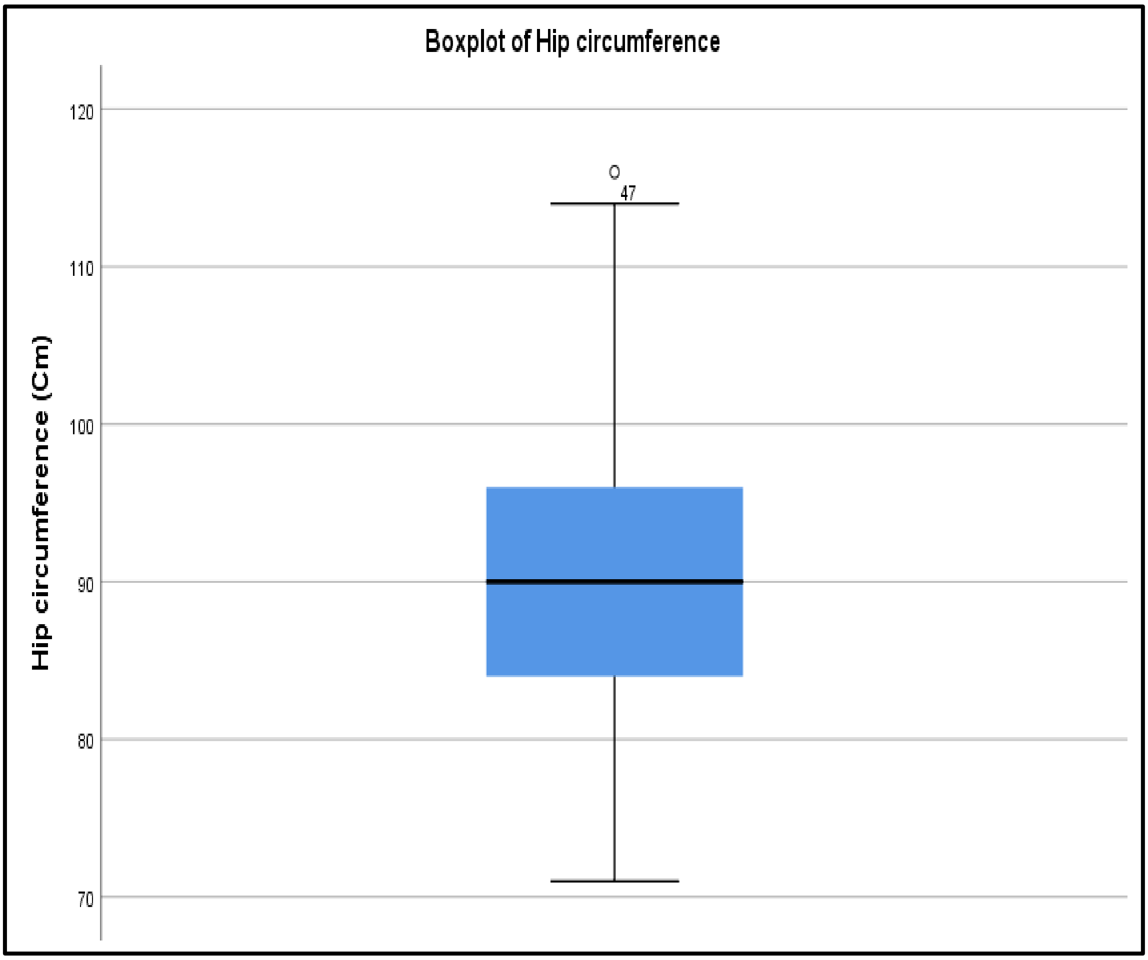

Simple Histogram of Waist Circumference
Mean = 76.13
Std. Dev. = 9.932
N = 399
Frequency
40.0
30.0
20.0
10.0
0.0
50
60
70
80
90
100
110
Waist Circumference (Cm)

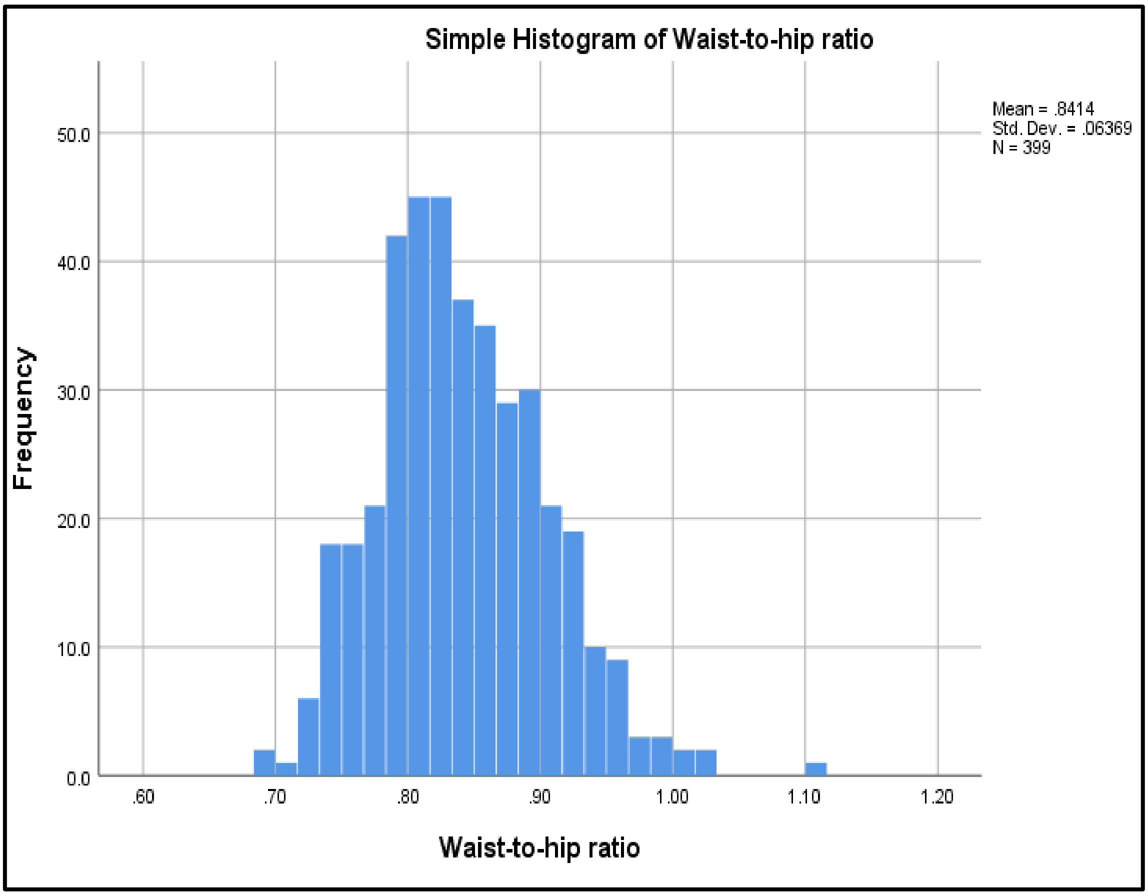

Boxplot of Waist Circumference
110
100
90
80
70
60
50
344
Waist Circumference (Cm)

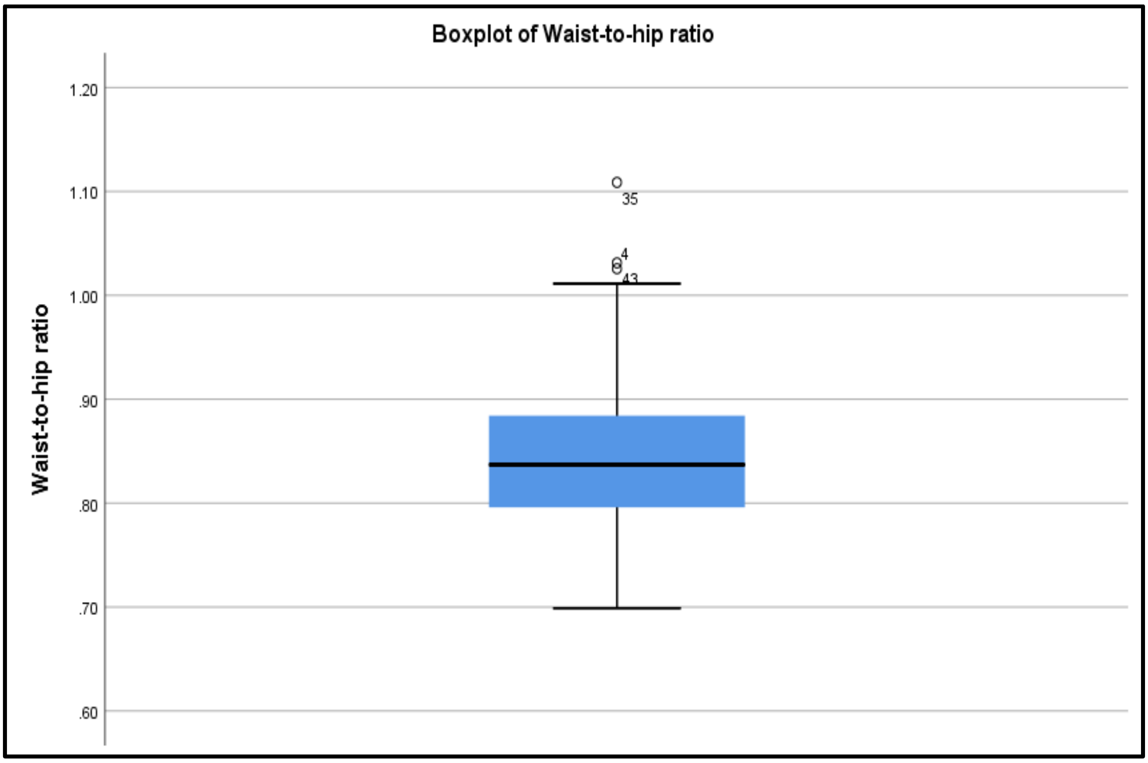

Simple Histogram of Waist-height ratio
Mean = .4901
Std. Dev. = .06405
N = 399
Frequency
50.0
40.0
30.0
20.0
10.0
0.0
.30
.40
.50
.60
.70
.80
Waist-height ratio


Boxplot of Waist-height ratio
Waist-height ratio
.80
.70
.60
.50
.40
.30
344


Simple Histogram of Hip circumference
Mean = 90.33
Std. Dev. = 8.293
N = 399
Frequency
50.0
40.0
30.0
20.0
10.0
0.0
70
80
90
100
110
120
Hip circumference (Cm)


Boxplot of Hip circumference
Hip circumference (Cm)
120
110
100
90
80
70
47


Simple Histogram of Waist-to-hip ratio
Mean = .8414
Std. Dev. = .06369
N = 399
Frequency
0.0
10.0
20.0
30.0
40.0
50.0
.60
.70
.80
.90
1.00
1.10
1.20
Waist-to-hip ratio


Boxplot of Waist-to-hip ratio
Waist-to-hip ratio
1.20
1.10
1.00
.90
.80
.70
.60
35
4
43

Appendix 4. Descriptive statistics for continuous variables

The value point of each variable was considered to be acceptable because there was little difference in value between the 5% trimmed mean and the original mean or there were completely equal (Pallant, 2011).

Descriptive Statistics					
	Minimum	**Maximum**	**5% Trimmed Mean**	**Mean**	**Std. Deviation**
Distance from the province-level diabetes health services (km)	34.74	97.43	54	55.2	20.9
Age (years)	26	85	55.2	55.0	11.2
BMI (kg/m^2)	12	36	22.3	22.4	4.2
WC (cm)	53	109	75.9	76.1	9.9
WtHR	.34	.74	0.5	0.5	0.1
HC (cm)	71	116	90.2	90.3	8.3
WHR	.70	1.11	0.8	0.8	0.1

Appendix 5.Verification of categorical variables for all participants

The number of male (124) and female participants (275), hypertensive (144), and non-hypertensive cases (255) in each commune, imported into SPSS.

	Sex			Hypertension		
Commune	**Male**	**Female**	**Total**	**No**	**Yes**	**Total**
	N	N	N	N	N	N
Dom Daek	20	28	48	34	14	48
Dan Run	27	47	74	56	18	74
Kien Sangkae	17	19	36	20	16	36
Samraong	2	9	11	6	5	11
Kampong Khleang	18	41	59	27	32	59
Kampong Kdei	11	29	40	23	17	40
Anlong Samnar	5	44	49	23	26	49
Svey Leu	12	17	29	23	6	29
Khvav	12	41	53	43	10	53
Total	**124**	**275**	**399**	**255**	**144**	**399**

Appendix 6. Letter of authorisation from the director of the Cambodian Diabetes Association

CAMBODIAN DIABETES ASSOCIATION
SIEM REAP BRANCH

#..... Choun Loung, Salakamreuk , Siem Reap, Cambodia
(NGO register: លេខ 358 សជណ
ចុះថ្ងៃទី11ខែឧសភាឆ្នាំ2004)
Tel: +855 97 484 3519

Letter of Authorization

11 February, 2020

Re: Vansak Soeum (post-graduate student, Auckland University of Technology)
Research project: *Spatial, demographic and physical risk factors for diabetes: a retrospective examination of adult screening data for nine communes in Siem Riep Province, Cambodia.*

I, Cambodian Diabetes Association (CDA) Director, authorise SOEUM Vansak, a post-graduate student at the Auckland University of Technology, to be provided with data from files compiled during a 2010 diabetes screening feasibility study conducted in nine communes of Siem Reap Province, Cambodia.

Specifically, I am pleased to authorise Vansak to have access to the following:

- De-identified data named "2010 SautNikum & Chikreng district screening villagers" registered through the CDA Mobile clinic in nine communes: Dom Daek, Dan Run, Kien Sangkae, Samraong, Kampong Khleang, Kampong Kdei, Anlong Samnar, Svay Leu and Khvav of Siem Reap Province, Cambodia.

As President of the Cambodian Diabetes Association, I am giving permission to share these data that have been de-identified for the purpose of this research project.

It should be noted that for the 2010 survey, participants provided express consent. Participants responded to a public health invitation to be screened for type II diabetes. Participants voluntarily attended the scheduled community screening and participated in an examination that took the following measurements blood pressure, anthropometrics, and finger prick for blood glucose.

Our CDA staff explained to them the procedures that would take place, and the participants either verbally or non-verbally agreed to participate.

It is my opinion, that the research analysis Vansak proposes may strengthen understanding of the risk factors for diabetes in Cambodia and help to inform future planning to improve management of diabetes in this country

Dr Lim Keuky
Director, Cambodian Diabetes Association

Appendix 7.PGR1 research approval confirmation

AUT

Auckland University of Technology
Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999
www.aut.ac.nz

7 February 2020

Vansak Soeum
Unit 218, 26 Te Taou Crescent
Auckland CBD 1010

Dear Vansak

Thank you for submitting your PGR1 Research Proposal application for the Master of Public Health.

Your proposal has been reviewed and approved by the Faculty of Health and Environmental Sciences, which will be noted at the Postgraduate Research Committee February 2020 meeting.

Details are:

Current programme:	Master of Public Health
Enrolment:	60pt HEAL901 Dissertation
Student ID	18009877
Topic:	Spatial, demographic and physical risk factors for diabetes: a retrospective examination of adult screening data for nine communes in Siem Riep Province, Cambodia
Primary supervisor:	Dr Ailsa Holloway
Secondary supervisor:	Dr Melanie Moylan
Mentor supervisor:	Dr Loic Le De
Start date:	10 February 2020
Expected completion date:	31 July 2020

For more information about the programme of study, please refer to the *Postgraduate Handbook*.

The AUT website for forms and handbooks is:
https://autuni.sharepoint.com/sites/sdw/research/prores/Documents/1%20Postgraduate%20Handbook.pdf

Yours sincerely

Assoc Prof Nigel Harris
Associate Dean (Postgraduate Research)
Postgraduate and Research Office
Faculty of Health and Environmental Sciences

Cc Primary supervisor Dr Ailsa Holloway
Mentor supervisor Dr Loic Le De

Appendix 8. Ethics approval from the Auckland University of Technology Ethics Committee

AUT

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

2 April 2020

Ailsa Holloway
Faculty of Health and Environmental Sciences

Dear Ailsa

Ethics Application:20/98 **Spatial, demographic and physical risk factors for type 11 diabetes: A retrospective analysis of adult screening data for nine communes in Siem Riep Province, Cambodia**

We advise you that a subcommittee of the Auckland University of Technology Ethics Committee (AUTEC) has **approved** your ethics application.

This approval is for three years, expiring 1 April 2023.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

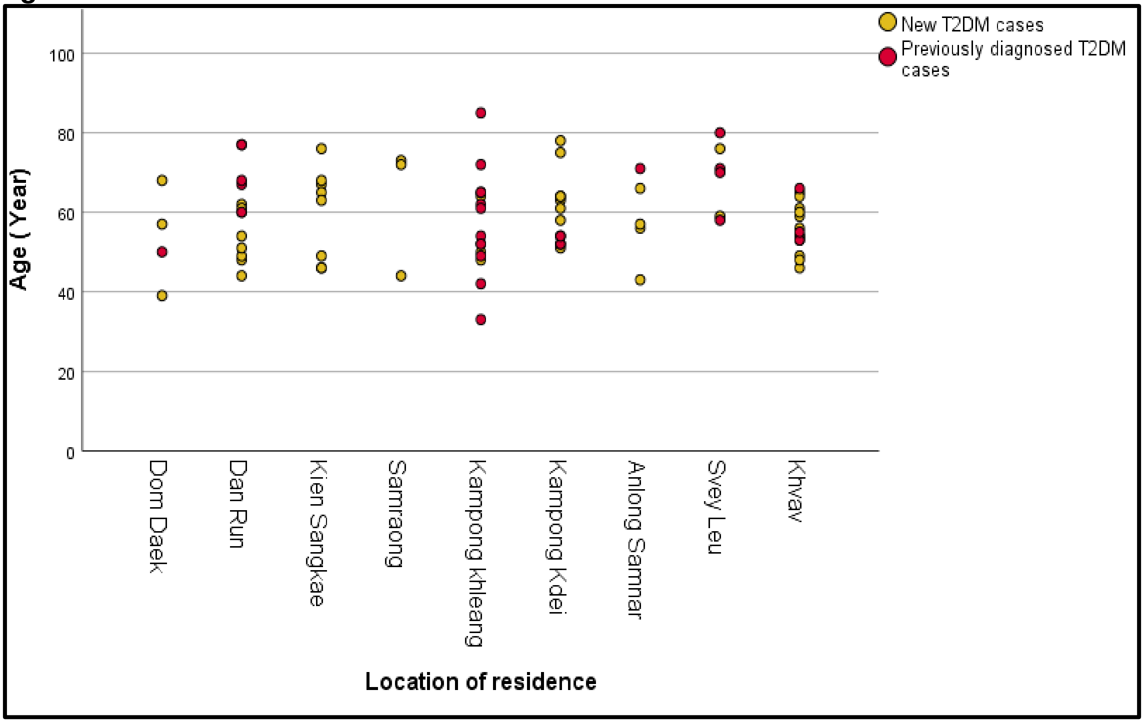
(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

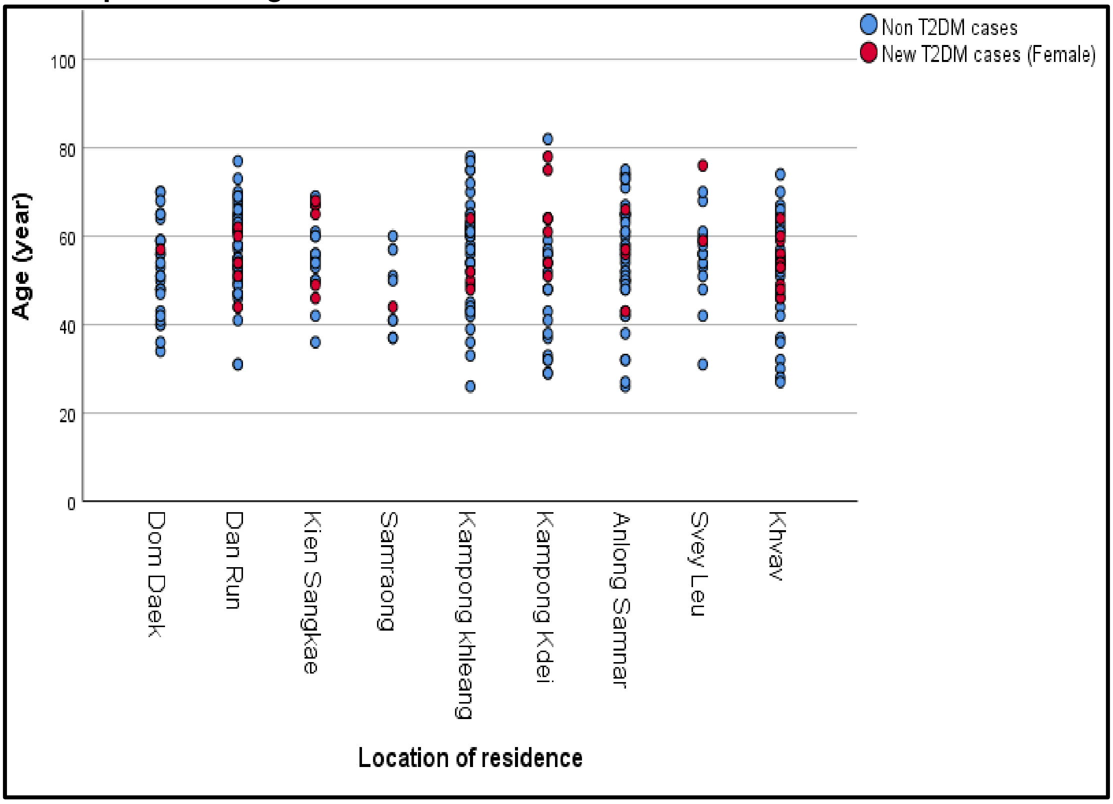
Cc: soeumvansak@yahoo.com; Melanie Moylan

Appendix 9. Scatterplots

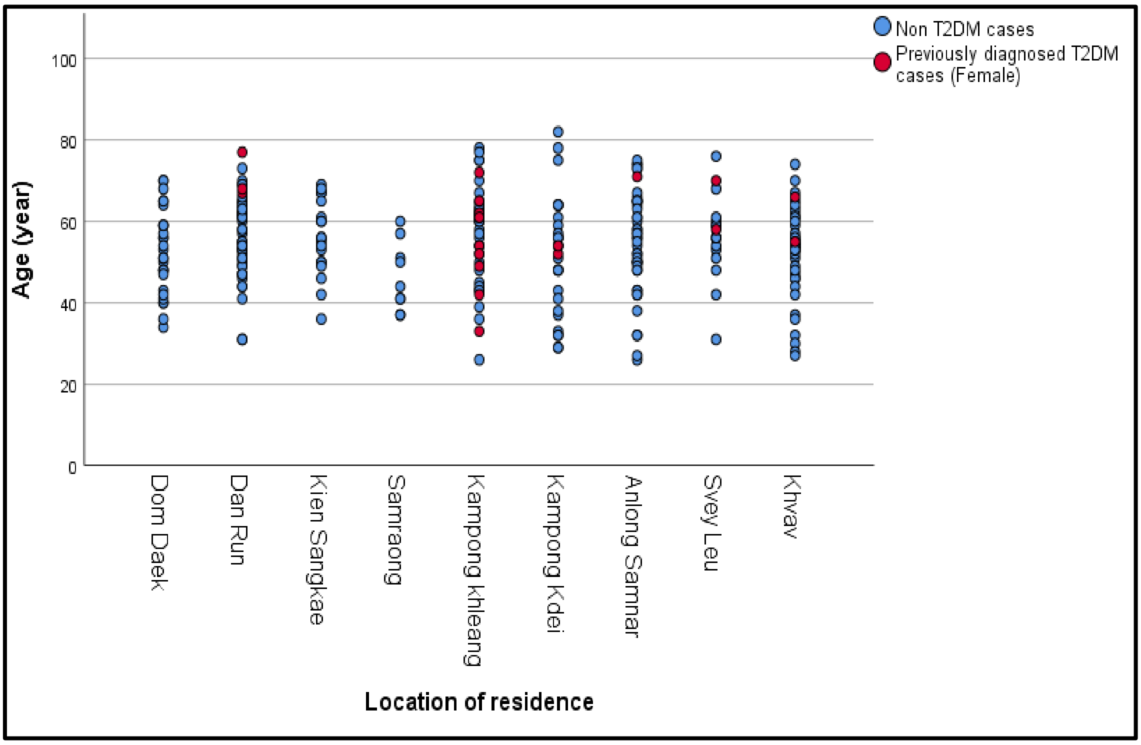
Scatterplot showing the distribution of type 2 diabetes mellitus (T2DM) cases by age and commune



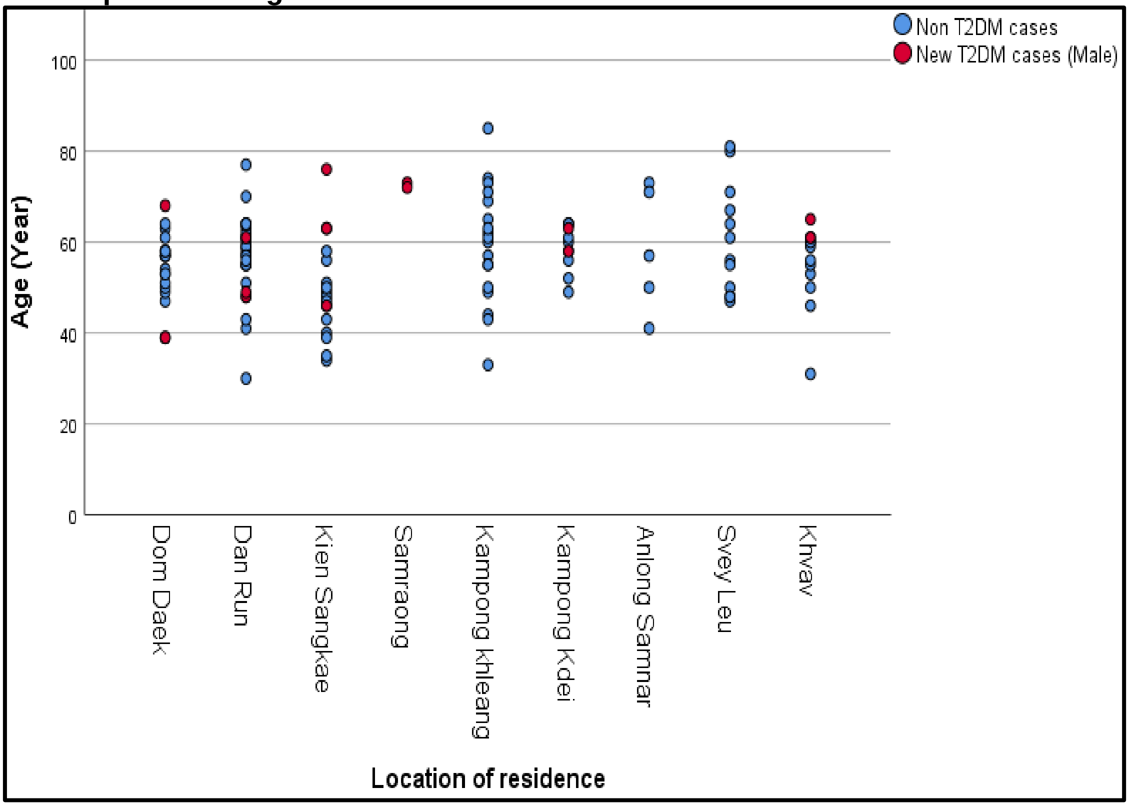
Scatterplot showing the distribution of new T2DM cases for females



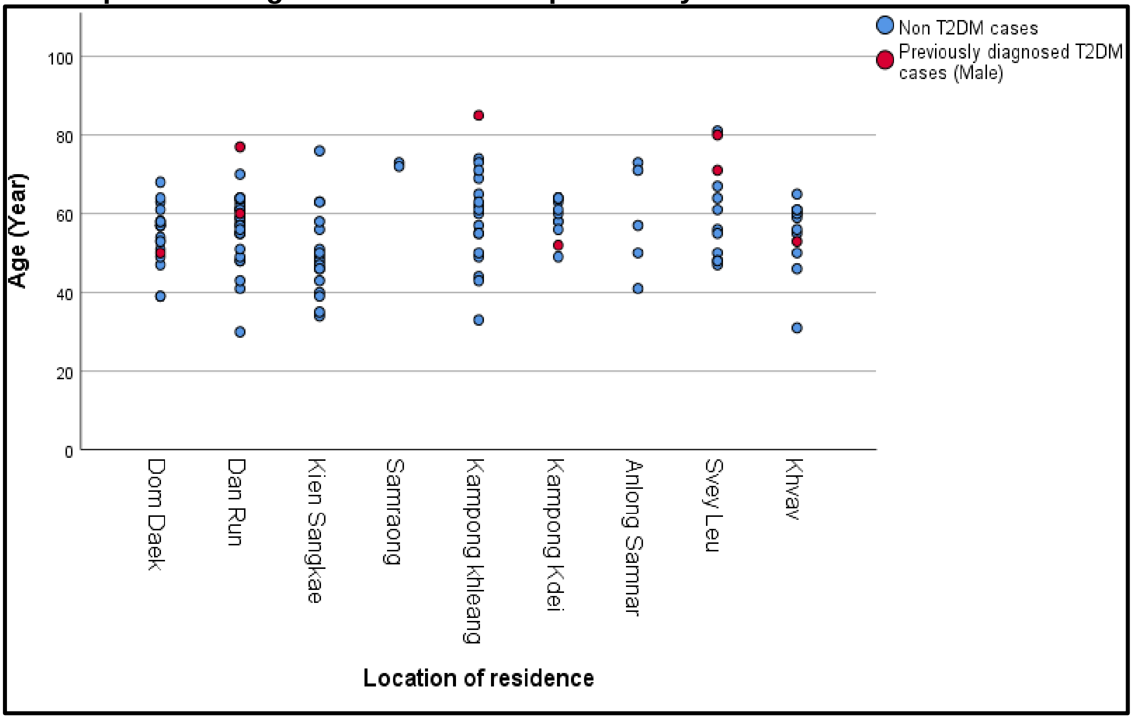
Scatterplot showing the distribution of previously diagnosed T2DM cases for females



Scatterplot showing the distribution of new T2DM for males



Scatterplot showing the distribution of previously T2DM cases for males



Appendix 10. Pearson correlation between independent variables

Variables	Distance from the province-level diabetes health services (km)	Age (years)	Sex (m/f)	BMI (kg/m^2)	WC (cm)	WtHR	HC (cm)	WHR	Hypertension (yes/no)
Distance from the province-level diabetes health services (km)	1	-.03	.14**	-.07	-.25**	-.18**	-.13*	-.28**	-.06
Age (years)	-.03	1	-.09	-.17**	.00	.04	-.09	.11*	.24**
Sex	.14**	-.09	1	.08	-.02	.15**	.15**	-.22**	.08
BMI (kg/m^2)	-.07	-.17**	.09	1	.81**	.8**	.85**	.37**	.18**
WC (cm)	-.25**	.00	-.02	.81**	1	.94**	.82**	.73**	.24**
WtHR	-.18**	.04	.15**	.81**	.94**	1	.78**	.66**	.30**
HC (cm)	-.13*	-.09	.15**	.85**	.82**	.78**	1	.21**	.16**
WHR	-.28**	.11*	-.22**	.37**	.73**	.67**	.21**	1	.22**
Hypertension	-.06	.24**	.08	.18**	.24**	.30**	.16**	.22**	1

***Correlation is significant at the .05 level (2-tailed) **Correlation is significant at the .01 level (2-tailed)**