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Bereich Endokrinologie & Diabetologie
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The change of lifestyle in an indigenous Namibian population group (Ovahimba) is associated with alterations of glucose metabolism, metabolic parameters, cortisol homeostasis and parameters of bone quality (quantitative ultrasound).

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to Martin

and to my parents

for their faith in me

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General Introduction

The number of patients suffering from diabetes (DM) worldwide has increased rapidly over the past few years and it is expected that the numbers will increase further: from 171 million people suffering from diabetes in 2000, to 382 million in 2013 and to 592 million people by 2035 (IDF 2013, Hossain et al. 2007).

Until some time ago diabetes, especially type 2 DM, was seen as a disease of the more affluent and therefore of the western industrialised world (King & Rewers 1991). However, this picture is changing as more and more data from the developing world become available showing an alarming rise of the prevalence of DM in these countries. From 1959 until the mid-80s less than 1.4% of diabetic patients were living on the African continent. Yet, in 2013 80% of the people suffering from DM are living in low- and middle-income countries. The prognosis for Africa is an increase in the number of patients with DM from 7.1 million in 2000, to 19.8 million in 2013 and to 41.4 million by 2035 (IDF 2013, Azevedo & Alla 2008). According to Azevedo & Alla (2008), DM and other non-contagious chronic diseases will be responsible for more deaths than the HIV/AIDS pandemic by the year 2030. Literature has raised the possibility that a genetic predisposition of the African population could be responsible for such a drastic increase in prevalence of DM (Cruickshank et al. 2001). Further arguments support the proposition that environmental factors could be supportive in developing this disease. Urbanisation and westernisation are referred to as the main environmental factors as these conditions often coincide with an unhealthy lifestyle consisting of a greatly increased body weight, smoking, the consumption of alcohol and reduced physical activity (Azevedo & Alla 2008, Hossain et al. 2008, Cruickshank et al. 2001, Mbanya et al. 1997). In their article on DM in sub-Saharan Africa (SSA), Azevedo & Alla (2008) argue that due to the ever increasing number of risk factors DM has now become an epidemic on the African continent. People living in rural areas who have kept their traditional lifestyle are showing a much smaller prevalence of DM (Hossain et al. 2008).

The high prevalence of DM has an enormous impact on the economy, especially in developing countries. This is due to the direct and indirect costs associated with the disease. Direct costs result from the medical treatment necessary for diabetic patients, while indirect costs result, for example, from the inability to work (Kirigia et al. 2009).

These high costs threaten to place the economies of African countries under great pressure. Problems of individual health-care supply and distress have to be expected since until now many governments have failed to acknowledge the threat of DM as a major health concern (Kirigia et al. 2009).

The primary question of the study is whether the rising urbanisation and the often accompanying adoption of a more westernised unhealthy lifestyle can be associated with an increase in the prevalence of disorders of glucose metabolism or DM. Secondary to this, the cortisol homeostasis as a comparison between urban and rural participants will be examined, the prevalence of the metabolic syndrome (MetS) established, the 10-year cardiovascular risk using the Framingham risk score (FRS) calculated and the acoustical properties of bone of the participants measured.

Current literature shows that a lot of research has been and still is being conducted and published on the topic of DM in many different countries, including SSA. However, so far no data have been published on the effect of the alteration of the lifestyle on the occurrence of disorders of glucose metabolism in Namibia. This is so despite many of the ethnic Namibians having encountered huge lifestyle changes over the past decade. Only the burden of the disease on the Namibian economy has been assessed as part of a large study in SSA (Kirigia et al. 2009).

We hope to gain a better understanding of the current situation and expected development in Namibia through the collected data. Furthermore, we hope that suggestions for preventative measures can be made in co-operation with the University of Namibia (UNAM) and the Namibian Ministry of Health (MoHSS).

Objectives

Primary question

1. Is a change of lifestyle associated to an increased risk of disorders of glucose metabolism in the Ovahimba people?

Secondary questions

2. Cortisol homeostasis of the Ovahimba people of Namibia. A comparison between urban and rural participants.
3. The prevalence of the metabolic syndrome in the Ovahimba people of Namibia. A comparison between urban and rural participants.
4. The 10-year cardiovascular risk according to the Framingham risk score in the Ovahimba people of Namibia. A comparison between urban and rural participants.
5. Assessment of the acoustical properties of bone of the Ovahimba people. A comparison between urban and rural participants.

PART A THEORETICAL BACKGROUND

Chapter 1 Diabetes

1. Definition, Classification, Treatment

1.1. Definition

According to the Guidelines 2011 of the American Diabetes Association (ADA), diabetes (DM) can be defined as 'a group of metabolic diseases characterised by hyperglycaemia resulting from defects in insulin secretion, insulin action, or both' (ADA 2011). Chronic hyperglycaemia is associated with long-term damage, dysfunction and failure of different organs (ADA 2011, Kerner et al. 2001): The diabetic-specific microvascular damages occur mainly in the eyes, kidneys and nervous system, while the diabetic-specific macrovascular damages lead to dysfunction and damage of the heart, brain and peripheral arteries (Kerner et al. 2001). Thus DM is associated with a significant morbidity, a reduced life expectancy and a diminished quality of life (WHO 2006).

The deficiency of insulin action on target tissue is due to an inadequate insulin secretion and/or diminished tissue response to insulin, leading to hyperglycaemia (ADA 2011). Chronically high glucose levels in the blood lead to abnormalities of the carbohydrate, fat and protein metabolisms. This in turn causes the symptoms of marked hyperglycaemia, which include polyuria, polydipsia, weight loss and ketosis/ketoacidosis (Kerner et al. 2001). Consequences of uncontrolled diabetes are extreme hyperglycaemia with ketoacidosis or the nonketotic hyperosmolar syndrome, both acute and life-threatening situations as they can lead to coma and death, especially in the developing world, where prognosis is worse than in developed countries (ADA 2011, Gill et al. 2009).

In addition to the above mentioned acute symptoms, DM causes a wide range of complications, especially prevalent in patients with poor glycaemic control (Azevedo & Alla 2008). Since high glucose concentrations cause microangiopathy, many diabetic patients suffer from retinopathy with the potential loss of vision, neuropathy with the risk of foot ulcers, Charcot joints and amputations. Furthermore, microvascular damage can cause autonomic and peripheral neuropathy also resulting in foot ulcers as well as gastrointestinal, genitourinary and cardiovascular symptoms and sexual dysfunction

(ADA 2011, Deshpande et al. 2008, WHO 2006). Patients with DM suffer from increased incidence of atherosclerotic cardiovascular, peripheral arterial and cerebrovascular disease because of the effects of macrovascular damage (Deshpande et al. 2008). Diabetes does not cause hypertension or abnormalities of lipoprotein metabolism, nevertheless these are often found as co-morbidities, as the risk factors are equivalent (ADA 2011).

Impaired glucose tolerance (IGT) and/or impaired fasting glucose (IFG) - conditions known as pre-diabetes - are conditions characterised by an increased risk for developing DM and cardiovascular diseases (CVD) (ADA 2011, Schwarz et al. 2009). These conditions can be observed as an intermediate stage in any of the types of DM and, if no interventions take place, will lead to the manifestation of DM in 50% of patients within 10 years. However, should intervention measures be taken, the IGT and/or IFG can regress and a normal glycaemic metabolism can prevail (ADA 2011, Schwarz et al. 2009). According to Nathan et al. (2007), IGT and IFG can be defined as intermediate states of abnormal glucose regulation that exist between normal glucose tolerance (NGT) and DM (Nathan et al. 2007). NGT was defined as a fasting venous plasma glucose (FG) <100 mg/dl and a 2-h glucose[1] (2-h Glc) <140 mg/dl (Nathan et al. 2007). Thus any conditions above these measurements can be seen as an abnormal glucose metabolism. However, research has shown that IFG and IGT do not necessarily define the same individuals, as the epidemiological characteristics suggest different pathophysiological mechanisms (Nathan et al. 2007, Carnevale Schianca et al. 2003).

1.2. Classification and treatment

The classification of DM comprises 4 categories: type 1 DM, type 2 DM, type 3 DM and gestational DM, with the vast majority of cases falling into the broad categories of type 1 and type 2 DM (ADA 2011, Maraschin et al. 2010). Assigning a type of DM to an individual, however, often depends on the current circumstances, and many diabetic patients do not fit into a single category. The severity of the metabolic abnormalities as well as the underlying pathogenesis causing the hyperglycaemia can progress, regress, stay the same or change altogether. Therefore, even though the right classification of DM allows for a more adequate treatment of the patient, it is more important to

[1] 2-h glucose level: glucose level in venous plasma measured two hours after the intake of 75 g of glucose as part of the OGTT.

understand the underlying pathogenesis of the hyperglycaemia at hand in order to treat the patient effectively (ADA 2011, Maraschin et al. 2010).

1.1.1. Type 1 diabetes

Type 1 DM is responsible for approximately 5-10% of all diabetic cases and was previously encompassed by the terms insulin-dependent diabetes (IDDM) or juvenile onset DM, as it commonly occurs in childhood and adolescence. This type of DM results from a progressive destruction of the pancreatic β-cells of the Islets of Langerhans which in turn leads to an absolute deficiency of insulin secretion. The disease often begins with a sudden appearance of signs and symptoms such as polyuria, polydipsia, constant hunger, weight loss, vision changes and fatigue (WHO 2011). However, type 1 DM also commonly presents with acute ketoacidotic metabolic imbalance and coma as the first manifestations, thus as an emergency situation (Kerner et al. 2001).

The majority of patients suffer from immune-mediated type 1 DM, a cellular mediated autoimmune destruction of the β-cells. The autoimmune destruction has multiple genetic predispositions and can also be related to environmental factors. These factors are as yet poorly defined (ADA 2011). Different markers of the immune destruction can be detected in 85-90% of patients and include islet cell autoantibodies, autoantibodies to insulin, autoantibodies to GAD65 and autoantibodies to tyrosine phosphatases. The condition furthermore has a strong genetic component with linkage to the HLA/DQB genes. The rate of β-cell destruction varies between individuals, with some patients requiring life-long insulin replacement therapy. Other patients may have a modest fasting hyperglycaemia with some rest insulin secretion requiring insulin replacement only in times of severe hyperglycaemia or ketoacidosis due, for example, to stress or infection (ADA 2011, Maraschin et al. 2010). Patients suffering from immune-mediated DM also have an increased susceptibility to other autoimmune disorders such as Grave's disease, Hashimoto's thyroiditis and Addison's disease (ADA 2011).

In a minority of patients the underlying cause of hyperglycaemia is idiopathic. These patients suffer from episodic ketoacidosis and varying degrees of insulin deficiency between episodes, thus the absolute requirement for insulin replacement therapy may come and go. This form of DM is strongly inherited, does not show β-cell immunity and

is not HLA associated (ADA 2011, Maraschin et al. 2010). Type 1 DM is treated with short-acting and long-acting insulin replacement therapy, depending on the patient's needs and understanding of the condition and therapy.

Table 1 Comparison of type 1 and type 2 DM

Characteristics	type 1	type 2
Age of manifestation	Childhood, adolescence, young adulthood	Middle to older adulthood
Onset	Insidious, acute	Generally subtle onset
Symptoms	Polyuria, polydypsia, weight loss, fatigue	Mostly in later stages, poplyuria, polydypsia, diabetes-specific complications
Body weight	Normal	Overweight or obese
Ketosis prone	Pronounced	Less pronounced or absent
Insulin secretion	Greatly reduced or diminished	Sub-normal to high secretion, qualitatively always defective
Insulin resistance	None or only very slight	Often pronounced
Familial clustering	Low	Typical
Heredity	Multifactorial and polygenic	Multifactorial
HLA-association	Present	Not present
Diabetes-associated antibodies	Present in 90-95%	Not present
Insulin therapy	Required from beginning	Required only in later stages of disease

The table shows a comparison of the characteristics, aetiology and therapy of DM type 1 and type 2.

Source: Kerner et al. 2001

1.1.2. Type 2 diabetes

Type 2 accounts for 90-95% of diabetic patients. It was previously known as non-insulin dependent diabetes (NIDDM) or adult-onset diabetes and is a disease which seldom leads to sudden profound metabolic imbalances but rather to serious micro- and macrovascular diseases resulting in short-term and long-term complications (ADA 2011, Kerner et al. 2001). This is due to the fact that symptoms of type 2 DM are mostly less profound and thus the disease frequently goes undiagnosed for years after its onset, commonly as part of the metabolic syndrome (MetS), and by then complications have already arisen (WHO 2011, Kerner et al. 2001). The symptoms arising from these neural and vascular states, such as polyneuropathy, retinopathy and gastrointestinal problems, are therefore often the first signs of type 2 DM. The main pathogenesis of type 2 DM is a peripheral insulin resistance with a relative, rather than absolute, insulin deficiency. In addition to this, there is some degree of defective insulin secretion in these patients, as they often show normal or only slightly elevated levels of insulin in the presence of very high blood glucose levels. However, patients generally do not require insulin treatment to survive in the earlier years of manifestation. An insulin substitute treatment might become necessary in later stages of the disease or if adequate blood glucose concentrations cannot be achieved with diet and oral hypoglycaemic agents alone (Benhalima & Mathieu 2009, Zimmet et al. 2001).

Specific aetiologies of type 2 are not yet known but some risk factors have been defined, which can be divided into non-modifiable and modifiable factors. According to Sobngwi et al. (2001), age and ethnicity are the main non-modifiable determinants of DM prevalence. Studies have shown that the prevalence increases with age and differs between various ethnic populations. A South African study has found that Indians are more susceptible to develop DM than Black Africans which in turn are more susceptible than South African Caucasians (Sobngwi et al. 2001). Other non-modifiable risk factors include a strong family history of DM, a history of gestational DM and low birth weight (Deshpande et al. 2008). Looking at the modifiable risk factors, obesity, especially abdominal or visceral obesity, is among the leading causes of DM type 2, since it can itself cause a certain degree of insulin resistance. The increasing obesity in children worldwide is now also causing more and more children to suffer from DM type 2, which has until recently only been seen in adults (WHO 2011). Dyslipidaemia with high

triglycerides and/or low HDL-cholesterol (HDL-Chol) concentrations and hypertension are also significant risk factors (ADA 2011).

Causing these are a sedentary lifestyle, inactivity and an unhealthy diet - all of which are often seen as the consequences of urbanisation (Hossain et al. 2007, Sobngwi et al. 2001). The latter is especially prevalent in the developing world, resulting in a massive increase of DM in these regions (Sobngwi et al. 2001). Psychosocial factors such as poor mental health, increased stress, lower social support and depression were identified as independent risk factors for the development of DM due to an increased level of cortisol in the blood (Deshpande et al. 2008).

The ADA and the European Society for the Study of Diabetes have together developed guidelines for the treatment of type 2 DM. Insulin resistance may improve with weight reduction and therefore a healthy diet and exercise (30 minutes sustained exercise per day: walking, cycling, swimming) aimed at weight reduction or maintaining a normal weight should be part of the therapy. Besides having enormous effects in lowering insulin resistance, these lifestyle interventions are cheap, easy to maintain and have no adverse effects. The guidelines further recommend that every newly diagnosed patient should be started on metformin, an oral hypoglycaemic drug, should no contraindications be present. Should metformin not be enough to maintain adequate glucose control (HbA1c < 7%), especially in later years of the disease, oral antidiabetics such as sulfonylurea, thiazolinedones, glinides, dipeptidyl peptidase-4-inhibitors (DPP-4-inhibitors), glucagon-like peptide-1 analogs (GLP-1-analogs), alpha-glucose inhibitors or basal insulin should be given (Karow & Lang-Roth 2010). As with all pharmacological agents, the possible adverse effects must be closely monitored. If this pharmacological therapy is adhered to and combined with a healthy and responsible lifestyle, the risk for long-term consequences of DM can be greatly reduced (Behalima et al. 2009, Kerner et al. 2001).

1.1.3. Type 3 diabetes and other types

Type 3 DM was previously known as ‘Other types of diabetes’. It is rare and therefore will only be briefly mentioned. For a complete list of all ‘Other types of diabetes’ see Figure 1 below. Several forms of DM can be associated with monogenetic defects in β-cell function resulting in an onset of hyperglycaemia generally before the

age of 25. These forms are referred to as maturity-onset diabetes of the young (MODY) and are characterised by an impaired insulin secretion with minimal or no defects in insulin action (ADA 2011). On the other hand, genetic defects in insulin action can also cause metabolic abnormalities ranging from hyperinsulinaemia and modest hyperglycaemia to severe diabetes. In addition, any process damaging the pancreas can cause diabetes. The damages, however, have to be severe in order for DM to occur. Such diseases would be, among others, pancreatitis, cancer, trauma, infection or a pancreatectomy. Several endocrinopathies, such as acromegaly, Cushing's syndrome, phaeochromocytoma or glucagonoma can cause DM as the resulting increased hormone levels of these conditions antagonise the action of insulin. The resulting hyperglycaemia normally resolves when the hormone excess is treated. Furthermore, several drugs can impair insulin secretion or insulin action resulting in drug-or chemical induced DM. Such drugs for example would be pentamidine, glucocorticoids, thyroid hormone, diazoxide and thiazides. Lastly, some genetic syndromes are associated with an increased incidence of DM. These include the chromosomal abnormalities of Down syndrome, Klinefelter syndrome, Turner syndrome and Huntington Chorea (ADA 2011).

Figure 1 Aetiological classification of diabetes

- I. Type 1 diabetes (β-cell destruction, usually leading to absolute insulin deficiency)
  - A. Immune mediated
  - B. Idiopathic
- II. Type 2 diabetes (may range from predominantly insulin resistance with relative insulin deficiency to a predominantly secretory defect with insulin resistance)
- III. Other specific type
  - A. Genetic defects of β-cell function
    1. Chromosome 12, HNF-1α (MODY3)
    2. Chromosome 7, glucokinsae (MODY2)
    3. Chromosome 20, HNF-4α (MODY1)
    4. Chromosome 12, insulin promoter factor-1 (IPF-1; MODY4)
    5. Chromosome 17, HNF-1β (MODY5)
    6. Chromosome 2, *NeuroD1* (MODY6)
    7. Mitochondrial DNA
    8. Others
  - B. Genetic defects in insulin action
    1. Type A insulin resistance
    2. Leprechaunism
    3. Rabson-Mendenhall syndrome

4. Lipoatrophic diabetes
5. Others

C. Diseases of the exocrine pancreas
1. Pancreatitis
2. Trauma/pancreatectomy
3. Neoplasia
4. Cystic fibrosis
5. Hemochromatosis
6. Fibrocalculous pancreatopathy
7. Others

D. Endocrinopathies
1. Acromegaly
2. Cushing's syndrome
3. Glucagonoma
4. Pheocromocytoma
5. Hyperthyroidism
6. Somatostatinoma
7. Aldosteronoma
8. Others

E. Drug or chemical induced
1. Vacor
2. Pentamidine
3. Nicotinic acid
4. Glucocorticoids
5. Thyroid hormone
6. Diazoxide
7. β-adrenergic agonists
8. Thiazides
9. Dilantin
10. γ-Interferon
11. others

F. Infections
1. Congenital rubella
2. Cytomegalovirus
3. Others

G. Uncommon forms of immune-mediated diabetes
1. "Stiff-man" syndrome
2. Anti-insulin receptor antibodies
3. Others

H. Other genetic syndromes sometimes associated with diabetes
1. Down syndrome
2. Klinefelter syndrome
3. Turner syndrome

4. Wolfram syndrome
5. Friedreich ataxia
6. Huntington chorea
7. Laurence-Moon-Biedl syndrome
8. Myotonic dystrophy
9. Porphyria
10. Prader-Willi syndrome
11. Others

IV. Gestational diabetes mellitus

Diabetes has many different aetiologies. The above figure gives an overview of the known common and uncommon causes of DM.

Source: adapted from ADA 2011

1.1.4. Types of diabetes in Africa

When looking at diabetes in Africa, one has to add two further subtypes: atypical African diabetes and malnutrition-related diabetes (Gill et al. 2009). Atypical African diabetes was first described in the late 1960s by researchers working in Africa. Subsequent reports described this as a form of DM with 'phasic insulin-requiring profiles in the absence of obvious precipitating factors for ketosis' (Gill et al. 2009). It has subsequently become apparent that there are still other forms of atypical diabetes in Africa which do not easily fit the criteria defining the main known types. These atypical forms are predominantly found in populations of African ancestry.

The most common form is the Ketosis-prone DM (KPD) or 'Flatbush diabetes', characterised by episodic ketoacidosis requiring insulin therapy at time of presentation as in type 1 DM, but without showing any immunologic or autoimmune markers of β-cell destruction. This ketoacidotic episode is then followed by an episode of non-insulin requiring type 2-like diabetes in 76% of patients. Only 24% remain insulin-dependent (Mauvais-Jarvis et al. 2004, Imram 2008). The long-term clinical course of ketosis-prone type 2 diabetes is then continued by a propensity to glucose toxicity with an impairment of glucose secretion and action. This can require a life-long insulin replacement therapy. However, in many cases complete remission is achieved after a few years. The underlying pathology is characterised by a reversible β-cell destruction and the absence of immunological and GAD65 autoantibodies. However, the non-autoimmune mediated impairment of β-cell function is slower than in type 1 DM (Mauvais-Jarvis et al. 2004). According to Mauvais-Jarvis et al. (2004), patients

suffering from non-insulin dependent KPD can show up to 80% recovery of β-cell function, while insulin-requiring KPD show no significant recovery but a faster loss of residual β-cell function. Insulin-sensitivity is equally impaired in both subgroups when presenting with ketotic symptoms. However, the insulin-sensitivity in non-insulin dependent KPD patients can improve by 200% to reach non-diabetic sensitivity values during remission or once hyperglycaemia is corrected (Imram 2008). When looking at the epidemiological data, KPD shows a strong male predominance, a strong family history and a high prevalence in non-white populations (Mauvais-Jarvis et al. 2004). The treatment of KPD must be amended according to the clinical presentation: whether insulin or non-insulin dependent KPD. Thus it becomes very important to regularly examine the patient as glycaemic changes occur frequently.

Malnutrition-related DM (MRDM), previously known as ‘tropical diabetes’ or ‘tropical pancreatic diabetes’ is characterised by the same clinical course as KPD, but with a strong history of malnutrition during childhood. In addition, a HLA association has been determined in some populations presenting with MRDM (Gill et al. 2009). These atypical forms of DM in Africa make it difficult to classify patients as having type 1 or type 2 DM based on the usual clinical criteria.

Figure 2 Features of 'atypical' and 'malnutrition-related' diabetes in Africa

Atypical	Malnutrition-related
Ketotic presentation	Insidious onset
Children or young adults	Young adults
3:1 Male excess	2:1 Male excess
Islet autoimmunity rare	Occasional 'type 1' HLA pattern
Often strong family history	Past or present malnutrition
Remission possible	Steatorrhoea in some areas

It has been found that in addition to the common type 2 DM there exists an atypical and a malnutrition related DM in Africa. The above figure gives a brief overview of the features of each type.

Source: Gill et al. 2009

1.1.5. Gestational diabetes

Gestational diabetes (GDM) is the most common metabolic disorder during pregnancy and according to the German Diabetic Association occurs in 1-5% of all pregnant women. Sadly, the prevalence of GDM is increasing worldwide fuelled by advancing maternal age, racial/ethnic shift in childbearing and obesity during pregnancy (Kim 2010, Kaaja & Rönnemaa 2008). It is most commonly defined as 'glucose intolerance first diagnosed during pregnancy'. However, several other definitions are being used as the diagnostic criteria are being reviewed and analysed (ADA 2011, Kim 2010). A wide range of perinatal and postpartum complications are associated with GDM. The former includes conditions such as hypertensive disorders/preeclampsia, preterm delivery, shoulder dystocia, stillbirths, clinical neonatal hypoglycaemia, hyperbilirubinaemia and caesarean deliveries. Postpartum complications are characterised by a predisposition to obesity, IGT and the MetS in the offspring as well as DM and CVD in the mother (Kim 2010, Kaaja & Rönnemaa 2008). The management of GDM consists of tight blood glucose control, caloric restriction, physical activity, weight reduction if indicated and pharmacotherapy with insulin. The care of women with GDM should ideally be managed by a multidisciplinary team (Kaaja & Rönnemaa 2008).

2. Epidemiology of diabetes

2.1. Prevalence of DM

The latest data released by the International Diabetes Federation (IDF) in the sixth edition of their Diabetes Atlas show staggeringly high numbers: 382 million people will have had DM in 2013 and by 2035 this number will have risen to 592 million (Figure 3) (IDF 2013). The IDF furthermore estimates that 175 million, that is 46%, of diabetic individuals are undiagnosed, 84% of who live in low- and middle-income countries. The largest increases will take place in the regions dominated by developing economies (IDF 2013, IDF 2009).

From 1959 until the mid-80s less than 1.4% of diabetic patients were living on the African continent. Yet, in 2006 80% of the people suffering from DM were living in developing countries of which African countries form a huge share. The prognosis for Africa is an increase in the number of patients with DM from 7.1 million in 2000, to 19.8 million in 2013 and to 41.4 million by 2035 (IDF 2013, Azevedo & Alla 2008). According to Azevedo & Alla (2008), DM and other non-communicable diseases (NCD) will by 2030 be responsible for more deaths than the HIV/AIDS pandemic. Since type 1 DM accounts for only 5-10% of the incidences of DM, the rapidly changing prevalence of DM is almost entirely in the subgroup of type 2 DM (Zimmet et al. 2001).

DM is the most common chronic disease in almost all countries and, as the above numbers indicate, should be playing an increasingly significant role in national and international health-care. To achieve this, estimates of the current and future burden of diabetes are important in order to allocate community and health resources to counteract trends for increasing prevalence.

Shaw et al. (2010) included all 216 member countries of the United Nations (UN) to calculate age- and sex-specific diabetes prevalence for the years 2010 and 2030, taking into consideration predicted demographic changes for urbanisation and ageing. Studies of these countries were included if they assessed diabetes prevalence using the WHO or ADA diagnostic criteria in a defined adult population sample (at least three distinct age groups within the 20-79 year range) (Shaw et al. 2010). 133 studies from 91 countries

were identified to calculate and analyse the trend of diabetes prevalence worldwide and per region.

The results showed that there will be an increase in the prevalence of DM from 6.4% in 2010 to 7.7% of the world population aged 20-79 by 2030, resulting in an increase of the number of adults with DM of 54.1% (Shaw et al. 2010, Sicree et al. 2009). Only three years later though, these statements have had to be revised as the latest calculations of the IDF have shown that the global prevalence will increase from 8.3% in 2013 to 10.1% in 2030 (IDF 2011).

Figure 3 Prevalence of diabetes and IGT

AT A GLANCE	2013	2035
Total world population (billions)	7.2	8.7
Adult population (20–79 years, billions)	4.6	5.9
DIABETES AND IGT (20-79 YEARS)		
Diabetes		
Global prevalence (%)	8.3	10.1
Comparative prevalence (%)	8.3	8.8
Number of people with diabetes (millions)	382	592
IGT		
Global prevalence (%)	6.9	8.0
Comparative prevalence (%)	6.9	7.3
Number of people with IGT (millions)	316	471

Research has shown that the prevalence of DM type 2 is rapidly increasing worldwide.

The above calculations by the IDF show the rapid increase expected between 2013 and 2035

Source: IDF 2013

There are marked regional differences and differences between developed and developing countries. The highest regional comparative prevalence[2] is for the Middle East and North Africa (MENA), with 10.9% and 11.3% of the population in 2013 and 2035 respectively. This region is closely followed by North America and the Caribbean (NAC) region with 9.9% and 9.9% in 2013 and 2035 respectively, and the South East

[2] Comparative prevalence: Comparative prevalence is calculated assuming that every country and region has the same age profile. The age profile of the world population is used. Since this figure removes differences of age between countries and regions, it is appropriate for making comparisons, but should not be used when assessing the proportion of people within a country or region who have diabetes (IDF 2009).

Asia (SEA) region with 8.7% and 9.4% (IDF 2013). The African region is expected to have the largest proportional increase in adult suffering from DM by 2035 of 109.1%, followed by the MENA with 96.2%. Furthermore, in developing countries, the adult diabetes numbers are likely to increase by 69% from 2010 to 2030 compared to 20% in the developed world. The total adult population growth, though, is expected to be only 36% and 2% respectively (IDF 2013, Shaw et al. 2010).

Tokelau is showing the highest national prevalence of 37.5%, followed by Federated State of Micronesia 35.0% and Marshall Islands 34.9%. For obvious reasons, countries with the greatest numbers of diabetics are those with the largest populations. Currently the list is led by China (98.4 million), India (65.1 million) and the USA (24.4 million). In 2011 Germany has not been on the list of the top 10 countries with the highest number of diabetics. However, by 2013 this has changed and Germany is now on eighth place with 7.6 million diabetics (IDF 2013, IDF 2011, Shaw et al. 2010).

When looking at different age groups, the greatest number of people with DM is in the 40-59-year age group, currently 184 million people, 80% of who live in low- and middle-income countries. This is projected to rise to 264 million people by 2035 of which 86% will be living in the developing world (IDF 2013). An even greater increase is expected in the 60-79-year age group, which will become the leading group. For the developing countries increases in numbers are also expected for the other age groups (20-39 and 60-79). In developed countries, however, an increase in numbers of people with DM is only projected for the over 60s, while a slight reduction in prevalence is predicted for the younger population (Shaw et al. 2010).

According to the IDF there is little gender difference in the estimate for 2010, with approximately one million more diabetics being women than men, though the difference is expected to increase to six million by 2030. This rise in gender differences is due to a worldwide rise in type 2 DM and obesity among pregnant women, both of which are risk factors for GDM, which then in turn presents a high risk factor for developing type 2 DM (Kaaja & Rönnemaa 2008). When analysing the urban/rural distribution of diabetes worldwide, it becomes obvious that the disease has been more prevalent in urban areas for decades (Fall 2001, King & Rewers 1991) and the discrepancy will further increase to 347 million people with DM in urban areas and ‘only’ 145 million in rural communities by 2035 (IDF 2013).

2.2. Prevalence of impaired glucose tolerance and impaired fasting glucose

IGT and IFG are recognised as pre-diabetes with a great risk for the development of DM and its associated complications. This means that the process of developing complications can already begin at the pre-diabetes stage. Therefore it becomes necessary to look at the worldwide estimates of IGT as well: in 2013 6.9% of people in the age group 20-79 would have suffered from IGT, of which the vast majority once again lives in low- and middle-income countries. This number is projected to increase to 8.0% in 2035, or 471 million people, with the highest numbers within the 40-59-year age group. The regional prevalence of IGT is similar to that of DM but somewhat higher for the African and Western Pacific regions and slightly lower in the North American region (IDF 2013).

2.3. Prevalence of diabetes in Africa and Namibia specifically

The president of the IDF, Sir Michael Hirst, has called sub-Saharan Africa, Middle East, Western Pacific and SEA 'emerging diabetes hotspots' (IDF 2013). In its latest edition of the Diabetes Atlas the IDF has given estimates of various data about DM in Namibia. As no national survey data were available from Namibia these estimates are calculations according to data available from the southern African region, taking into account the demographics of Namibia. It is estimated that the population size in the 20-79-year age group was just above 1.2 million people in 2013 for whom the national diabetes prevalence was 4.8% (IDF 2013). This is the same prevalence as estimated for the whole of Africa for the year 2013 and accounts for 58 540 diabetics in Namibia.

Figure 4 **Comparative prevalence (%) estimates of diabetes (20-79 years), 2013, Africa Region**

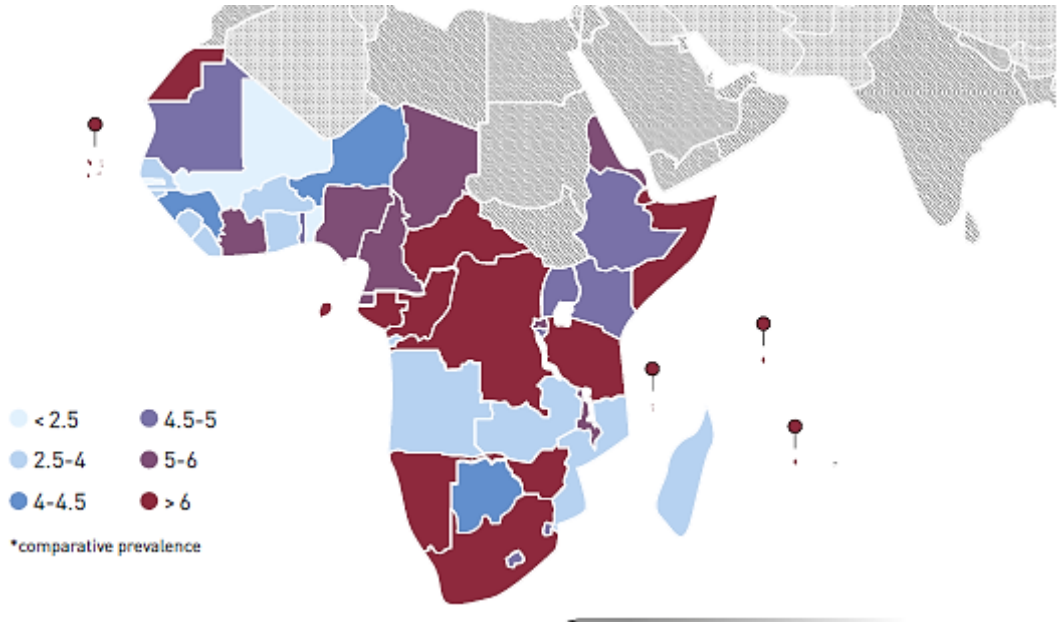


Figure 4 gives the percentages of the comparative prevalence of DM in the African regions. Africa is one of the regions hardest hit by the diabetic epidemic.

Source: IDF 2013

Furthermore, when looking at the comparative prevalence of 6.29% for Namibia in 2013 (Figure 4), this is higher than the 5.7% for the African region (IDF 2013). The data estimates done by the IDF in 2009 were somewhat lower: national prevalence 3.9% in the age group 20-79 years of age, accounting for 43 100 diabetics in the country (IDF 2009), showing how rapidly the number of diabetics is also increasing in Namibia.

The projections of the prevalence of diabetes worldwide, for Africa and for Namibia, are higher than predictions made a few years earlier. In 2004 Wild et al. used data from a number of countries where the prevalence of DM was explored using the WHO criteria. The prevalence was then extrapolated for the 191 member states of the WHO, including criteria such as ethnic and socio-economic similarities and estimates of urbanisation (Wild et al. 2004). The estimate of Wild et al. (2004) for 2030 was 20% lower than the estimate made by Shaw et al. (2010) in 2010. Even greater discrepancies are apparent when comparing current projections to older estimates. In 1997 Amos et al. made an estimate of diabetic prevalence for the year 2010 of 221 million people, compared to the calculations presented by the IDF in 2009 of 285 million people (IDF

2009). The discrepancies of estimates made for Africa show an even greater range: in 2009 the IDF calculated the prevalence of DM in Africa to be 3.2% by 2030, in contrast to the estimate made by King et al. in 1998 of 1.3% by 2025 for sub-Saharan Africa (SSA). This discrepancy is also true for Namibia for which the same authors estimated a prevalence of 1.4% and 3.9% for 2025 and 2030 respectively (IDF 2009, King et al. 1998). The data from IDF 2011 show another discrepancy: prevalence of DM in Africa by 2030 is calculated to be 4.3%.

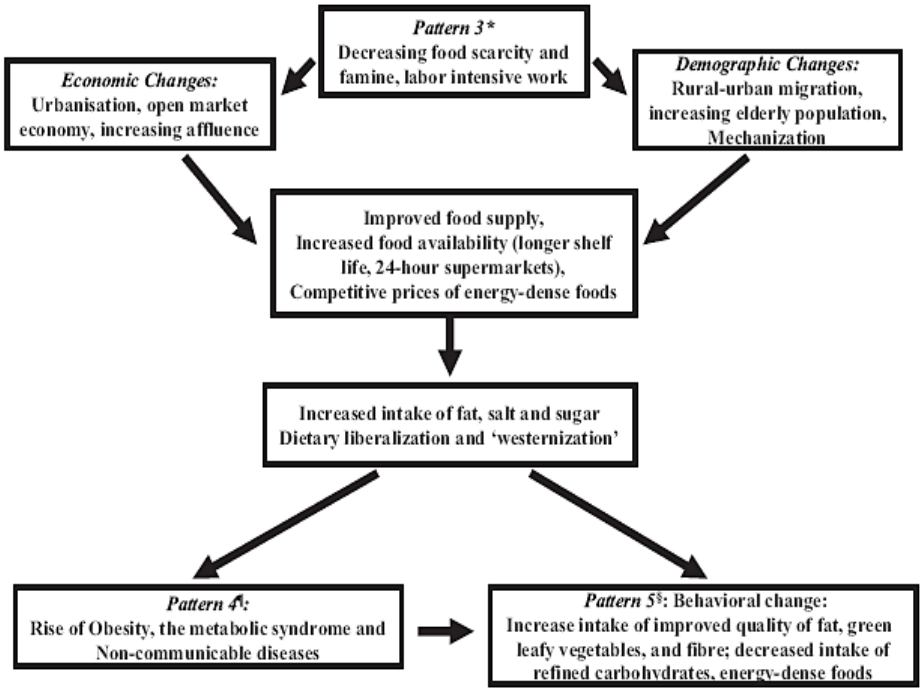
It is believed that these differences do not occur due to different statistical methods applied, but rather due to more recent studies being used for the calculations as well as genuinely increasing incidences of DM worldwide (Shaw et al. 2010, Wild et al. 2004).

3. Causes of the diabetic epidemic

3.1. Demographical, epidemiological and socio-economic transitions

What are the possible reasons for such drastic increases of diabetes? In the past few years numerous studies have been published suggesting that the consequences of demographic, epidemiological and socioeconomic transitions, as well as urbanisation and changing lifestyle factors, are the major causes of the extreme rise of NCD such as DM type 2, CVD and hypertension (BeLue et al. 2009, Gill et al. 2009, Ziraba et al. 2009, Misra & Khurana 2008). Many developing countries are slowly becoming more resourceful, undergoing a so-called 'socioeconomic transition', which is characterised by a shift of people from low socioeconomic status to a higher socioeconomic status (Misra & Khurana 2008). This in turn causes a 'demographic transition', a shift to low fertility, low mortality and higher life expectancy, but also to a significant shift in dietary and physical activity patterns, a 'nutritional and lifestyle transition' (Figure 5) (Misra & Khurana 2008). These changes can have significant effects on body composition and metabolism such as increased body mass index (BMI), obesity, dyslipidaemia and diabetes. As the study aims at examining the effects of lifestyle changes on the risk of DM, special focus will be put on the consequences of urbanisation and nutritional transition in the following paragraphs.

Figure 5 The relationship between nutrition transition, urbanisation, obesity and NCD



Various factors driving the diabetic epidemic have been established. Two of these are the rapid urbanisation taking place especially in low and middle income countries and the nutritional transition often associated with it. As can be seen in the diagram above, these pose a high risk for obesity and NCD.

Source: Misra & Khurana 2008

Research has shown that the prevalence of type 2 DM is higher in people who moved away from their traditional way of life, either to migrate to other countries or to live in urban areas, compared to people living a traditional lifestyle either as hunter gatherers or subsistence farmers (Fall 2001).

According to the United Nations' Department of Economics and Social Affairs Population Division, rapid urbanisation of the world's population took place in the twentieth century: in 1900 only 13% of people lived in urban areas. This increased to 29% in 1950 and, according to the 2005 Revision of World Urbanisation Prospects, reached almost 50% in 2005. This number is projected to rise to over 60% by 2030 as the world is expected to urbanise further (UN 2005). Even though developed countries are also experiencing rural-to-urban migration, the bulk of the urbanisation is taking place in the developing world. Particularly in SSA, increasing numbers of people are moving from rural environments into urban areas (Gill et al. 2009).

Urbanisation and economic development have led to the emergence of a nutritional transition characterised by a shift to a higher caloric content diet and/or reduction in physical activity (BeLue et al. 2009, Popkin et al. 2006). It has been shown that the migration to urban areas is associated with a change in lifestyle from a relatively healthy traditional pattern to the urban scenario of increased food quantity consisting mostly of foods high in saturated fats, cholesterol and refined carbohydrates and low in polyunsaturated fatty acids and fibre. Under improved economic conditions people become more affluent and tend to consume diets as described above, which are more widely available and cheaper than healthier food (Popkin et al. 2006).

In addition, the availability of unhealthy foods has become more widespread in developing countries as globalisation and import policies are taking effect; the availability of edible vegetable oils for consumption has nearly tripled throughout developing countries and a rapid spread of global fast-food chains can also be seen in these regions, to name just two of the adverse effects of globalisation (Popkin et al. 2006). Furthermore, locally prepared fast food, widely sold by street vendors in the developing world, is equally unhealthy containing high amounts of trans-fatty acids due to deep frying in cheap hydrogenated vegetable oil (Misra & Khurana 2008). Lastly, less physical effort is required in city living, due to, for example, less physically strenuous jobs or no need to carry water or food over long distances. It seems as if leisure time is spent more on physically inactive activities in comparison to previous years, often resulting in a markedly sedentary lifestyle (Popkin et al. 2006, Ziraba 2009). This nutritional transition results in many urbanised people exceeding caloric requirements and this positive energy balance leads to overweight and obesity, great risk factors for the development of DM (Figure 5) (Ziraba et al. 2009).

3.2. Obesity

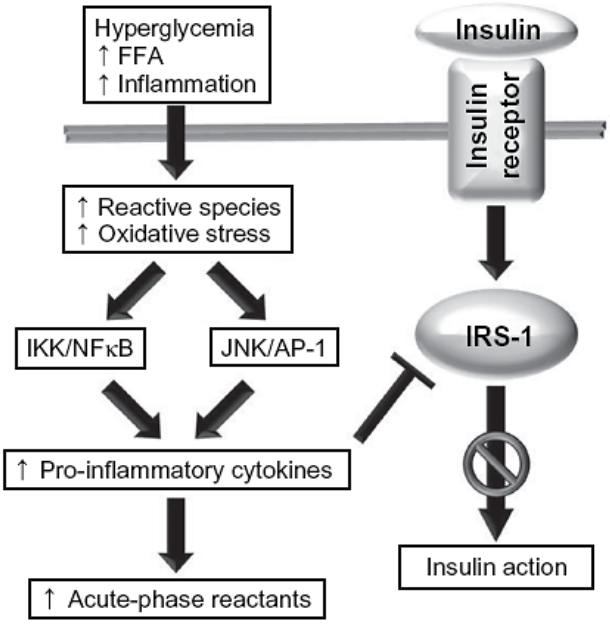
The World Health Organisation defines obesity and being overweight ‘as abnormal or excessive fat accumulation that may impair health’ (WHO 2011). The cheapest and simplest way to measure obesity and overweight is the BMI. This is specified as the weight in kilograms divided by the height in meters squared (kg/m^2). The WHO and the National Institute of Health (NIH) have defined being overweight as having a BMI between 25.0 and 29.9 kg/m^2 and obesity as having a BMI of greater than 30 kg/m^2 (WHO 2011, Nguyen & El-Serag 2010).

3.2.1. The pathophysiology of obesity and insulin resistance

Looking at the pathophysiological aspect of the interaction of obesity and DM it has been established that obesity is associated with a state of chronic low-level inflammation (Wellen & Hotamisligil 2005). It has been found that inflammatory cytokines like tumour necrosis factor alpha, interleukin-6 and interleukin1-β are overexpressed in obese mice and humans, released primarily by macrophages. The exact cause of this inflammation is not yet fully understood (Wellen & Hotamisligil 2005). However, it sets forth a cycle of chronic inflammation by activating the production of acute phase proteins, which in turn enhance the inflammation. The inflammatory cytokines and acute phase proteins, collectively known as inflammatory markers, are found in early stages of DM type 2 and their concentrations increase with the progression of the disease (Figure 6) (Garcia-Bailo et al. 2011).

This chronic inflammation causes oxidative stress. The latter is furthermore caused by hyperglycaemia and free fatty acids (hyperlipidaemia), both characteristics of obesity and the MetS. This results in the production of reactive oxygen species and reactive nitrogen species which, among other effects, activate the nuclear factor κB, a proinflammatory transcription factor, activator protein-1, c-Jun N-terminal kinase (JNK) and inhibitor of NFκB kinase-β (IKK). Through complicated processes, these mediators stimulate the secretion of proinflammatory cytokines (Garcia-Bailo et al. 2011).

Figure 6 The role of inflammation and oxidative stress in insulin resistance



The state of obesity results in a chronic low-level inflammation in the body. The latter in turn causes oxidative stress, which is enhanced by hyperglycaemia and hyperlipidaemia. By various biochemical processes outlined in the diagram above, this state results in insulin resistance, a characteristic of type 2 DM.

Source: Garcia-Bailo et al. 2011

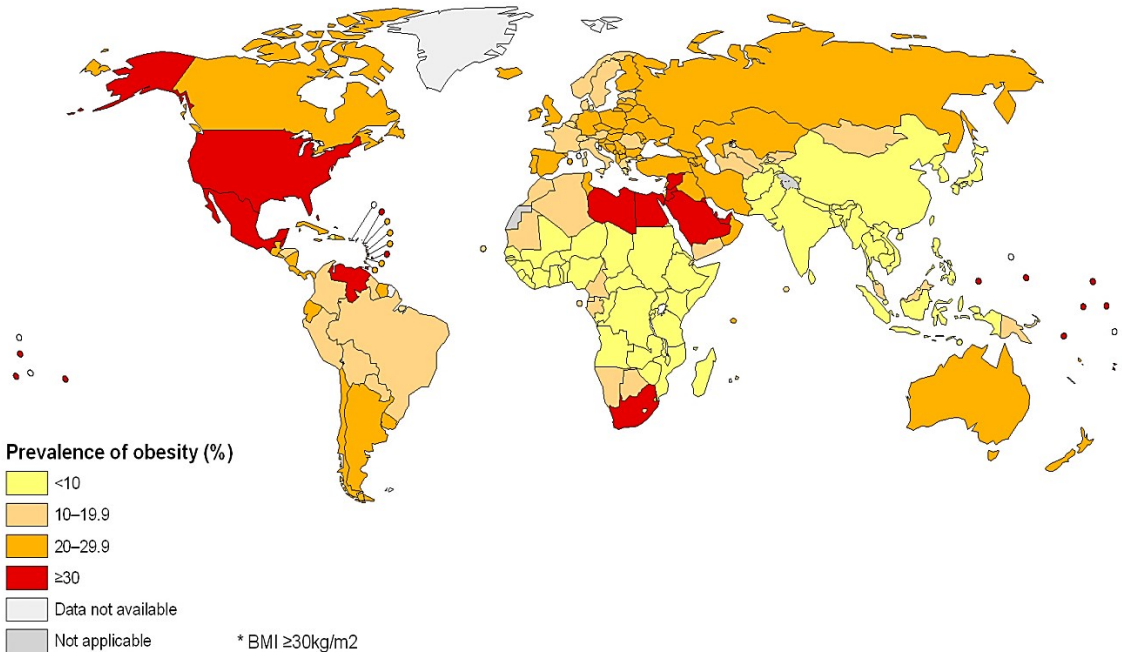
It has been found that high concentrations of these cytokines inhibit the insulin signal pathway by dysregulating the insulin receptor substrate-1 (IRS-1) and, as can be seen in Figure 6, prevent the action of insulin. This model explains how obesity and its characteristics are linked to the MetS and DM (Garcia-Bailo et al. 2011, Wellen & Hotamisligil 2005).

3.2.2. Prevalence of obesity

According to the 2010 analysis of the International Obesity Task Force (IOTF), a policy arm of the International Association for the Study of Obesity (IASO), approximately 1.0 billion adults worldwide are currently overweight and a further 475 million are obese. Furthermore, IASO/IOTF estimates that up to 200 million school-aged children are either overweight/obese and in 2008 the WHO estimated 43 million children under the age of five to be overweight/obese. Looking at the 27 member states of the European Union, approximately 60% of adults and 20% of school-age children

are overweight or obese (IASO/IOTF 2010). Of the populations in the USA, Canada and the United Kingdom 66.3%, 48.3% and 61.0% respectively are overweight and 32.2%, 14.9% and 22.7% respectively are obese (Low et al. 2009). According to the same study of Low et al. (2009), more than 30% of school aged children in the USA, Canada and the UK are either overweight/obese, clearly marking a steep rise in obesity among children.

Figure 7 Worldwide prevalence of obesity in 2008, ages 20+, both sexes



Many researchers regard obesity as the main driving force of the epidemic in NCDs. Figure 7 gives an overview of the prevalence of obesity worldwide.

Source: WHO 2011, Global health observatory map gallery, www.who.org

Obesity is not only increasing dramatically in the developed world, but many countries of the developing world also present horrendous figures (Figure 7). In South Africa, 45.06% of adults were overweight in 1998 and 24% were obese, while in Zimbabwe in 2005, 37.3% were overweight and 15.7% obese. In their study on overweight and obesity in Africa, Ziraba et al. examined the transformation of overweight/obesity in seven different countries across the African continent between 1992 and 2005. The study showed that in total 31.4% of women in these SSA countries were overweight or obese in 2005. However, an increase of 35.5% in

overweight/obesity has taken place during the period between the two surveys, with an increase of 42% in obesity and 14.5% in overweight. In addition, in 2008, the WHO estimated that 35 million overweight/obese children were living in the developing countries and 8 million in developed countries. The onset of obesity in childhood is an even greater risk for a vast number of disease and illnesses, including the development of DM (Fall 2001).

Looking at the statistics of obesity in developed countries, no notable difference in the prevalence between men and women is evident. However, the statistics for developing countries indicate that obesity is far more prevalent in the female than the male population (Low et al. 2009). Literature suggests that cultural factors and health beliefs might be the reason: in regions where malnutrition and malnourishment are still widespread, food remains a daily challenge for many people. Therefore, being obese is often seen as a symbol of status, wealth, health and beauty (Gill et al. 2009, Fall 2001). It reflects the man's ability to provide for his family and the woman's skill as a mother and cook (Fall 2001).

3.2.3. The thrifty phenotype and thrifty genotype theory

It becomes obvious that the developing world is struggling with two extremes: overweight and obesity while malnutrition and malnourishment are still widespread (BeLue et al. 2009). The finding that men and women who were small at birth with a low birth weight had an increased risk of developing obesity, DM, hypertension and CVD, led to the establishment of the 'thrifty phenotype' hypothesis (Fall 2001). The thrifty phenotype hypothesis proposes that foetal nutritional deprivation can have long-term consequences on health. Low birth weight is now considered a risk factor for later development of coronary heart disease, stroke, DM and MetS (Prentice & Moore 2005, Fall 2001). Considerable evidence has shown that such effects are most exaggerated when faced with over-nutrition in later life, presenting a disparity between experiences in utero and subsequent environmental conditions (Wells 2007). The theory suggests that intra-uterine growth retardation and nutritional deprivation, still common in non-industrialised countries largely due to maternal stunting and malnutrition, creates a phenotype characterised by insulin resistance which is advantageous in times of starvation. The developing organism interprets information given by the maternal

nutritional state as a forecast concerning the future environmental conditions. This might prove to be lifesaving in times of poverty, but predisposes to a detrimental phenotype in times of affluence (Wells 2007, Prentice & Moore 2005, Fall 2001). As outlined above, many developing countries are undergoing economical and nutritional transitions mimicking times of affluence. This greatly increases the risk of their citizens becoming subjects of the 'thrifty phenotype' hypothesis, and in turn the latter can be faced with an increased risk of obesity and NCD in later life.

Two decades ago literature had already raised the possibility that a genetic predisposition of the African population could be responsible for such a drastic increase in the prevalence of DM (Cruickshank et al. 2001, Mbanya et al. 1997). Research of the late 80s and early 90s has shown that prevalence of DM is higher among Afro-Americans, Afro-Caribbeans and African migrants compared to their Caucasian counterparts (Mbanya et al. 1997). Already in 1962, James Neel formulated the hypothesis of a 'thrifty genotype', suggesting that human evolutionary history has developed a genotype compatible to the diet of hunter gatherers: cycles of feast and famine. During periods of abundance, having a pancreatic response which minimises post-prandial glycosuria leads to highly efficient fat storage, which would then in turn be advantageous during periods of famine (Neel 1962). Zimmet et al. (2001) then further concluded that thrifty genes 'promote fat storage, perhaps mediated by leptin resistance, providing a survival advantage during periods of starvation' (Fall 2001). However, in the current era of food abundance - especially unhealthy food - and sedentary lifestyles, this thrifty genotype leads to metabolically disadvantageous phenotypes such as obesity and DM (Southam et al. 2009). In their study, Southam et al. (2009) analysed and examined various genomic loci, alleles and sequences associated with obesity and DM, seeking to validate or reject the thrifty genotype hypothesis. No consistent footprint of selection could be identified on the loci. However, some loci appear to have 'more thrifty gene characteristics than others' (Southam et al. 2009). Southam et al. (2009) suggest that more research should be undertaken, especially associated studies in populations of non-European descent, in order to answer the above question.

3.3. The role of gestational diabetes

The importance of gestational diabetes (GDM) on the diabetic epidemic is not yet known. The obvious consequence of the increased prevalence of DM and obesity, also among women in childbearing age, is an increase in the number of pregnant women with DM (Kaaja & Rönnemaa 2009). The question remains whether the glucose intolerance antedated the pregnancy or started concomitantly with the pregnancy (ADA 2011). It is assumed that 5-10% of GDM is due to previously undetected DM leaving the vast majority of GDM to be caused by the metabolic stresses of pregnancy combined with an impaired insulin secretory response (Kim 2010). Approximately 10% of women with GDM are diagnosed with type 2 DM soon after delivery. This number increases to 40% in the ten years following the pregnancy. The risk is highest during the first five years after delivery reaching a plateau after ten years postpartum (Kaaja & Rönnemaa 2009). The fact that offspring of mothers with GDM are more susceptible to DM has been proven in many studies. According to Kim (2010), intrauterine diabetic exposure can lead to permanent changes in foetal metabolism, causing excess foetal growth, decreased insulin sensitivity and impaired insulin secretion. In the longer term this change in foetal metabolism may be associated with obesity, IGT or DM in early youth and adolescence (Kim 2010, Fall 2001).

3.4. The role of cortisol

3.4.1. Synthesis, function and metabolism of cortisol

The role of cortisol in diabetes and the MetS has been debated for some time. Cortisol is the most important glucocorticoid hormone of the body and as part of the adrenocorticotropic system it plays a vital role in the stress response of the body (Kann 2009). It is synthesised in the zona fasciculata of the adrenal cortex stimulated by the adrenocorticotropic hormone (ACTH). The latter is secreted pulsatile and according to a circadian rhythm by the pituitary gland as a result of the secretion of corticotropin-releasing hormone (CRH) from the hypothalamus. The effect of the CRH on the pituitary gland is in turn inhibited by an increasing concentration of cortisol in the blood by a negative feedback mechanism (Kann 2009). This whole cycle is called the hypothalamic-pituitary-adrenal (HPA)-axis (Figure 8).

Figure 8 The hypothalamic-pituitary-adrenal (HPA)-axis

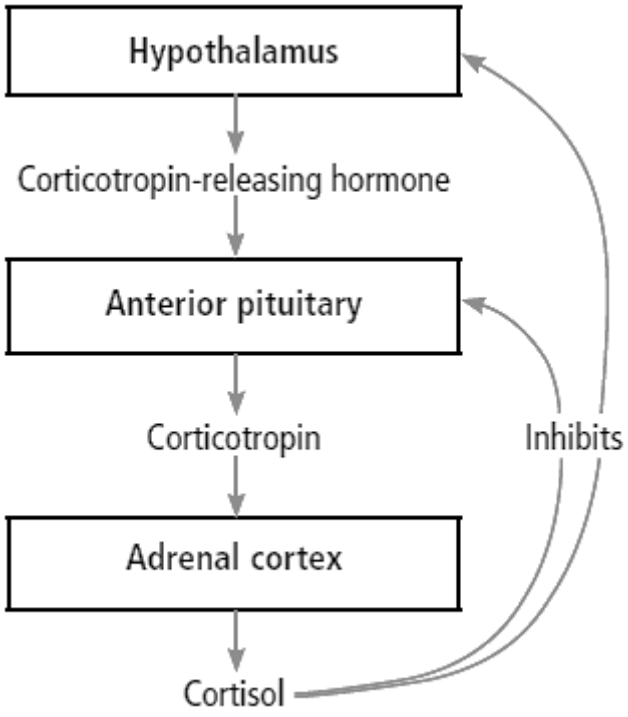


Figure 8 shows the feedback system of the glucocorticoid hormone cortisol.
Source: Albashir et al. 2011

The effects of cortisol on the body are antagonistic to those of insulin and therefore the glucose concentration in the blood is increased. The gluconeogenesis in the liver is enhanced while the effect on the protein metabolism is katabolic, leading to a breakdown of muscle mass. The fat metabolism of the body is affected variedly: a reduction of the peripheral adipose tissue but an increase in the abdominal and interscapular fat tissue (Kann 2009). Cortisol furthermore has an anti-inflammatory action, most probably by influencing microvascularisation and suppressing inflammatory cytokines. By enhancing the effects of catecholamines it results in a positive inotropic response of the heart and a vasoconstriction of the peripheral blood vessels. Lastly, cortisol is involved in the regulation of blood pressure (BP) and electrolyte and water balance (Kann 2009). Chronically high concentrations of cortisol can lead to central adiposity, hepatic steatosis, dyslipidaemia, muscle wasting, pancreatic β-cell dysfunction and glucose intolerance (Praveen et al. 2011).

When looking at the effects of cortisol on the body it becomes obvious that a state of increased cortisol concentration, regardless of the cause, carries risk factors for the

development of the MetS and diabetes. Clinical characteristics often present in the MetS and diabetes (abdominal obesity, hyperglycaemia, high triglyceride and low HDL-Chol levels, hypertension) are also shared by patients presenting with Cushing's syndrome (CS), a syndrome resulting from chronically high cortisol concentrations. This led to the hypothesis that excessive glucocorticoid exposure could cause the MetS and also DM (Anagnostis et al. 2009). Taniguchi et al. (2008) published a study undertaken in Japan in 2008 where 77 diabetic patients were tested for hypercortisolism. 2.6% presented with subclinical hypercortisolism (impaired ACTH/cortisol homeostasis without signs and symptoms of CS). This corresponds to similar studies done in Western countries, where the prevalence ranged between 2% (Catargi et al. 2003) and 9.4% (Chiodini et al. 2005), depending on diagnostic criteria used for diagnosis of hypercortisolism (Mullan et al. 2010, Taniguchi et al. 2008). Mullan et al. (2010), on the other hand, found no patient with hypercortisolism in their study of 207 diabetics and 79 controls. Similar results have been published by other researchers as well (Mullan et al. 2010). The inconsistencies of the data reflect the on-going debate in the scientific and clinical world whether abnormalities of the cortisol metabolism could be a possible cause of the MetS and/or DM (Praveen et al. 2011).

3.4.2. Interaction of cortisol and diabetes

The best established causes of hypercortisolism are tumours in the region of the adrenal cortex, the pituitary gland, the hypothalamus or a paraneoplastic syndrome. These conditions present with a focal point of increased or decreased activity of the HPA-axis at different levels of the cascade. This abnormality can result in an increased concentration of cortisol leading to the clinical presentation of hypercortisolism or CS (Albashir et al. 2011). Long-term glucocorticoid therapy for whatever condition requires it, is another well established and the most common cause of hypercortisolism often resulting in CS or iatrogenic DM (Albashir et al. 2011, Kann 2009). This is also seen in patients who did not exhibit any kind of impaired glucose metabolism before steroid treatment (Kim et al. 2011). Kim et al. (2011) did a study on the incidence of steroid-induced diabetes in patients receiving long-term steroid treatment for respiratory conditions. Only patients with pre-treatment normal glycaemic concentrations were included. Out of 231 patients, 34 (14.7%) presented with steroid-induced DM (Kim et al. 2011). A similar study of patients suffering from renal disease showed 40.5% of

patients suffering from steroid-induced diabetes (Uzu et al. 2007). Many such studies have been done and Kim et al. (2011) report that the prevalence rate of steroid-induced DM lies between 0.4% and 54%.

The actions of the enzyme 11-β-hydroxysteroid dehydrogenase type 1 (11βHSD1) as part of the cortisol metabolism are another widely discussed aspect of cortisol-associated DM. This enzyme that is expressed only in specific tissue such as liver, adipose, vasculature, brain and macrophagic tissue, converts inactive cortisone to active cortisol, thus amplifying the glucocorticoid action on the cells (Rosenstock et al. 2010, Anagnostis et al. 2009, Kann 2009). As was previously established, Kann (2009) points out that 11βHSD1 levels correlate positively to the BMI, body fat index, central obesity, fasting glucose, insulin concentrations and insulin resistance. The first studies undertaken to test whether 11βHSD1-inhibitors would improve glycaemic control in patients with DM showed promising results (Rosenstock et al. 2010).

The correlation between obesity and increased cortisol levels has been discussed above.

Another relevant aspect, especially when looking at DM in Namibia, is the increased cortisol concentration due to stress of various kinds. While the sympathoadrenergic stress response is a reaction to a positive or negative mental effort or exertion, the response of the adrenocorticotropic system is to a negatively perceived emotion to a specific situation (Kann 2009). Stressful situations such as low socioeconomic status, chronic work stress, anxiety and depression may lead to a hyperactivity of the HPA-axis and in turn to excessive cortisol concentrations, resulting in intra-abdominal obesity and insulin resistance predisposing to MetS and DM (Anagnostis et al. 2009, Kann 2009). In a multifactorial analysis done, 5-37% of differences between individuals with and without the MetS could be explained by psychosocial factors (Anagnostis et al. 2009). Besides the high prevalence of low socioeconomic standards in Namibia, one must also look at the effects of negative stress perceived through racism, acculturation and urbanisation.

In their study on the effects of internalised racism in African-Caribbean women, Tull et al. (2005) found that high scores of perceived stress, a defeated coping style (such as “restraint”, “denial” and “behavioural disengagement”) mechanism and high cortisol

concentrations correlated positively in women with distinct internalised racism[3] compared to women with low internalised racism (Tull et al. 2005). The consequence is that a higher risk for metabolic imbalances is being postulated (Kann 2009). Another study done by Tull et al. (2003) examined the relationship between acculturation and psychosocial stress and insulin resistance in two groups of the black population residing on the Virgin Islands (Tull et al. 2003). Afro-Americans who immigrated to the Islands showed a strong relationship between increased abdominal obesity and insulin resistance and psychosocial stress due to despair and the feeling of disconnection. Afro-Americans born on the islands on the other hand showed a strong relationship between the risk factors for the MetS and the process of acculturation. Once analysed accordingly, these findings demonstrated that immigration and acculturation are both processes associated with increased psychosocial stress, which in turn is positively related to increased abdominal obesity and insulin resistance (Tull et al. 2003). In his work on stress hormones and culture, Kann (2009) illustrates that urbanisation, currently widespread in Namibia and other SSA countries, associated with acculturation is often also perceived as a negative psychosocial stressor, especially when experienced with little familial support (Kann 2009). Consequently, as the processes of urbanisation, immigration and racism are common in Namibia, these factors should not be ignored as possible causes of hypercortisolism and thus risk factors for the development of the MetS and DM.

However, research has also shown that chronic stress can sometimes result in a hypoactivity of the HPA-axis (Kann 2009). This issue is picked up again in the discussion of our study.

3.5. The role of the metabolic syndrome

3.5.1. Definition of the metabolic syndrome

Various definitions for the MetS exist, but all agree on the core components of the MetS: a cluster of metabolic abnormalities consisting of dysglycaemia, hypertension, abdominal obesity, reduced HDL-Chol and elevated triglycerides (Anagnostis et al. 2009, IDF 2006). This group of abnormalities is associated with a significantly

[3] Internalised racism: the 'extent to which blacks agree with racist stereotypes about blacks' (Tull et al. 2005).

increased risk for CVD and DM in addition to the risks associated with each abnormality alone. It can be roughly said that the risk for CVD is increased two-fold and the risk for the development of DM is increased five-fold (IDF 2006). Wannamethee et al. (2005) also showed that there is a significant increase in risk with an increasing number of the MetS components present. The MetS can therefore be used to identify patients in need of lifestyle or pharmacological interventions in order to reduce the risk factors and subsequent cardiovascular and diabetic incidents (IDF 2006, Wannamethee et al. 2005).

There is much controversy about the various criteria of the MetS and its ability to predict the risk for CVD and DM (Cornier et al. 2008). The WHO was the first to release a definition placing great emphasis on the importance of insulin resistance in the MetS, making high insulin levels, IFG or IGT a compulsory component. As more research became available, data indicated the role of abdominal obesity in the development of the MetS, leading to the release of the National Cholesterol Education Program's Adult Treatment Panel III (NCEP/ATP III) definition of the MetS. The latter places more weight on abdominal obesity than on insulin resistance, while giving the same importance to all five components. Lastly, the definition of the IDF places the most weight on abdominal obesity by making it a compulsory component in the diagnosis of the MetS. The IDF also recommends different ethnic-specific cut-off points for increased waist circumference (WC), taking into consideration the ethnical disparities of one of the components of the MetS (Cornier et al. 2008). Figure 9 shows the various definitions.

Figure 9 Various definitions of the metabolic syndrome

Clinical Measure	WHO (1998)	NCEP (2001)	IDF (2005)
Insulin resistance	IGT, IFG, T2DM or ↓ insulin sensitivity* plus any two of the following	None but any three of the following five features	None
Body weight	Males: waist to hip ratio >0.90; females: waist to hip ratio >0.85 and/or BMI >30 kg/m^2	WC ≥102 cm in men or ≥88 cm in women†	Increased WC (population specific) plus any two of the following
Lipid	TG ≥150 mg/dL and/or HDL-C <35 mg/dL in men or <39 mg/dL in women	TG ≥150 mg/dL	TG ≥150 mg/dL or on TG Rx
		HDL-C <40 mg/dL in men or <50 mg/dL in women	HDL-C <40 mg/dL in men or <50 mg/dL in women or on HDL-C Rx
Blood pressure	≥140/90 mm Hg	≥130/85 mm Hg	≥130 mm Hg systolic or ≥85 mm Hg diastolic or on hypertension Rx
Glucose	IGT, IFG, or T2DM	≥110 mg/dL (includes diabetes)‡	≥100 mg/dL (includes diabetes)
Other	Microalbuminuria		

WHO indicates World Heath Organization; NCEP, National Cholesterol Education Program Adult Treatment Panel III; IDF, International Diabetes Federation; IGT, impaired glucose intolerance; IFG, impaired fasting glucose; T2DM, type 2 diabetes; WC, waist circumference; BMI, body mass index; TG, triglycerides; HDL-C, HDL cholesterol.

*Insulin sensitivity measured under hyperinsulinemic euglycemic conditions, glucose uptake below lowest quartile for background population under investigation.

†In Asian populations, the WC threshold for abdominal obesity is ≥90 cm in men or ≥80 cm in women.

‡The 2001 definition identified fasting plasma glucose of ≥110 mg/dL (6.1 mmol/L) as elevated. This was modified in 2004 to be ≥100 mg/dL (5.6 mmol/L), in accordance with the American Diabetes Associations updated definition of impaired fasting glucose (IFG).

No uniform definition for the MetS exists. A such, various organisations have come up with definitions placing emphasis on different aspects of the syndrome. Figure 9 gives an overview of the definition of three important organisations.

Source: Grundy 2008

For the purpose of our study, the definition of the Joint Interim Statement (JIS) will be used as it is an attempt by several major organisations to harmonise the MetS (Alberti et al. 2009). It was agreed upon that IDF prerequisite of abdominal obesity be dropped, but the ethnic-specific cut-off points for WC be kept. In their article on cut-off points for WC best predicting the MetS in urban Africans, Prinsloo et al. (2011) suggested an ethnic specific cut-off of 90 cm for males and 98 cm for women, as opposed to the current 94 cm and 80 cm respectively. These recommendations will be applied to our study cohort. Thus, the definition of the MetS will be made if any three of the five components are present in an individual, giving equal weight to all components (Alberti et al. 2009).

Figure 10 Joint Interim Statement for the clinical diagnosis of the MetS

Measure	Categorical Cut Points
Elevated waist circumference*	Population- and country-specific definitions
Elevated triglycerides (drug treatment for elevated triglycerides is an alternate indicator†)	≥150 mg/dL (1.7 mmol/L)
Reduced HDL-C (drug treatment for reduced HDL-C is an alternate indicator†)	<40 mg/dL (1.0 mmol/L) in males; <50 mg/dL (1.3 mmol/L) in females
Elevated blood pressure (antihypertensive drug treatment in a patient with a history of hypertension is an alternate indicator)	Systolic ≥130 and/or diastolic ≥85 mm Hg
Elevated fasting glucose‡ (drug treatment of elevated glucose is an alternate indicator)	≥100 mg/dL

HDL-C indicates high-density lipoprotein cholesterol.

*It is recommended that the IDF cut points be used for non-Europeans and either the IDF or AHA/NHLBI cut points used for people of European origin until more data are available.

†The most commonly used drugs for elevated triglycerides and reduced HDL-C are fibrates and nicotinic acid. A patient taking 1 of these drugs can be presumed to have high triglycerides and low HDL-C. High-dose ω-3 fatty acids presumes high triglycerides.

‡Most patients with type 2 diabetes mellitus will have the metabolic syndrome by the proposed criteria.

In 2009 several major organisations made an attempt to harmonise the definition of the MetS. The Joint Interim Statement was developed. This definition will be used for the study. The latter has been extended for the purpose of the study to include the ethnic-specific cut-offs suggested by Prinsloo et al. 2011.

Source: Alberti et al. 2009

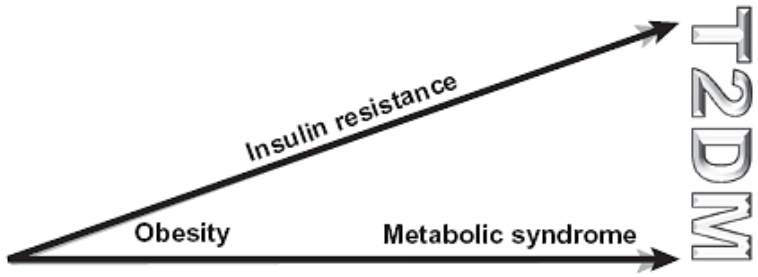
3.5.2. Causes of the metabolic syndrome

3.5.2.1. Obesity

Although the MetS is driving the global epidemic of CVD and diabetes ferociously, it is still remains a 'syndrome' as no single pathogenesis has been elucidated yet (Grundy et al. 2005). It appears to be clear though that both central obesity and insulin resistance are significant factors (Figure 11) (IDF 2006, Alberti et al. 2006). Obesity on its own is a great risk factor for CVD. Since it also causes hypertension, insulin

resistance and a pathological fat metabolism, fat accumulation is one of the main driving forces of the MetS epidemic. However, the excess of body fat in the abdomen, measured by the WC is more indicative of the MetS than peripheral fat accumulation, measured by the BMI (Alberti et al. 2006, IDF 2006). In their article on metabolically healthy and unhealthy obese individuals, Pajunen et al. (2011) point out that it is vital to not only estimate the degree of obesity, but also examine for the presence of metabolic abnormalities. The researchers have suggested this as their study results in a Finnish population showed that 9.2% of obese men and 16.4% of obese women were metabolically healthy. On the other hand, they observed that 20.4% of normal weight men and 23.8% of normal weight women presented with the MetS (Pajunen et al. 2011).

Figure 11 Interaction of obesity, insulin resistance, the MetS and type 2 diabetes



There is strong interaction between obesity, insulin resistance, the MetS and DM as they share common characteristics, risk factors and enhance each other, as can be seen in the above figure.

Source: Garcia-Bailo et al. 2011

Looking at the US (United States) population, Ervin (2009) found that obese males were 32 times and obese females 17 times more likely to meet the criteria for the MetS than their non-obese peers (Ervin 2009). For obvious reasons, individuals with the MetS had a more adverse metabolic profile and a greater risk for CVD and DM as individuals without the MetS (Pajunen et al. 2011). Various studies have shown that an increase in BMI generally is strongly associated with an increased risk for the development of the MetS irrelevant of the age group or gender (Pajunen et al. 2011, Ford 2005). It must also be noted that there is a rapidly increasing number of children also suffering from the MetS, mainly due to the obesity epidemic hitting ever younger age groups (Misra & Khurana 2008). For information on the worldwide and southern African prevalence of obesity and its consequences see ‘Epidemiology of diabetes’ (pg 18).

3.5.2.2. Insulin resistance

As mentioned above, insulin resistance, or its precursor IGT, is another major factor in the development of the MetS and with that there is a high risk for the development of DM (Alberti et al. 2006). According to Alberti et al. (2006) numerous studies have shown that insulin resistance is present in the majority of people with the MetS and the degree of insulin resistance correlates with the number of metabolic abnormalities. This is reinforced by a study done in the US population using the National Cholesterol Education Program – Third Adult Treatment Panel (NCEP/ATP III) showing that hypertension, obesity and hyperglycaemia were the most prevalent factors of the MetS (Ervin 2009). The WHO and the European Group for the Study of Insulin Resistance (EGIR) included insulin resistance or IGT as a compulsory component in the diagnosis of the MetS. In their study in the Finnish population, Pajunen et al. (2011) established that a total of 37% of obese individuals with MetS also presented with DM and only 4.3% of obese individuals without the MetS suffered from DM. There was also a significant trend towards a higher fasting glucose (FG) and 2-h Glc concentration in participants with the MetS compared to healthy individuals (Pajunen et al. 2011).

Other factors that have been associated with the development of the MetS are physical inactivity, as it causes obesity and modifies insulin sensitivity. Furthermore, ageing, genetics, hormonal changes and a proinflammatory state, enhance the development of the MetS (IDF 2006). According to the IDF the role of these factors may vary depending on the ethnic group.

3.5.3. Prevalence of the metabolic syndrome

When looking at the prevalence of the MetS, one has to take the various definitions into account: using the IDF definition will give a slightly higher percentage of individuals suffering from the MetS, because the criteria for central obesity are very tightly made, putting emphasis on its importance (Ford 2005). Using the NCEP/ATP III or EGIR definition will give only slightly lower prevalence data. Whatever definition is used, the core components are the same and the data show an increasing epidemic. Evaluation of the prevalence of the MetS has also shown that it is important to look at the race/ethnicity, as great differences have presented in the past. A research population in China and Iran for example showed a higher prevalence when the NCEP/ATP III

criteria were applied compared to when the IDF criteria were applied, even though the latter has resulted in higher prevalence in most other studies (Cornier et al. 2008).

The IDF estimates that around 20-25% of the world's adult population suffers from the MetS (Anagnostis et al. 2009, IDF 2006). According to Grundy, the data from Europe shows a similar prevalence to the world prevalence. Looking specifically at Germany, a study done in 2008 by Moebus et al. (2008) showed that Germany has a crude prevalence of 19.8%. Data from the National Health and Nutrition Examination Survey (NHANES) evaluated using the NCEP/ATP III criteria showed that 34% of the US population above the age of 20 presented with the criteria for the MetS. Using the IDF definition on the other hand, Ford (2005) found that in 2005 almost 40% of US adults met the criteria for the MetS. The prevalence increased with each age group in the NHANES study: 20% of males and 16% of females under 40 years of age, while 52% of males and 54% of females over the age of 60 presented with the MetS (Ervin 2009). Various other studies have confirmed the positive correlation between an increase in prevalence of the MetS and an increase in age (Cornier et al. 2008, Motala et al. 2011, Grundy 2008). No significant differences were found in the prevalence of the syndrome between men and women. This seems to be a more or less universal phenomenon (Grundy 2008). Where there is a significant gender difference in the prevalence, this is predominantly based on varying socioeconomic status, work-related activities and cultural views on body fat rather than on a pathophysiological basis, according to Cornier et al. (2008).

There were, however, differences when comparing the prevalence between various ethnicities in the NHANES study: 25.3% of non-Hispanic black men presented with the MetS, while 37.2% of non-Hispanic white men met the criteria. For women, the percentages were 38.8% for non-Hispanic black women and 31.5% for non-Hispanic white women (Ervin 2009, Gaillard et al. 2009). Inconsistencies and disparities between different ethnicities have also been established by other researchers (see 'The metabolic syndrome in Africa', pg 42).

3.5.4. Management of the metabolic syndrome

Once the diagnosis of the MetS has been made, the management should be fast and aggressive to reduce the risk of CVD and DM. Because the underlying mechanisms of

the MetS are not yet fully understood, there is unfortunately no pharmacological agent as yet that would modulate all the components simultaneously. Therefore, it is necessary to treat each risk factor individually (IDF 2006, Grundy et al. 2005). Effective lifestyle changes to mitigate the modifiable risk factors such as obesity, physical inactivity, smoking and an atherogenic diet are vital in the management of the MetS. According to Grundy et al. (2005), these lifestyle changes should include moderate caloric restriction so that a 5-10% loss of weight is achieved in the first year of diagnosis. In addition there should be an increase in physical activity, cessation of smoking and a change in dietary composition to reduce saturated fat and overall intake, and increased fibre intake. The target of these lifestyle interventions should be a normal BMI and/or a normal WC (Alberti et al. 2006, IDF 2006, Grundy et al. 2005). If the absolute risk for the development of CVD and DM is very high, pharmacological treatment in addition to the above mentioned lifestyle changes should be considered. The main aim of the drug therapy would be, if present, to lower the BP, normalise the glucose concentration and reduce the LDL-cholesterol (LDL-Chol) concentration (Cornier et al. 2008, Grundy et al. 2005).

3.5.5. The metabolic syndrome in Africa

Very little research is available on the MetS in the SSA region. However, as Motala et al. (2009) have pointed out in their article on the MetS in SSA, this region is at the centre of the most rapid demographic and epidemiological transitions bringing with them the problems of urbanisation and westernisation: non-communicable diseases (Hoebel et al. 2010, Motala et al. 2009, Misra & Khurana 2008). A matter of concern is that the effects of these transitions on the prevalence of the MetS are not yet known. The rapidly increasing prevalence of obesity and DM in the region though, leads one to expect a similar increase in the prevalence of the MetS (Gaillard et al. 2009, Motala et al. 2009).

Using the definition suggested by the 2009 Joint Interim Statement (JIS), Motala et al. (2011) examined 957 South Africans of Zulu origin for the MetS and for an optimal cut-off point for WC in African individuals. The crude prevalence in this population was 26.5%, with 30.2% prevalence in women and 11.6% in men (Motala et al. 2011). The peak prevalence for men was 25.0% in the 45 to 54-year old age group, while the

peak prevalence for women lay at 44.2% in the above 65-year age group (Motala et al. 2011). The most frequent components of the MetS in people suffering from the syndrome were high WC and a low HDL-Chol in men and women, with the least common being elevated fasting glucose (FG) and elevated total triglycerides. This corresponds with other research published on the MetS in other parts of SSA (Hoebel et al. 2010, Motala et al. 2009). Looking at the cut-off points for WC, Motala et al. (2011) have suggested that the cut-off point for women be raised from 80 cm to 92 cm, but that for men be lowered from 94 cm to 86.3 cm.

The prevalence of the MetS in South Africa (SA) is much higher when compared to data available from countries of western Africa (using the IDF and ATP III definitions): SA (crude 23.3%), Benin rural (4.1%) and urban (11.0%), Cameroon urban (1.3%) and rural (0.1%), Nigeria rural (3.0%) (Motala et al. 2011). When comparing the prevalence of the study done by Motala et al. (2011) to other countries of the world, SA showed a higher prevalence of the MetS than Asian groups and some European communities, but a lower prevalence than ethnic groups in the US. As can be seen above, the research data on the MetS in the SSA region is very limited and efforts should be made by the research community to improve this situation, as constructive ideas for the handling of the epidemic can then be brought forward.

Several researchers have raised the question whether the current criteria for the MetS, mainly derived from studies done in developed countries, can be applied to individuals from developing countries (Hoebel et al. 2010, Gaillard et al. 2009, Motala et al. 2009, Misra & Khurana 2008). Gaillard et al. (2009) argue that there seem to be racial and/or ethnic differences in the relationship between the various components of the MetS, for example: in blacks the relationship between insulin resistance and BP as well as between lipids and lipoproteins remains weak, while in whites this relationship is strong and thus accounts for a higher risk of CVD and/or DM. The authors have called this ‘the blood pressure and insulin paradox’ (Gaillard et al. 2009). Furthermore, there seem to be ethnic differences of the impact of the five components of the MetS on the future risk of CVD and DM. The argument is based on the fact that there is a higher rate of CVD among blacks, despite the lower rates of the MetS. However, due to the limited data available from SSA, it is difficult to make definite recommendations (Gaillard et al. 2009). Similar disparities and inconsistencies can also be seen when

comparing Asian individuals with white American or European individuals or with individuals from other developing countries (Misra & Khurana 2008). The authors therefore call for more research to be undertaken on this topic in developing countries, and the establishment of new criteria for different ethnic groups (Gaillard et al. 2009, Misra & Khurana 2008). For more detail on the specific racial and/or ethnic inconsistencies the reader is referred to the article 'Metabolic Syndrome in the African Diaspora' by Gaillard et al. (2009) and the article 'Obesity and the Metabolic Syndrome in developing countries' by Misra & Khurana 2008.

4. Burden of the diabetes epidemic

Many projections and estimates of the burden of NCD for the years 2010, 2020 and 2030 have been made in the past few decades, but none has foreseen the gigantic dimension of the epidemic of NCDs worldwide. This is not attributable to incorrect research or faulty calculations, but rather due to an unpredictable increase in number of people suffering from CVD, DM, chronic pulmonary diseases and cancer. By 2010 chronic diseases accounted for 60% of all deaths worldwide, and by 2020 it is predicted that NCDs will cause seven out of ten deaths (Narayan et al. 2010, Boutayeb & Boutayeb 2005). Until some time ago, NCDs were seen as diseases of affluence and therefore of the western and industrialised world (Boutayeb & Boutayeb 2005). However, this picture is changing as more and more data from developing countries become available showing that the adverse effects of economic development and globalisation, such as urbanisation, unhealthy diets and tobacco and alcohol misuse, are spreading at enormous speed (Narayan et al. 2010,, King & Rewers 1991). Since the question of this research revolves around DM, the burden of this disease will be looked at. Nevertheless, this does not mean that the burden caused by other NCDs is not similar or even worse, but the analysis of these would be beyond the scope of this work.

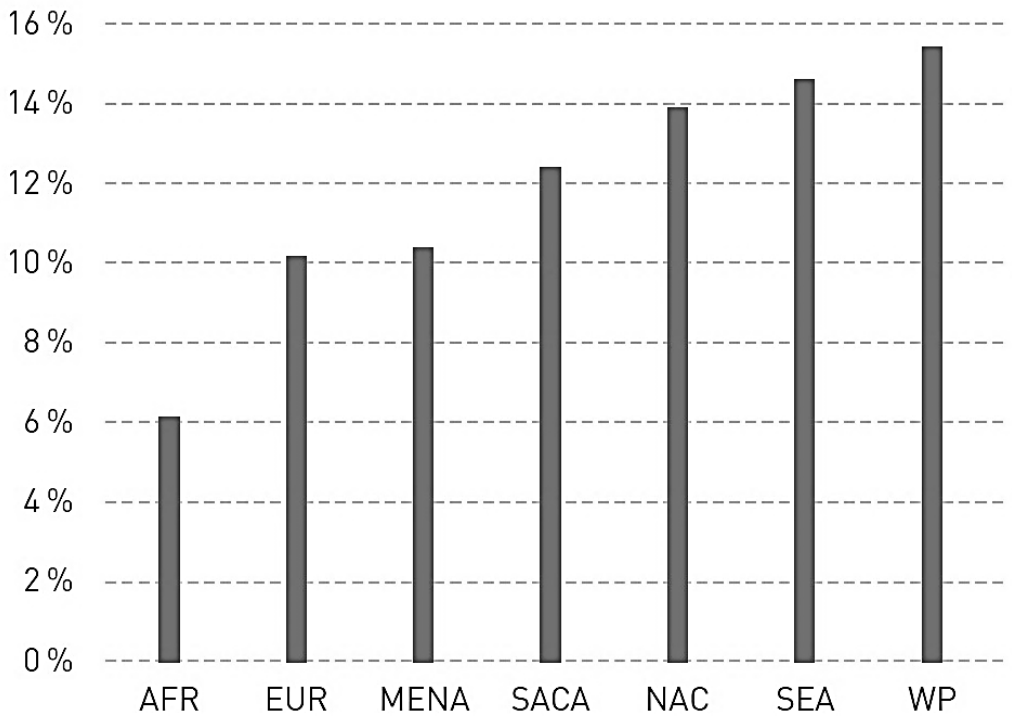
As the prevalence and impact of DM is growing, it is slowly becoming a major public health challenge for the 21st century as a result of its impact on personal and national health and its associated premature morbidity and mortality. Mortality is an important measure of population health. The true mortality rates due to DM, are, however, difficult to assess and often underestimated since the persons with DM frequently die of CVD or renal failure rather than a more diabetes-specific complication. Most routine health statistics are based solely on the cause of death

recorded on the death certificate, and thus the underlying DM is failed to be included in mortality statistics (Roglic & Unwin 2010). In order to eliminate this discrepancy, Roglic & Unwin (2010) used a software program DisMod II, designed for the 'Global Burden of Disease 2000' study, to calculate more accurate numbers of the morbidity and mortality caused by DM. As early as 2000 already, the DisMod II method yielded an estimate three times higher than the estimates in international statistic reports mainly based on death certificates (Roglic et al. 2005). According to Roglic et al. (2005), the number of excess deaths attributable to DM is similar to that reported for the HIV/AIDS epidemic in 2000. In addition, the new global estimates move DM from the eighth to the fifth highest ranking cause of death, after communicable diseases, CVD, cancer and injuries (Roglic et al. 2005).

4.1. The burden of mortality

The IDF estimates that in 2013 close to 5.1 million deaths in the 20-79 year age group were attributable to DM, accounting for 8.2% of global all-cause mortality. This magnitude is similar to the combined estimated deaths of HIV/AIDS, malaria and tuberculosis, all of which are a major public health priority (IDF 2013, IDF 2011). The Western Pacific region overtook North America as the region with the highest proportion of deaths due to DM (Figure 12) (IDF 2011). Meanwhile, Africa (specifically SSA) presents the lowest proportion of excess deaths due to DM with just over 6% of all-cause deaths in the age group 20-79 years.

Figure 12 Deaths attributable to diabetes as a % of all deaths, age group 20-79 years



AFR: Africa (south of the Sahara), EUR: Europe, MENA: Middle East and North Africa, SACA: South and Central America, NAC: North America and the Caribbean, SEA: South East Asia
WP: Western Pacific
As a result of the increasing prevalence of DM worldwide, the percentage of deaths attributable to DM has risen dramatically. This varies greatly by WHO region as can be seen above.
Source: IDF 2011

In 2011, 344 500 people died of diabetes-related causes in Africa in the age group of 20-79 years, in 2013 this number rose to 522 600, 76.4% of deaths occur in the age group < 60 (IDF 2013, IDF 2011). Even this number accounted for 1 in 20 deaths and represented 911.18 deaths per day due to DM in 2010 (IDF 2011, Roglic & Unwin 2010). The number in Namibia amounted to 1 386 deaths in 2013. It is significant to note that the highest number of diabetes-related deaths in Africa is in the 30-39 years age group, which also presents the highest percentage of deaths (IDF). When looking at the number of deaths attributable to DM the highest occurs in countries with large populations: 1 008 000 deaths in India, 575 000 deaths in China, 231 000 in the USA and 182 000 in the Russian Federation (Roglic & Unwin 2010). Furthermore, DM

makes for a higher proportion of deaths in women than in men, greatly contributing to female mortality in many countries. Women with DM have a higher relative risk of death than men with DM in most age groups, reaching up to a quarter of all deaths in middle-aged women in some regions (IDF 2010).

Some countries have documented a decline in morbidity and mortality for a few chronic diseases; however this is not the case for DM (Mathers & Loncar 2006). The number of deaths attributable to DM in 2010 shows an increase of 5.5% over the estimates for the year 2007 and an increase of 13.3% over the estimate for 2010 (IDF 2011, IDF 2010). This increase can be explained by a rise in diabetes prevalence in some highly populated regions particularly among women. The increased prevalence results in increased numbers of deaths due to diabetes: 29% increase in North America and Caribbean, 12% increase in South-East Asia region and an 11% increase in the Western Pacific region (IDF 2010, Roglic & Unwin 2010). In 2006, Mathers & Loncar (2006) estimated the average annual rate of change in global death rate for DM from 2002 to 2020 to be an increase of 1.1% for men and 1.3% for women. The authors furthermore project that DM will change in the ranking of the 15 leading causes of death from place 11 in 2002 to place 7 in 2030, accounting for the most drastic rise in the ranking other than stomach cancer (increase from place 15 to place 10) (Mathers & Loncar 2006).

4.2. The burden of morbidity – DALY, YLL, YLD

With a rising epidemic of DM the prevalence of morbidity and disability due to the complications of DM will also be increasing drastically. Disability-adjusted life years (DALY) is a measurement combining years of life lost (YLL) due to premature mortality and years lived with disability (YLD) (WHO). This measurement 'represents the loss of the equivalent of one year of full health' (WHO 2008). According to the WHO's report on global burden of disease 2004, NCD make up almost 50% of disease burden in low- and middle-income countries. DM specifically made up 2.8% of all DALY in the developing world in 2001 and 1.3% of all total DALY (including communicable, non-communicable diseases and all types of disabilities) in 2004. The latter is predicted to increase to 2.3% by 2030 (De Oliveira et al. 2009, WHO 2008). The WHO furthermore predicts that diabetes will move up from place 19 to place 10 of the leading causes of burden of disease due to DALY by 2030 (WHO 2008). De

Oliveira et al. (2009) also elucidate that the DALY due to diabetes vary greatly among the countries of the world, depending on many factors such as the prevalence and severity of complications, effectiveness of the health-care system and education of individuals. However, at this point we intend to present only a very broad picture of the morbidity of DM.

4.3. The economic burden

The diabetes epidemic not only has a huge impact on global mortality and morbidity but also on global health expenditure. The WHO defines total health expenditure to 'include all expenditure for medical care regardless of who paid for them' (Zhang et al. 2010). It also includes health expenditure for public health programmes, water supply, hygiene activities and research, but only if these activities primarily and intentionally address a health problem. The definition excludes unpaid care-giving by relatives and possible loss of paid employment. It also excludes other opportunity costs such as loss of education opportunities for children who must stay at home to care for disabled parents (Zhang et al. 2010).

Despite these shortcomings, the calculations of the WHO and IDF show exorbitant amounts of money being paid for diabetes care worldwide. These costs can be divided into direct and indirect costs. Direct costs result from the medical treatment necessary for diabetic patients, while indirect costs consist of opportunity cost of time lost due to morbidity and premature mortality (Kirigia et al. 2009).

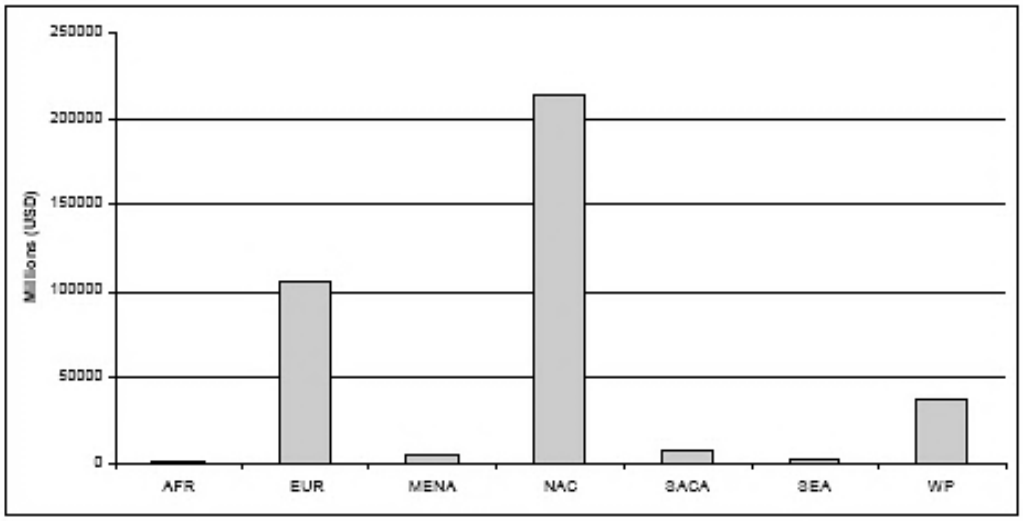
DM requires continuous medical care and patient self-management in order to prevent short-term complications and decrease the risk of long-term complications. In the US people with DM spent on average 2.5 times more money on medical care than people without diabetes, only including the direct costs (Zhang et al. 2010). These would include costs such as outpatient visits and consultations, transport, tests, medications, and the costs of operating hospitals. In addition, costs for the treatment of the many complications resulting from diabetes, such as foot ulcers, blindness and renal failure must be added to these expenses (Kirigia et al. 2009, Boutayeb et al. 2004, Fall 2001). Moreover, DM may add to cost of care by complicating healing of other unrelated conditions such as infections, injuries due to accidents, and surgery (Boutayeb et al. 2004). According to the IDF, health expenditure on DM was expected to account

for 11.0% of the total global health-care expenditure in 2011. The amount was estimated to total at least 465 billion US dollar (USD), which amounts to 499 billion International dollars (ID)[4], the latter corrects for differences in purchasing powers. This calculates to an average of USD 1 274 (ID 1 366) per person spent on diabetes per year (IDF 2011, Zhang et al. 2010). These amounts are expected to exceed 595 billion US dollar and 654 billion ID by 2030. However, in their latest issue of the Diabetes Atlas, the IDF estimates that in 2013 already, the health spending on DM has risen to 548 billion USD.

There are great disparities, however, in the spending on DM across the WHO regions (Figure 13). The North American and Caribbean region spent the most, a total of USD 214.2 billion - 57% of total global health expenditure on DM in 2010. This is followed by the European region spending 28% or USD 38.2 billion on DM. In contrast, the African region spent USD 1.4 billion or 0.4% of the global total, averaging to USD 111 per person per year in 2010 (IDF 2010, Zhang et al. 2010). This means that almost 91% of the global expenditure on DM is in the developed countries and only 9% in the developing countries, where 80% of diabetics will soon be living (Zhang et al. 2010). There is also a large disparity in expenditure among the most populous regions. Again North America has the highest total health expenditure on its diabetics totalling 52.7% of global diabetic expenditure, while India, the country with the second highest number of diabetic patients spends an estimated USD 2.8 billion or less than 1% of the world's total.

[4] International dollar: The International dollar is a USD that has been adjusted to account for differences in purchasing power. It is estimated from surveys of how much the USD can buy of a standard basket of goods and services in different countries.

Figure 13 Health expenditure for diabetes in 2010 (USD) by IDF region



AFR: Africa, EUR: Europe, MENA: Middle East and North Africa, SACA: South and Central America, NAC: North America and the Caribbean, SEA: South East Asia

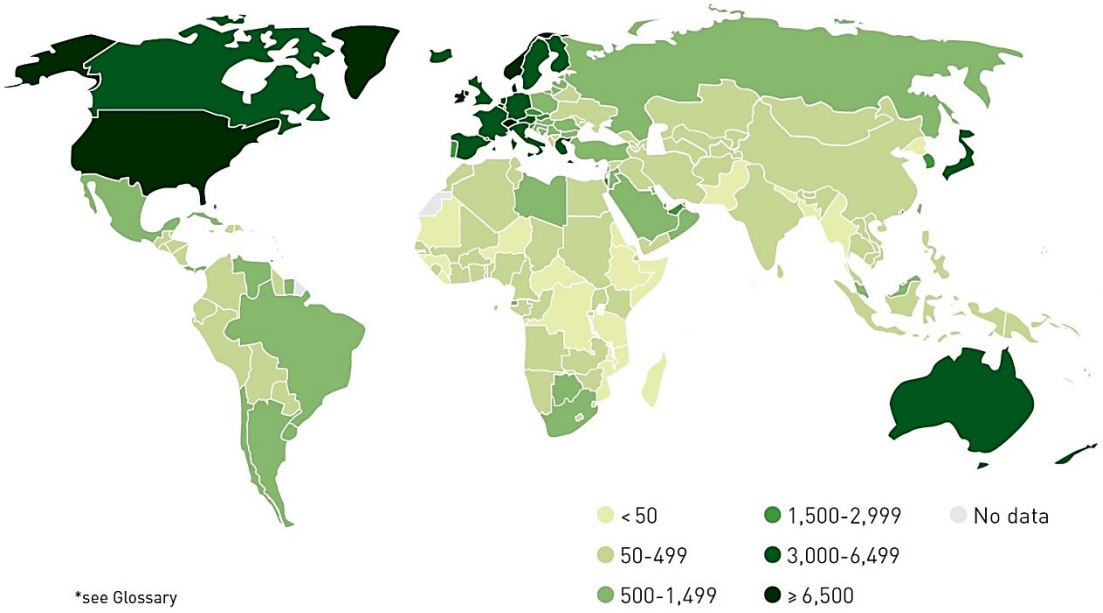
WP: Western Pacific

Figure 13 gives a clear view of the dramatic differences of health expenditure for diabetes in the different WHO regions. It can be seen that the North American and Caribbean and European regions spent by far the highest amount on caring for diabetics (91%), while it is expected that soon 80% of diabetics will live outside these regions.

Source: Zhang et al. 2010

This leaves great differences in the per-person per year spending (Figure 14): the European regions spend an average of USD 2000 per diabetic person, while the lowest spending countries (Burundi, Côte d'Ivoire, Myanmar) spend less than USD 20 per person. This amount would not even cover the annual wholesale cost of a generic oral agent needed to prevent acute life-threatening hyperglycaemia (IDF 2011, Zhang et al. 2010).

Figure 14 Mean diabetes-related health-care expenditure per person with diabetes (20-79 years)



The marked difference of health expenditure for diabetics is also clearly visible when looking at the per person spending. Again, the NAC and European regions exhibit by far the highest per person spending.

Source: IDF 2011: Diabetes Atlas

Namibia lies in the lower half of the per-person spending with an average of USD 284 per year when comparing global averages. However, when comparing per-person spending in SSA, Namibia lies in the top quarter (IDF). Unfortunately, these divergences also bear great discrepancies in the financial burden borne by people with DM and their families. The individual financial burden depends on the economic status of the family and the social insurance policies of their countries. Thus, people in low-income countries pay a larger share of the health expenditure because of poorer organised systems of medical care insurance and/or lack of public medical services (IDF 2010).

4.4. Predictions for future burden

The estimate for the year 2030 made by the IDF shows a huge increase in the global expenditure on DM. The annual global health expenditure on DM in the year 2030 is estimated to fall between USD 490.1 billion and USD 893.0 billion. This would mean an increase by 30-34% globally (Zhang et al. 2010). However, the rate of growth in expenditure will vary greatly across regions; the developed countries will have a growth

rate of 27% while that of developing countries is estimated to average 67%. Thus, the share of global spending of developing countries will rise from 9% in 2010 to 12% in 2030 (Zhang et al. 2010). Furthermore, nine of the top 10 countries with the highest growth rate will be African. The countries with the highest expenditure will remain the same as 2010 though, led by the US.

Since the scope of the diabetic prevalence is becoming more and more obvious, especially western countries and organisations such as the WHO are spending vast sums of money on research of DM. The development of newer and better medicines for the treatment of diabetes is a major focus of research, but also possible preventative and early intervention measures as well as more accurate diagnostic criteria and tools are being studied. A big focus is also the increasing prevalence of DM among children and young adults. In 2001, Zimmet et al. (2001) pointed out that epidemiological data is urgently needed as most reports are based on clinical experience rather than epidemiological studies. In her study on the burden of hospitalisation due to uncontrolled DM in the US, Kim (2007) found that 40% of admissions were children or young adults. The rise in diabetes in children furthermore poses the questions of how to diagnose diabetes in children accurately and how treatment and complications should be tackled at an early age. Most pharmacological agents for the control of diabetes, BP and dyslipidaemia have not yet been tested for their medical benefit and effectiveness on children. Therefore, either studies in this area need to be conducted, or the development of new antidiabetic drugs for children is required (Zimmet et al. 2001).

4.5. The burden of indirect costs

Besides the enormous sums of money being paid for direct costs related to DM, the illness also imposes a large burden of indirect costs on the patients, families and governments. These indirect costs result from loss of productivity and forgone economic growth and include lost earnings due to lost work days, restricted activity days, lower productivity at work, mortality and permanent disability. Furthermore it includes productivity losses by family members accompanying patients to, for example, hospital or consultations, or family members having to stay home to care for disabled patients or children of the household. The latter is especially common in many developing countries (IDF 2010, Kirigia et al. 2009).

According to the World Economic Forum's 2009 Report, DM poses a severe threat to global economic development with the potential to be more detrimental than fiscal crises or natural disasters (Narayan et al. 2010). The best method to calculate the monetary value of this economic burden has yet to be found, but the discussion of different methods would be beyond the scope of this paper. In 2007, the ADA estimated an economical loss of USD 58 billion, equivalent to half of the direct costs due to (IDF 2010). Furthermore, the WHO predicted net losses in national income from diabetes and CVD for China, the Russian Federation, India and Tanzania of ID 557.7 billion, ID 303.2 billion, ID 236.6 billion and ID 2.5 billion respectively (IDF 2010). The IDF further states that the losses sustained by developing countries are expected to be relatively higher because of premature death and morbidity occurring at much younger ages in these regions.

5. Preventative strategies

This economic burden, morbidity and premature mortality could be reduced by the implementation of prevention and intervention strategies, some of which are inexpensive and easy-to-use. However, this would require many governments to change their health-care policies from a curative approach to a more preventative approach (Narayan et al. 2010). The prevention of risk factors should be a main focus of new policies, both in developed and developing countries. Reduced obesity, a healthier diet and increased physical activity would greatly reduce the prevalence of DM. Increasing the physical activity will also improve insulin sensitivity, consequently allowing for a better blood glucose control. Boutayeb et al. (2004) furthermore suggest that early diagnosis of diabetes is paramount to fight the losses, both human and economic, of the epidemic as short-term and long-term complications could be prevented earlier.

The early diagnosis of an IGT or IFG is considered even more important by some researchers since the implementation of appropriate lifestyle changes can, in many patients, prevent the onset of diabetes altogether (Sakane et al. 2011, Ramachandran et al. 2006). Sakane et al. (2011) conducted a study of lifestyle intervention in order to prevent the onset of diabetes in people with IGT and/or IFG and found that even a relatively modest intervention of increased physical activity and healthier diet had beneficial effects on the incidence of DM over a three-year period. This effect was more profound in people with a BMI > 22.5, where 3% of weight reduction led to a 53% drop

in the risk of developing DM (Sakane et al. 2011). In their latest publication on the diagnosis and classification of DM, the American Diabetes Association recommended a 5-10% loss of body-weight, a healthy diet and if necessary pharmacological agents to prevent or delay the development of DM in people with IGT and/or IFG.

Besides the early diagnosis of the disease, the control of the blood glucose concentration is vital in order to reduce the onset of complications, the health-care resources spent and the costs associated with DM (Menzin et al. 2010, Holman et al. 2008, Kim 2007). It has been found that costs associated with patients with good glycaemic control (HbA1c 7% or less) are 16% and 20% less compared to patients with fair (HbA1c 7-9%) and poor control (HbA1c more than 9%), respectively (Oglesby et al. 2006).

A good glycaemic control would also significantly reduce the number of diabetes-related admissions of diabetic patients to hospital and thus also the associated costs. A study done in the US with 200 000 members of the Fallon Clinic Health Plan showed that the rate of diabetes-related hospitalisation for patients with a mean HbA1c of > 10% was twice that of patients with a mean HbA1c < 7% (Menzin et al. 2010). The same study also showed that the cost of inpatient stay for patients with a mean HbA1c < 7% was USD 2792 on average while the costs for patients with a mean HbA1c of > 10% averaged USD 6759. In another study in the US by Shetty et al. (2005), it was demonstrated that diabetes-related costs were 32% higher for patients with a mean HbA1c > 10% than for patients at or below the target level (Menzin et al. 2010). Nevertheless, only 10% of diabetic patients in the US show appropriate glucose and BP control (Narayan et al. 2010).

Besides the tight control of blood glucose levels, it has been found that the control of BP is also vital in the care of diabetic patients since it greatly reduced the risks of diabetes-associated complications (Holman et al. 2008). In developing countries the number of diabetics having uncontrolled blood glucose concentrations and BP is expected to be much higher, but no detailed data on this topic could be found.

Kim (2007) suggests that the improvement of diabetes care on primary health-care level would greatly reduce the rate of complications and the preventable high number of hospital admissions due to DM. This would necessitate the implementation of new

models of care based on community health and patient empowerment by, for example, expanding health-care provided by non-physicians ensuring public health education and awareness (BeLue et al. 2009). This is especially necessary in developing countries where diabetic drugs and medical diabetic care are often scarce. The latter issue will be dealt with in more detail in the section on DM in Africa.

It becomes obvious that governments of developed and developing countries alike are now asked to act, otherwise the rapid escalation of premature morbidity and mortality due to DM will absorb much of the health-care budget. Organisations such as the WHO and IDF are putting great effort into designing and implementing policies to dampen the diabetic epidemic. However, it appears as if well established, developed countries are often more pragmatic in accepting new and experimental policies than developing countries. Thus, the fight against diabetes is an opportunity for global co-operation: a chance for the developed and the developing world to learn from each other and work together (Narayan et al. 2010).

6. Diabetes type 2 – The African picture

Since the topic of this research is DM in Namibia, more specific aspects of the diabetic epidemic in SSA and Namibia will be discussed. Even though Africa is a large and varied continent, its countries often face similar challenges in the delivery of health-care: resources are limited and systems are strained. Common themes of problems and, at times, solutions are found across the continent (Whiting et al. 2003). As research results from Namibia are scarce, such information as is available will be given; the bigger picture will be on the whole SSA though.

It has long been determined that DM is no longer a disease of the western more affluent world, but is also gaining enormous grounds on the African continent and as in other parts of the world DM type 2 accounts for well over 90% of DM in Africa. In their articles on global NCD, Narayan et al. (2010) and Misra & Khurana (2008) discuss the adverse effects of the economic development that has been taken place in Africa over the past decades. Even though this economic transition has brought about many improvements in health, it also brought about more poverty and widening disparities. This is due to the adverse effects of globalisation and urbanisation and the attitude of many African governments to favour economic growth at the expense of health, for

example booming government-owned tobacco industries or industrial growth in the face of environmental pollution (Narayan et al. 2010, Yach et al. 2004).

6.1. The challenge of communicable and non-communicable diseases

One of the biggest challenges, if not the biggest challenge the African countries are faced with is the emerging epidemic of NCD in the face of an existing, raging epidemic of communicable diseases (CD) such as HIV/AIDS, tuberculosis and malaria. The so-called epidemiological transition is 'the process by which the pattern of mortality and disease shift. It is often characterized by a shift in communicable diseases and nutritional deficiencies to chronic diseases' (BeLue et al. 2009). Chronic diseases have not just displaced infectious diseases, but rather added to the burden of disease leaving African countries with a polarised and protracted double burden. The WHO has projected that the combined deaths from infectious diseases, maternal and perinatal conditions, and nutritional deficiencies will decline by 3% over the next 10-year period, while deaths due to chronic illnesses are projected to rise by 17% (Ziraba et al. 2009). In South Africa, 28% years of lives lost (YLL) are due to infectious diseases and 25% due to chronic diseases (Yach et al. 2004). Maher & Sekajugo presented data on the health transition in Uganda: a continuing high burden of communicable diseases with a 5.4% prevalence of HIV in 2007 and a tuberculosis incidence of 330/100 000 is joined by a raising prevalence of DM from 98 000 in the year 2000 to 328 000 in 2030.

6.2. HIV/AIDS, tuberculosis and diabetes

According to the Joint United Nations Program on HIV/AIDS (UNAIDS) Global Report on HIV/AIDS 2011, 22.9 million people were living with AIDS in the SSA region and 1.9 million got newly infected in the same year. This accounts for an adult (15-49 years of age) prevalence of 5% in the region (UNAIDS 2011). In Namibia, the HIV/AIDS epidemic hit 13.1 people per 100 000 inhabitants in 2009, which calculates to 150 000-200 000 infected people. Figure 15 gives an overview of the estimated number of children and adults living with HIV by WHO region in 2011. Looking at the tuberculosis (TB) epidemic 475 out of 100 000 people living in SSA were infected in 2009, with a higher than average prevalence of 588 per 100 000 inhabitants in Namibia. Globally, the prevalence of people infected with TB lies at 201 per 100 000 (WHO 2009).

Figure 15 Estimated number of children and adults living with HIV in 2011, by WHO region

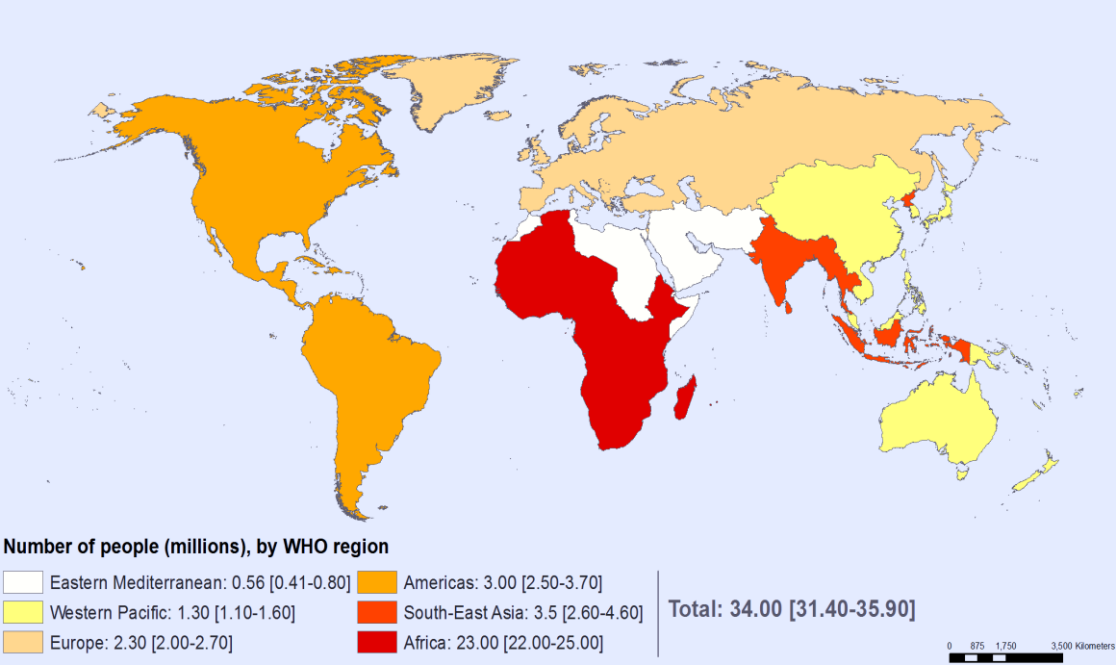


Figure 15 shows the number of children and adults living with HIV/AIDS worldwide. As can be seen, Africa is hit hardest by the epidemic. This poses great strains on the health systems of African countries as they are confronted by an epidemic in communicable and NCD.

Source: WHO 2011: Global health observatory map gallery, www.who.org

6.2.1. TB and diabetes

This combined epidemic of infectious and non-infectious diseases is affecting the health systems of Africa's countries in many ways. The fact that some infective agents may predispose to the development of chronic diseases has long since been determined. Examples of this would be infections triggering cervical, liver and stomach cancers and the possibility of an infection causing diabetes is being discussed (Young et al. 2009). It has been established that HIV/AIDS and TB are interacting with DM should the same person be sick of either two; DM predisposes to tuberculosis infections, since it negatively affects the immunity status of a patient thus making the patient more susceptible to an infection by various infective agents including mycobacterium tuberculosis.

A study done in Mexico has shown that 25% of pulmonary TB was attributable to DM, while in India the corresponding percentage was 14.8% (Stevenson et al. 2007). Though the overall importance of DM as a risk factor for TB is not yet fully known, it is

hypothesised that the impact of the diabetes epidemic on tuberculosis could be as great as the impact of the HIV/AIDS epidemic on the burden of TB (Stevenson et al. 2007). Moreover, according to Young et al. (2009) there is evidence that TB also predisposes to the development of diabetes. A study done by Karachunskii et al. (1993) showed that people with TB could develop changes in carbohydrate metabolism, for example insulin deficiency and hyperglycaemia (Young et al. 2009). Furthermore, research has shown that TB is associated with an increased prevalence of IGT and therefore predisposing to the development of manifested DM. This was already stated by Stevenson et al. (2007) saying that DM is present in 18.4% of adults with TB in an Indian population with an average diabetes prevalence of 4.3%. Looking at this data it becomes obvious that the diabetes epidemic can be a great threat to the global TB control strategies should the issue not get more attention.

6.2.2. HIV/AIDS and diabetes

Next to the rather strong interaction between TB and DM, a significant interaction between HIV/AIDS and its treatment, and DM could be established. It is known that people suffering from HIV/AIDS have an increased risk of insulin resistance due to the pro-inflammatory processes of the infection. The pathogenesis of this interaction is not yet fully understood though (Young et al. 2009). Research has determined that there is a strong link between antiretroviral therapy (ART) and the development of DM. The gold standard for HIV/AIDS treatment is the HAART strategy: Highly Active Antiretroviral Therapy, which consists of three or more drugs to prevent the development of drug resistance. This ART/HAART has brought profound positive changes to the lives of many HIV/AIDS patients; it does, however, have a wide range of potential adverse effects, including among others gastro-intestinal disturbances, hepatotoxicity and pancreatitis. Moreover ART can be associated with the development of various metabolic changes predisposing the patient to the development of DM.

A reposition of body fat is often seen in patients on ART. This condition, called HIV lipodystrophy, is characterised by metabolic abnormalities in the form of hyperlipidaemia and insulin resistance and a body fat redistribution with peripheral fat wasting and central obesity (Kalra et al. 2011, Young et al. 2009). Furthermore patients on antiretroviral medication often develop dyslipidaemia. Dyslipidaemia presents with

high triglyceride and cholesterol and low HDL-Chol concentrations in the blood. All these abnormal lipid profiles predispose a patient to the development of the MetS and DM to a great extent (Young et al. 2009). This constellation of abnormalities in patients receiving antiretroviral medications is also called 'antiretroviral-associated diabetes' and is consistent with type 2 diabetes rather than type 1 diabetes (Kalra et al. 2011). Kalra et al. also mention that it is vital for the fight against the diabetes epidemic to also treat the metabolic and chronic adverse effects of ART. For a detailed pathogenesis of the interaction between HIV/AIDS and DM and suggestions for its management the reader is referred to the article 'Understanding diabetes in patients with HIV/AIDS' by Kalra et al. (2011).

6.3. Challenges faced by the epidemic

In order for policy makers of African health systems to respond effectively to this overwhelming health transition, much more research needs to be done in this region. Research is needed on the interactions between communicable and NCD, their clinical picture and course, and research on possible treatment and preventative measures. According to Maher & Sekajugo, low and middle-income countries are lacking significant high quality health information on epidemiological data of the burden, risk and distribution of NCD in SSA. This would aid the judgment of the extent of the epidemic as well as to allow for demand-based health policies. Furthermore, Maher & Sekajugo suggest more research being done in the area of health service delivery, especially the transformation of current primary health-care services, aimed mainly at acute infectious diseases into effective, adequate and structured care for both CD and NCD. Since most African health systems are already greatly strained economically by the load of communicable diseases it is also of vital importance to design health-care approaches to diabetes care which are less expensive but nonetheless effective.

Aside from the burden of the combined CD and NCD epidemic, African countries, including Namibia, are faced with various other challenges in the care for their diabetic patients. In order to treat DM effectively and prevent the early development of short-term and long-term complications, an early diagnosis and treatment is mandatory. However, research in five African countries has shown that people only attend clinics once complications of DM are present. Only 26% of tested people knew they had diabetes at the time of the study, compared to 71% in North America (Sicree et al.

2009). This clearly shows that health programmes for the education of people on diabetes and more testing in the primary health-care setting is urgently needed. Late presentation of diabetic patients is often also associated with the extreme vastness combined with poverty of many parts of the African continent. Access to health services is often far and expensive, especially for people in rural areas, and thus health services will only be called upon in urgent and dire situations (Motala et al. 2008). Motala et al. (2008) further point out that the clinical combination of weight loss, polyuria and sepsis often lead to the hasty, uneducated and faulty diagnosis of HIV as the latter is so prevalent in many countries. This of course delays the right diagnosis and possible treatment of DM.

6.3.1. Diabetic complications in the African setting

In contrast to the western world, which is mainly confronted by renal and cardiovascular complications associated with DM, the most common chronic diabetic complications in SSA are retinopathy, neuropathy and nephropathy (Figure 16) (Gill et al. 2009, Azevedo & Alla 2008, Mbanya & Ramiaya 2006). Retinopathy is a very common cause of blindness in diabetics while neuropathy causes > 80% of foot ulcers in the African region. Studies have shown that many foot ulcers progress rapidly due to lack of treatment and early lower-limb amputations are frequent. The latter poses a problem itself, as prosthetic rehabilitation after amputation is uncommon often leaving the patient permanently bed-ridden (Fall 2001). In addition, many African cultures regard the loss of a limb worse than the loss of life, thus treatment in these cultures is very often not called upon even if available (Gill et al. 2009).

Figure 16 Chronic complication prevalence studies of diabetes in Africa

Complication	Location	Year	Prevalence (%)
Retinopathy			
[47]	Cape Town	1997	55
[48]	Nigeria and Ghana	2003	18
Nephropathy			
[49]	Egypt	2004	14
[50]	Nigeria	2003	28
Neuropathy			
[51]	Tanzania	2000	25
[52]	Libya	1999	46
Microalbuminuria			
[53]	Tanzania	2007	11
[54]	Cameroon	1999	53

The complications of DM can be manifold. While the western countries are mainly confronted with renal and cardiovascular complications, African countries are confronted by retinopathy, neuropathy and nephropathy

Source: Gill et al. 2009

Most public health services are not able to treat patients presenting with nephropathy or renal failure adequately, making this complication of DM one of the most common causes of death in diabetics in Africa. Other very common causes of death are acute complications of DM: infections and metabolic complications (diabetic ketoacidosis, hyperosmolar nonketotic coma and hypoglycaemia). Gill et al. (2009) and Mbanya & Ramiaya (2006) have found that the reasons for these high mortality rates due to acute complications are late presentation by patients, lack of medication and treatment to prevent and treat metabolic imbalances, poor glycaemic and BP control, and misdiagnosis by health staff. Devastatingly, as the onset of DM in Africa has its vertex between 40-59 years of age, most patients will still experience the complications during their working life; needless to say that this further increases the burden of the diabetic epidemic (Fall 2001).

Not only the diagnosis and complications of DM pose a challenge to African health systems, but the treatment of diabetic patients too. Problems, challenges and failures of the Namibian health system will be discussed at length in the section on Namibia and will only be mentioned briefly here. The reader is referred to the section ‘The Namibian health system’ (pg 108).

6.3.2. Challenges in the treatment of diabetes in the African setting

The WHO has identified problems and barriers in the treatment of diabetic care, including lack of organisational structures for chronic disease care, minimal staffing and training in this field, lack of resources, and minimal communication to the public to address preventative strategies. Whiting et al. (2003) have further identified care inadequacies, including non-existent diabetes multidisciplinary health-care teams, lack of national policies, poor attendance by patients, and lack of infrastructure to support services. Unaffordable medicines and other resources have been mentioned by various authors and present a major obstacle in the treatment of diabetic patients. As most African public health systems only have a very basic insurance system, if at all, most diabetics are faced with two options: try to survive as long as possible without medication or pay the crippling prices for insulin, metformin and other oral diabetic medications. Fall (2001) found that in some developing countries the price of oral diabetic medication for a week could be as high as 6-12 months' worth of wages for a person. Treatment is further hindered by the unavailability of medication in many countries, even in large hospitals and particularly in rural areas. This especially, but not only, affects patients suffering from type 1 diabetes requiring insulin for survival. Whiting et al. (2003) therefore suggest that the 'focus for treatment in Africa should be on cheap and cost-effective generic drugs […] since protocols for the implementation of such drugs for hypertension and diabetes have been developed' already (Whiting et al. 2003).

6.3.3. The role of traditional and faith healers

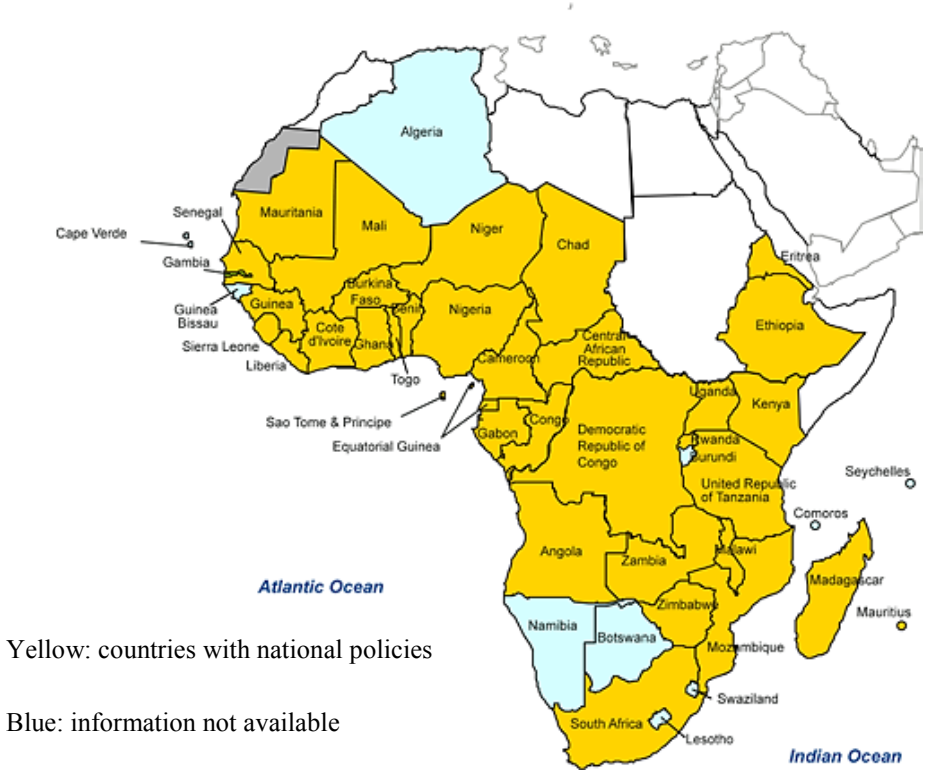
The role of traditional and faith healers cannot be ignored when studying African health-care since these healers play a vital role in many African cultures. The WHO estimates that 80% of people in developing countries rely on traditional medicine as their primary health-care (Kasilo et al. 2010). Traditional healers are often the first and sometimes only point of contact for a sick person. The problem with traditional healers is that they rarely have a good understanding of DM and seldom refer patients to public health facilities. The services, care and medications offered by traditional healers have been found to be more accessible and affordable in most countries, presenting an obvious reason for sick people to seek their help (BeLue et al. 2009, Azevedo & Alla 2008). A study in South Africa has shown that traditional and faith healers prescribe

cures for DM instead of treatment and intervention leaving the patient to believe that DM can be reversed and cured. Treatment included the use of prayer, diet and herbs (Peltzer et al. 2001). Another study done in South Africa determined that many patients had more faith in traditional healers and herbs than in conventional medicine. In addition, many community health workers share this belief (BeLue et al. 2009, Haque et al. 2005). The use of traditional healers and medication is an integral part of many African societies, therefore it is important that efforts should be undertaken to include traditional medicine into the health system.

In 1978, traditional medicine and its practitioners were officially recognised by the Alma Ata Declaration[5]. Since then member states and organisations such as the WHO have made great efforts to ensure the integration of traditional medicine into allopathic medical care. Furthermore, great efforts have been made to study the safety, efficacy and quality of traditional herbs in the use of medical care (Kasilo et al. 2010). Some African countries such as Ghana, Senegal, Mali and Congo have institutionalised programmes for the training of traditional healers (Kasilo et al. 2010). For more information on the progress of integrating traditional healers and medicine into the health systems, the reader is referred to the special August 31, 2010 issue of 'The African Health Monitor' for the African Traditional Medicine Day, published by the Regional Office for Africa of the WHO.

[5] Alma Ata Declaration: in 1978 all WHO member countries unanimously adopted a declaration adopting primary health care 'as the means for providing a comprehensive, universal, equitable and affordable health care service for all countries' (Hall & Taylor 2003).

Figure 17 Countries with national policies on traditional medicines in the African region



The use of traditional medicine is still widespread in Africa. This has been recognised by some governments and policies were implemented to include traditional healers into the health system. Figure 17 indicates which countries have implemented such policies.

Source: Kasilo et al. 2010

In conclusion, one can say that the whole approach to health-care should be reformed in African countries. Health systems are designed to treat acute, infectious diseases with the result that health staff and health services are not equipped and trained for effective and efficient diabetes care. The management of a diabetic requires the involvement of several services and specialties, therefore the care must be more coordinated than that required for acute conditions (Whiting et al. 2003). A 10-year study done in South Africa on the care of diabetic patients showed that staff training is limited and more continuing education is desperately needed. The control of blood glucose and BP as well as the monitoring of complications is very poor, and the education of patients on DM is almost non-existent. These shortages have been found to exist in many other African countries (Whiting et al. 2003). These problems seem easy to solve, however, many African countries lack the resources and public health infrastructure to fight communicable diseases, diseases of poverty and malnutrition as well as NCD at the

same time. This health transition places an enormous challenge to Africa, the region with the least resources for an effective response. It is important that policies and scarce resources are diverted away from infectious diseases only and programs addressing both, infectious and chronic diseases, must be implemented (Tollman et al. 2008, Yach et al. 2004). In order to achieve this goal, local governments, health ministries, non-governmental organisations, WHO, academic health centres and research institutions as well as donors and health and development initiatives need to work together (Yach et al. 2004).

7. The Framingham risk score (FRS)

Diabetes and CVD such as heart attack, coronary artery disease, stroke and congestive cardiac failure among others, have most risk factors in common. Therefore, it is not surprising that there is a rapid increase in CVD across the world (BeLue et al. 2009, Gill et al. 2009).

The Framingham Heart Study (FHS) was initiated in 1948 in Framingham, a town in Massachusetts, US to examine the mounting epidemic of CVD. It is under the directorship of the National Heart, Lung and Blood Institute, formerly known as the National Heart Institute, and the Boston University. The study is committed to identify common factors and characteristics that contribute to CVD (FHS website, Bitton & Gaziano 2010). The original study cohort (Original Cohort) consisted of 5 209 men and women between the ages of 30 and 62 without any history of overt cardiovascular symptoms. Since then the FHS has added five more study groups consisting of offspring in second and third generation of the Original Cohort. Furthermore, two generations of Omni Cohorts were added. As the community of Framingham changed over the years it became apparent that a new group reflecting the diversity of Framingham needed to be established. Therefore, the Omni cohorts consist of African-Americans, Hispanics, Asians, Indians, Pacific Islanders and Native Americans. The last group to be added was the New Offspring Spouse Cohort in 2003, including spouses and parents of non-original participants to ensure statistical power for family history of diseases (FHS website).

Participants return every two years to have full physical examination, medical history and laboratory tests done. These data have given rise to a great understanding of the risk factors and characteristics of CVD: high BP, high blood cholesterol, smoking, obesity, diabetes, and physical inactivity as well as its associated factors such as blood triglyceride and HDL-Chol levels, age, gender, and psychosocial issues (FHS website). Over time, the effect of individual or combined risk factors on a cardiovascular event has been established and the interaction of risk factors and individual CVD understood (Bitton & Gaziano 2010). Due to new technologies available genetic patterns of CVDs are being examined as well as for example the effects of risk factors on the brain or heart activity analysed by CT-scan or echocardiography. More than 1 200 articles have been published on the research done in the FHS and 35 research milestones have been achieved since 1960 (FHS website). For details of the latter, the reader is referred to the FHS website available at: http://www.framinghamheartstudy.org/about/milestones.html.

Based on the information gathered in the Framingham study, several algorithms for risk prediction estimates have been developed, the FRS (FRS website, Bitton & Gaziano 2010). Such include 10-year risk for atrial fibrillation, coronary heart disease, general CVD; risk calculator for congestive heart failure, stroke, hypertension, intermittent claudication and others. The respective risk calculators haven been developed by researchers using statistical methods and relevant data of the FHS to predict individual aspects of CVDs. The purpose of this would be to identify people at risk, ideally in the primary care setting, offer adequate interventions or treatment and thus reduce the risk of a cardiovascular event (Greenland et al. 2010, D'Agostino et al. 2008). To achieve this, the WHO recommends that all patients with a 10-year cardiovascular risk of $\geq$ 30%, or $\geq$ 20% if resources permit, be treated pharmacologically (Mendis et al. 2011).

For the purpose of our study, the 10-year general/global cardiovascular risk of the participants will be calculated. D'Agostino et al. (2008) developed a single multivariable risk assessment tool in 2008 which enables physicians to identify patients at risk for any initial atherosclerotic CVD (D'Agostino et al. 2008). Being multivariable, it takes the following predictors into consideration: age, diabetes, smoking, treated and untreated systolic BP (SBP), total cholesterol, HDL-Chol or BMI replacing lipids (FHS website, D'Agostino et al. 2008). The result is an estimate of the

probability of disease according to the intensity of each risk factor. The advantage of a multivariable assessment tool is the fact that it avoids alarming persons with just one isolated risk factor, while on the other side detects people with multiple marginal risk factors, who could be at high risk. This can then guide preventative measures or further treatment (Greenland et al. 2010, D'Agostino et al. 2008).

The FRS is based on data mainly derived from Caucasians and does not include ethnicity in its calculation model. However, despite this and despite the existence of other calculation models which do take ethnicity into consideration, the FRS was used in our study. This was done, for the FRS is a well-established, widely validated across large prospective studies and commonly used assessment tool and it is the gold standard among the CVD risk assessment tools (Tripepi et al. 2013, Jaquish 2007). Furthermore, the FRS received Grade I recommendations by the American College of Cardiology and the American Heart Association, making it a highly recommendable assessment tool (Cook et al. 2012, Greenland et al. 2010).

Chapter 2 Bone ultrasound and Osteoporosis

1. Definition

Osteoporosis is defined as a systemic skeletal disease characterised by low bone mass as well as a deterioration of the micro-architectonical structure of bone tissue. This results in increased bone fragility and therefore a greater risk of fractures (Dachverband Osteologie [DVO[6]] 2011, National Osteoporosis Federation of South Africa (NOFSA) 2010). Once a fracture has occurred on the basis of underlying osteoporosis the condition is called 'manifest osteoporosis' (DVO 2011).

2. Clinical manifestation

The loss of bone structure in osteoporosis is generally slow and painless and consequently there are no known clinical symptoms preceding an osteoporotic fracture (DVO 2011, International Osteoporosis Foundation [IOF], WHO 2007). These fractures can occur anywhere in the body, but peripheral, especially hip, humerus, wrist, and vertebral fractures are the most common clinical manifestations. While peripheral fractures are generally obvious, vertebral fractures can be more discreet, less painful and even without specific clinical symptoms. Therefore they are commonly miss-diagnosed as other sources of chronic back pain (Därr et al. 2008, WHO 2007, IOF).

In contrast to non-osteoporotic fractures, osteoporotic fractures occur by definition due to minimal, low-energy trauma that would not cause dense bone to break (WHO 2007). The clinical and health relevance of osteoporosis lies in the morbidity secondary to occurring fractures. There is an obvious loss of quality of life due to acute and later often chronic pain of the fracture site, functional limitation, immobility, and often also mortality. According to the DVO the risk of mortality is highest in the first year after the fracture and increases with age. Hough (2006) and Rachner et al. (2011) mention that 20% of patients die within one year of a hip fracture and its consequences. Hough (2006) further stipulates that less than 50% of patients are able to live an independent life following an osteoporotic hip fracture (Hough 2006). Specific consequences of

[6] Dachverband Osteologie: the umbrella societies for osteology in Germany, Austria and Switzerland.

vertebral fracture can be chronic back pain, a loss of height and a Dowager's Hump[7] (DVO 2011, WHO 2007, IOF).

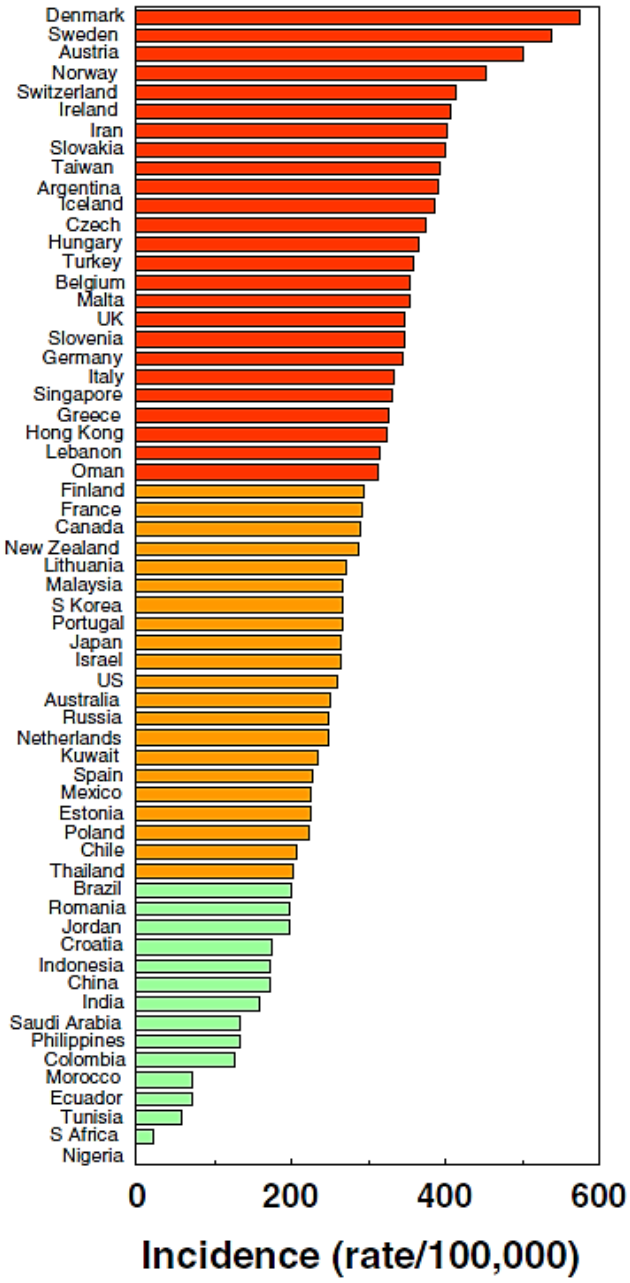
3. Epidemiology of osteoporosis

The common measurement for the prevalence of osteoporosis is the incidence of associated fractures, mainly hip and vertebral fractures. Osteoporosis is a common disease which affects every fourth postmenopausal woman and worldwide one in three women and one in five men are at risk of an osteoporotic fracture (Hough 2006, IOF). The female to male ration lies at six to one with an estimated 200 million women being affected worldwide (IOF, Johnell & Kanis 2006). For both sexes the risk for osteoporosis and thus an osteoporotic fracture increases dramatically with age: one-tenth of women aged 60, one-fifth aged 70, two-fifths aged 80 and two-thirds of women aged 90 (IOF). Men experience the same increase in fracture risk as women do, five to ten years later though around the age of seventy years (Uebelhart & Uebelhart 2012). However, these numbers vary greatly by race and ethnicity.

Kanis et al. (2012) published a systematic review of the worldwide fracture incidence and probability in 2012 according to data available until this year. The review showed a marked diverseness of fracture risk between countries (Figure 18): the lowest fracture incidence was found to be in Nigeria, followed by South Africa, Tunisia and Ecuador. The highest were found to be in Denmark, Norway, Sweden and Austria. The numbers presented an estimated 10-fold range in hip fracture incidence between the countries. It must be mentioned however that data from Nigeria and South Africa are of poor quality due to study procedures (Nigeria) and old data (South Africa, data collection 1957-1963) (Kanis et al. 2012).

[7] Dowager's Hump: a curved upper back.

Figure 18 Age-standardised hip fracture incidence in women



Red: high fracture risk

Orange: medium fracture risk

Green: low fracture risk

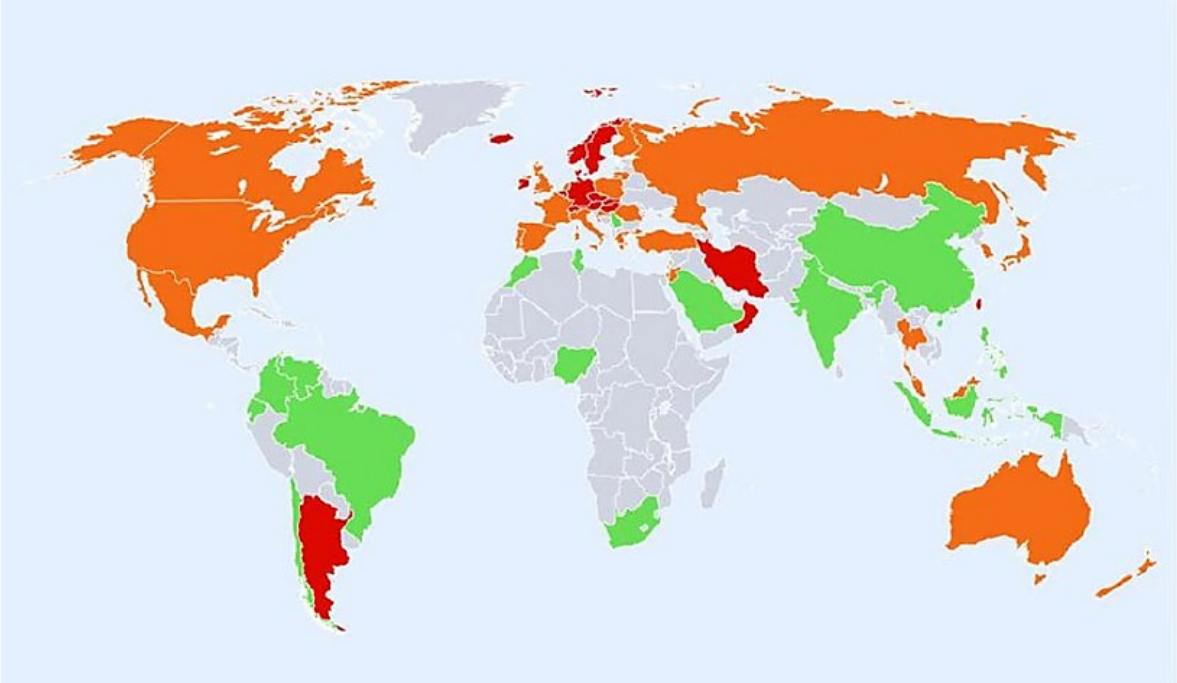
A marked difference exists in the fracture risk rates of different populations across the world. It is up to 10-fold higher in Scandinavian countries compared to African countries.

Source: Kanis et al. 2012

Looking at the geographical distribution of fracture risk and incidences, high and low risk zones can be identified that are similar in men and women (Figure 19). The high

risks countries begin in northern Europe, run through middle Europe and then extend through south-eastern Europe. Other high risk countries include northern America and Australia as well as Malta, Argentina and Taiwan (Kanis et al. 2012, Cauley 2011).

Figure 19 Hip fracture rates for men and women categorised by risk



Red: annual incidence > 250/100 000
Orange: 150-250/100 000
Green: < 150/100 000
Grey: no data available

Several countries and regions have been identified as high risk areas for osteoporotic fractures (Figure 19). This allows for the hypothesis that geographical patterns must be taken into consideration when analysing the aetiology of osteoporosis.

Source: Kanis et al. 2012

Johnell & Kanis (2006) included a table in their article (Figure 20) on the worldwide prevalence of osteoporosis and associated disability comparing different regions of the world:

Figure 20 Estimated prevalence of osteoporotic fractures (in thousands) in different regions of the world

Region	Men	Women	Total	Percentage	F/M
Africa	205	207	412	0.7	1.0
Americas	2,621	6,375	8,999	16.0	2.4
Eastern Mediterranean	746	789	1,535	2.7	1.1
Europe	6,650	13,927	20,577	36.6	2.1
Southeast Asia	4,169	4,453	8,622	15.3	1.1
Western Pacific	7,067	9,003	16,069	28.6	1.3
World	21,457	34,755	56,212	100	1.6

The above table gives an indication of the prevalence of osteoporotic fractures across different regions. Western Pacific, Europe and South East Asia can be identified as the regions with the highest risks.

F/M: female to male ratio

Source: Johnell & Kanis 2006

Data on the prevalence of osteoporosis or osteoporosis associated fractures in Africa are scarce. It is said that osteoporosis is rare on the continent, so little research is being done (Zebaze & Seeman 2003). According to Zebaze & Seeman (2003) the studies available for West Africa (1997), Gambia (1996) and South Africa (1968) all show a low rate of osteoporotic fractures. Based on this, Zebaze & Seeman (2003) did a retrospective analysis of patients admitted with fractures to various hospitals in Cameroon. The study showed that even though osteoporotic fracture incidence in Cameroon lies above that in other African countries, it is still far below the incidence rates of western countries. However, as urbanisation and westernisation take root in Africa, it is predicted that the prevalence of osteoporosis will increase drastically (Zebaze & Seeman 2003).

4. Burden of disease

Looking at the prevalence of osteoporosis and its associated clinical manifestations, it becomes obvious that the burden of disease is high. According to Johnell & Kanis (2006), the estimated DALY of osteoporosis were 1,75 million years lost in 1990, representing 0,1% of the global burden of disease. DALY takes the YLL and Years Lived with Disability (YLD) into account. YLL is calculated taking the incidence of death causally related to an osteoporotic fracture while YLD is calculated looking at the

disability and morbidity resulting from osteoporotic fractures (Johnell & Kanis 2006, Johnell & Kanis 2004).

In 2006, Johnell & Kanis (2006) estimated the DALY to be 5.8 million years lost. The burden was higher for women (64%) than for men (36%), corresponding to the female-to-male ratio of 6:1 of osteoporosis. Europe and America account for most of the DALYs, with Africa only contributing 1.1% (Figure 21).

Figure 21 Estimated burden of disease expressed in DALY (in thousands)

Region	Men	Women	Total	Percentage
Africa	28	36	64	1.1
Americas	218	609	827	14.3
Eastern Mediterranean	77	100	177	3.0
Europe	655	1,351	2,006	34.6
Southeast Asia	446	606	1,051	18.1
Western Pacific	666	1,008	1,674	28.9
World	2,090	3,710	5,800	100

The Disability Adjusted Life Years gives is a calculation of the years of life lost and the years lived with disability due to the disease. This gives an indication of the disability the disease causes.

Source: Johnell & Kanis 2006

The burden of osteoporosis accounted for 0.83% of the global burden of non-communicable diseases. As can be seen from Figure 22 below, this varied greatly by region (Johnell & Kanis 2006). Furthermore, osteoporosis presents a greater DALY than rheumatoid arthritis and cancer of all sites, with the exception of lung cancers (Johnell & Kanis 2006, Johnell & Kanis 2004).

Figure 22 DALY of osteoporosis as % of global burden of NCD

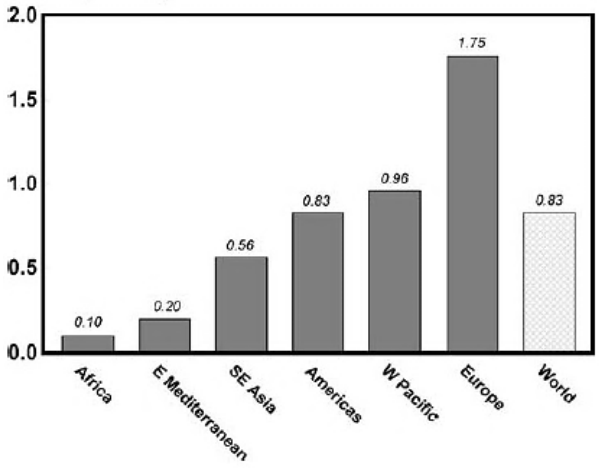


Figure 22 shows the DALY of osteoporosis compared to other NCD.
Source: Johnell & Kanis 2006

The economic burden of osteoporosis is not to be neglected. As with diabetes, the direct and indirect economic costs must be considered. A study done in the United States (US) showed that a patient with osteoporosis and a fracture incurred costs of $ 15 942 annually due to acute and post-fracture health-care (Rousculp et al. 2007). 59% of these costs are associated with nursing home expenses due to post-fracture morbidity. Furthermore, female employees with osteoporosis would incur $ 4 000 due to lost productivity, compared to $ 2 300 for non-osteoporotic employees (Rousculp et al. 2007).

Lippuner (2012) showed that total costs for acute hospitalisation of patients with osteoporosis in Switzerland was approximately 291 and 102 million Swiss francs[8] for women and men respectively in 2008. In women, this was almost as much as for acute hospitalisation of patients with cardiovascular diseases (CVD), COPD and breast cancer together. When looking at Germany, the total cost for treatment of osteoporosis and osteoporotic fractures amounted to € 5.4 billion in 2003 accounting for 3.5% of total health-care allocation. 56% of these costs were consumed by in-patient treatment, while 17% were spent for long-term care and 15% for medication (Häussler et al. 2007).

No data could be found on the economic burden of osteoporosis in African countries. However, analysing the figures above it becomes obvious that osteoporosis places a great burden on health-care systems in developed countries. It is expected that the same

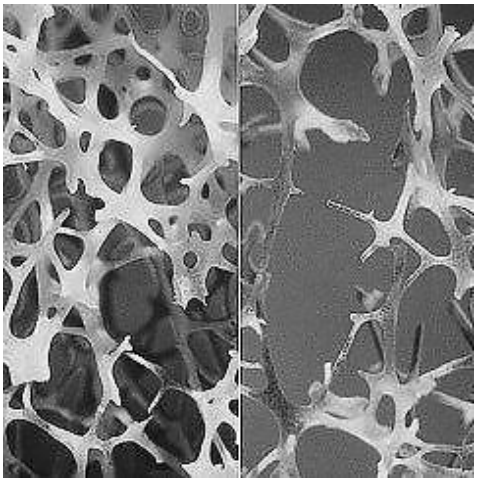
[8] Appr. 362.05 and 114.29 million USD (currency converted on 8.12.2013)

applies to health-care systems in developing countries, where, the impact of the economic burden may be even greater.

5. The physiology of bone

Cortical and trabecular bone tissue have three different constituents: unmineralised bone matrix that is newly formed, bone minerals (like calcium phosphate and hydroxyapatite crystals) and bone cells. Osteoblasts are responsible for the formation of bone tissue, osteoclasts for its resorption and osteocytes are responsible for the remodelling of bone tissue as well as the mechanoreception signalling by sensing and communicating mechanical stress within the bone. In adults there is no net gain or loss of bone mass, as the remodelling process consists of a normally well balanced bone resorption and bone formation (Rachner et al. 2011, NOFSA 2010, IOF). However, this also means that any uncoupling of this balance will lead to a net gain or, as in osteoporosis, a net loss of bone mass (NOFSA 2010). Figure 23 shows normal and osteoporotic bone structure in comparison.

Figure 23 Normal (left) and osteoporotic (right) bone structure



The pathophysiology of osteoporosis lies in the loss of balance between bone formation and bone resorption, with the latter outbalancing the former.
Source: IOF website 2012

Bone formation and bone mass continually increase from childhood through adolescence until reaching a peak bone mass (PBM) at the age of 20-30 years (NOFSA 2010, Laabes et al. 2008). Therefore, the basis for bone strength is laid down in early childhood. It has been found that adequate calcium intake and physical activity during this time are mandatory for a sufficient PBM (Laabes et al. 2008). Reaching and

maintaining PBM in adulthood depends largely on heredity, genetics and gender. Hormones like oestrogen, parathyroid hormone, growth hormone and testosterone are vital for optimal bone development and maintenance, and a large number of genes have been identified to influence bone physiology (IOF, NOFSA 2010). However, body size, diet (total energy and calcium intake), lifestyle factors and physical activity also play an important role (NOFSA 2010, Preisinger 2009). According to the International Osteoporosis Federation, a 10% increase in PBM during adolescence reduces the risk of an osteoporotic fracture in later life by 50%.

The PBM is maintained by a balance of bone resorption and bone formation. However, from the fourth decade on there is an age-related, slow increase in bone resorption while bone formation becomes impaired (NOFSA 2010, IOF). The latter is caused by an age-related loss of function of osteoblasts as well as defects in the production of local and systemic growth factors. The former is caused by a menopausal oestrogen deficiency, vitamin D and calcium deficiency due to poor intake, insufficient sun exposure and/or insufficient intestinal absorption in addition to genetic variations of bone-resorbing factors (Rachner et al. 2011, NOFSA 2010). Therefore, the pathogenetic mechanisms underlying loss of bone mass and osteoporosis are firstly a failure to achieve optimal PBM, secondly excessive bone resorption and thirdly an inadequacy to replace lost bone mass due to defects in bone formation (Rachner et al. 2011, NOFSA 2010).

6. Risk factors and prevention of osteoporosis

Looking at the metabolism of bone structure it becomes obvious that the risk factors for osteoporosis can be divided in fixed and modifiable risk factors. Fixed risk factors include age, female gender, family history of osteoporosis, genetics and ethnicity as well as menopause/hysterectomy. Various medical conditions such as primary or secondary hypogonadism in men, primary hyperparathyroidism, hyperthyroidism, endogenic hypercortisolism and inflammatory rheumatoid conditions predispose the patient to osteoporosis. Other non-modifiable risk factors are previous fractures and/or falls (Kanis et al. 2012, Kann et al. 2002, IOF).

Modifiable risk factors on the other hand include alcohol, smoking, low body mass index (BMI) and eating disorders, poor nutrition, sustained therapy with steroids,

heparin or thyroxine, vitamin D and calcium deficiency (reduced sunlight exposure), insufficient physical activity and the intake of bone toxic medication (Kanis et al. 2012, Rachner et al. 2011, NOFSA 2010, IOF). It becomes apparent that the neglect of bone health during childhood and adolescence, as well as the addition of avoidable risk factors onto age-related decrease of bone mass, greatly increases the risk for osteoporosis.

7. Diagnosis of bone quality and osteoporosis

The diagnosis of osteoporosis should not only be based on bone densitometry, but also on the past medical history, clinical examination and, where appropriate, laboratory tests. The aim is to establish an individual risk profile for each patient (DVO 2011, Hadji 2003, Pfeilschifter & Kann 2002, Kann 2001). In this research study the aim was to measure the acoustical properties of the bone as an indicator of fracture risk, and not to diagnose osteoporosis. Therefore, only a brief outline of the diagnosis of osteoporosis will be given, and more emphasis placed on the measurement of bone ultrasound and acoustical properties.

The DVO recommends a full diagnostic examination for all persons who have a 20% or higher risk of suffering from a vertebral and/or hip fracture in the next 10 years. Conditions such as age, vertebral fractures, hip fractures, Cushing's syndrome, treatment with glucocorticoids, hormone imbalances, falls, smoking, underweight, and many more, present a clinical risk factor. If a combination of risk factors is present, the DVO recommends a bone density measurement using the dual-energy X-ray absorptiometry (DXA) technique, based on X-ray absorption in bone (see pg 79) of the lumbar vertebral spine and the hip. Once other causes of low bone quality, for example osteomalacia, have been excluded the results should be interpreted according to the WHO definition of osteoporosis:

Table 2 Definition of osteoporosis according to the WHO

T-score	
> -1	Normal
-1 to -2.5	Osteopenia
< -2.5	Osteoporosis
Clinical fracture	manifest osteoporosis

T-score: the number of standard deviations below/above the average of a **30-year-old,** same-sex adult with peak bone quality

Z-score: number of standard deviations below/above the average for a healthy person of the same age

Osteopenia: low bone quality, it is a condition, not a disease

Source: WHO

As can be seen from the Table 2 above, a T-score of ≤ -2.5 in combination with clinical symptoms should result in the diagnosis of osteoporosis. The DVO further recommends that a T-score < -2.0 in high-risk patients should be used as the threshold for the consideration of a pharmacological treatment (DVO 2011, Rachner et al. 2011).

A widely used assessment tool is the FRAX model. FRAX was developed by the WHO Collaborating Centre for Metabolic Bone Disease and first released in 2008. It is a computer-based algorithm that can be used to calculate fracture risk in individuals, based on clinical risk factors. The algorithm output is the 10-year probability of a major osteoporotic fracture (FRAX website 2012, Kanis et al. 2011, Moayyeri et al. 2009). The probability is calculated from anthropometric data, age and the presence of risk factors for osteoporosis. To further enhance the risk assessment, bone quality can be added. In contrast to other risk algorithms, the FRAX model uses country-specific fracture and mortality rates in order to be calibrated for the diverseness of osteoporotic fracture risk (DVO 2011, Kanis et al. 2011, Moayyeri et al. 2009). Models are currently available in 11 languages and for 31 countries. The use of FRAX lies in the identification of patients eligible for bone quality measurements or pharmacological treatment of osteoporosis. It can be especially useful in the primary health-care setting as it is also available in paper form. Even though it is now being in-cooperated into

many clinical guidelines, Kanis et al. (2011) argue that attention must be given to its weaknesses. These include, for example, non-validation in many countries and non-suitability for young adults presenting with secondary osteoporosis. For more information on and use of the FRAX algorithm, the reader is referred to the FRAX website www.shef.ac.uk/FRAX/.

The NOFSA recommends a bone mineral density (BMD) measurement for any woman above the age of 65 years and any man over 70 years of age. In younger individuals bone density should be measured if any risk factors present or in the case of a low-energy fracture or vertebral fracture. Furthermore, routine follow-ups should be performed every 18-24 months (NOFSA 2010).

The BMD should be interpreted according to the WHO guideline outlined above. For premenopausal women and men under the age of 50 years the Z-score should be applied. Due to the lack of reference data for a South African black population it is recommended that the Caucasian reference values be used, rather than values of Afro-Americans (NOFSA 2010).

8. Measurement of bone mass and acoustical properties of bone

BMD 'is the amount of bone mass per unit volume (volumetric density), or per unit area (areal density)' (WHO 2007). Both these parameters can be measured by densitometry.

The standard method of measuring BMD is by DXA which is based on the absorption of X-ray by the calcium content of the bone (Därr et al. 2008, WHO 2007, Kann 2001). The result is given in areal density (g/cm²). This number is then used to calculate the T- and Z-score[9] (Därr et al. 2008, WHO 2007). Research has shown that the density assessment of the lumbar spine and/or the total hip is best for fracture risk prediction and the control of treatment efficiency (DVO 2011). However, it is not uncommon that DXA is also used for whole-body measurements or assessments of other specific regions, for example wrist, humerus or tibia (Därr et al. 2008). The advantage of DXA is that it is a widely used, well established technique with numerous

[9] T-score: the number of standard deviations below/above the average of a **30-year-old,** same-sex adult with peak bone quality.

Z-score: Is a comparison of the participant's acoustical properties of bone to that of a healthy person of the same age, sex and ethnicity. The score is expressed in standard deviations.

studies having shown its efficiency and many guidelines recommending its use, allowing for international standardisation. This also allows for cross-calibration between different machines using a phantom limb. On the downside though, DXA uses high-energy radiation techniques exposing the patient to a certain degree of radiation at each examination. The machines are large, cumbersome and expensive. Also, an existing fracture of a vertebral body or calcification of the aorta can lead to false positive results and, lastly, the fat tissue covering the hip can reduce the precision of this technique (Hadji 2003). However, the significance of DXA is partly due to the fact that the technique is often set as an entry criterion for pharmacological studies. This allows for the connection between low bone quality measured by DXA, pharmacological treatment and therapy success to have been proven in numerous studies. Other techniques are less often set as entry criteria for pharmacological studies and therefore might seem inferior, giving DXA a clear advantage.

Alternatively, quantitative ultrasound (QUS) techniques can be used for the assessment of the acoustical properties of bone. This technology was introduced in 1984 by Langton et al. and utilises sound waves of between 0.25 and 1.25 MHz (Hadji 2003). The shape, speed and intensity of the sound wave are altered as it passes through the bone by its physical and mechanical properties. Thus the characteristics of bone tissue can be measured in terms of the transmission of sound called speed of sound (SOS) in metres per second as well as frequency dependent attenuation of the wave called broadband ultrasound attenuation (BUA) in decibel per megahertz (Moayyeri et al. 2012, Moayyeri et al. 2009, Kann 2001). This means that QUS measurements are influenced by the bone mineralisation, its elasticity and its architecture. For the influence of genetics on the transmission and absorption of ultrasonic waves the reader is referred to the article on this topic by Kann et al. (2002).

As with DXA, the results are presented in the form of T- and Z-scores, which can then be interpreted accordingly. The measurement of acoustical properties of bone at the heel is the most widespread and most reviewed technique, but other peripheral sites such as the wrist can also be used (Hadji 2003).

Various machines based on the QUS techniques are available. Some use only BUA or SOS, but the most recommended are those that use a composite parameter of BUA and SOS for the assessment of bone quality. It is also the latter combination that has

been proven to be the most effective and is therefore the most recommended (Moayyeri et al. 2012). BUA and SOS results are combined to form an index called the stiffness index (SI). This is an expression of the measured bone strength in comparison to that of young adults (at PBM) stated as a percentage (Trimpou et al. 2010).

The QUS scanners have several advantages: they are relatively inexpensive, have a small size and thus are easy to transport, and most importantly this technology does not use ionising radiation. On the other hand though, the measurements are to some extent dependent on temperature and acoustic coupling as well as the thickness of the overlying soft tissue. In addition, the lack of a universally accepted QUS phantom for cross-calibration makes the comparison of data acquired from different devices difficult (Moayyeri et al. 2012).

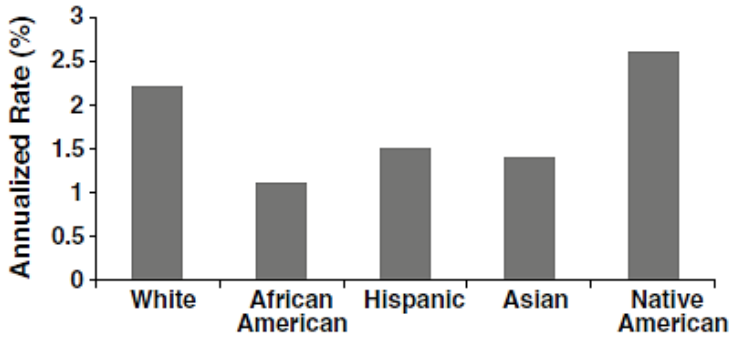
At the moment QUS is not recommended for the use of diagnosing osteoporosis in terms of the WHO definition, for various reasons: the variability of the QUS devices does not allow for cross-calibration and international standardisation. Furthermore, there is a lack of pharmacological studies setting the use of QUS as an entry criterion. Therefore the connection between low bone mineral contents, pharmacological therapy and treatment success could not be proven to the fullest extent yet. However, numerous studies comparing the accuracy of QUS to DXA results have shown that the former technology can well be used for the prediction of osteoporotic fracture risk (Moayyeri et al. 2012, Trimpou et al. 2010, Huopio et al. 2004, Hadji 2003). This good state of current data in combination with the low cost and non-ionising technique is the reason for the wide use of QUS devices.

9. Ethnic differences in bone quality and osteoporosis

The presence of ethnical differences in bone quality, osteoporosis and its manifestations has long been established. The evidence is particularly rich concerning black and white American men and women (Chantler et al. 2012, Travison et al. 2011, Pollitzer & Anderson 1989). In her article on this topic, Cauley (2011) argues that rates of hip fracture are about 50% less in black compared to white women. This is supported by Hochberg (2007) who reports age-adjusted annual incidence rate for hip fractures to be 10.1 and 4.1 per 1000 white and black women respectively. Looking at the hip fracture rate of women in the US (Figure 24), the number is highest among white

women, followed by Asian, Afro-American and then Hispanic women (Cauley 2011). The difference in prevalence of osteopenia, osteoporosis and fractures is also present in white and black males, far less pronounced though (Cauley 2011, Hochberg 2007, Travison et al. 2011).

Figure 24 Annual fracture rates by ethnicity in US women



Research has shown that there is a difference in osteoporotic fracture rates between ethnicities. The above graph presents the annual fracture rates in different ethnicities of the US, clearly showing that fracture rates are highest in Caucasian and Native Americans and lowest among Afro-Americans.

Source: Cauley 2011

Ethnical disparities not only exist in the number of fractures occurring, but also in the diagnosis and treatment of osteoporosis. Studies in the US have shown that pre-fracture bone quality testing is 20-50% less in Afro-Americans and 30% less in Hispanics compared to white Americans. These differences are generally interpreted as poorer quality of care available (Neuner et al. 2007). Furthermore it has been shown that post-fracture morbidity is higher in black than white Americans, as the former are less likely to be ambulatory when leaving hospital. Mortality after hip fractures is higher among men than women, but also higher in black compared to white women. This could be due to the often higher age, more pronounced co-morbidities of blacks or disparities in health-care when presenting with an osteoporotic fracture (Cauley 2011, Hochberg 2007).

The reasons for the disparities in fracture rates, prevalence of osteoporosis and post-fracture morbidity and mortality are manifold. The strongest component is the difference in bone quality and thus in bone strength. A study done in South Africa showed that black women have a significantly higher BMD at the femoral neck and the

total hip measured by DXA compared to white South African women. However, the white women presented with higher BMD at the lumbar spine (Chantler et al. 2012). These findings are consistent with other international studies (Ishii et al. 2011, Travison et al. 2011, Hochberg 2007).

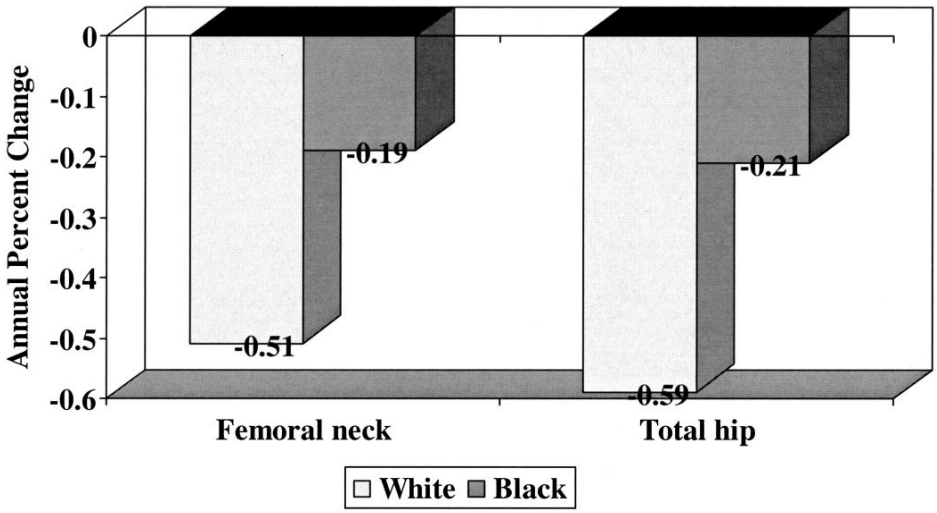
Many factors influencing bone strength have been identified. The presence of better bone quality in black compared to white children is an important factor as it shows that this is to some extent genetic and hereditary. Micklesfield et al. (2009) did a study in South Africa comparing site specific bone mass in South African children of different ethnic groups using a DXA machine. Even after adjusting for height and pubertal status it was demonstrated that black children have a higher BMD compared to their white counterparts. In the same study it was found that children of mixed-race present with an even higher BMD than black children. In a study done in 2007, Micklesfield et al. (2007) furthermore demonstrated that South African children, regardless of ethnicity, have a higher whole body BMD when compared to children from the US (Micklesfield et al. 2007). This in turn would speak again for an environmental influence to bone strength.

Wetzsteon et al. (2009) explain that these ethnic differences are due to variances in bone geometry (a greater bone area) and volumetric density. This is why Afro-American and Hispanic children presented a better compressive and bending strength than Caucasian children. Furthermore, Afro-American children show higher bone strength relative to muscle cross-sectional area, meaning that these children have higher bone strength to the loads placed on their bones. This could be due to a higher menchanosensitivity of Afro-American compared to Caucasian skeletons (Wetzsteon et al. 2009). Furthermore, the length of the hip axis (distance from trochanter to inner pelvis) seems to play an important role in fracture risk (Cauley 2011, Leslie et al. 2009, Cummings et al. 1994). It has been established that a shorter hip axis length is protective for osteoporotic fractures. Asian women for example present with a similar or even lower BMD as Caucasian women measured by DXA, however fracture rate is far lower in the former group. Cummings et al. (1994) explained this phenomenon by the shorter hip axis length of Asian women, as proven by their study. Black women taking part in the same study also presented with a shorter hip axis length than white women,

adding this factor to reasons for ethnical disparities in fracture risk (Leslie et al. 2009, Cummings et al. 1994).

An ethnical difference is also visible in the decline of bone strength. As outlined above, bone quality decreases with age due to various physiological factors. According to Hochberg (2007) this decline is more pronounced in white than black females (Figure 25).

Figure 25 Average annual change in bone mineral in black and white women (1988-2000)



Various factors influence the decline of quality with increasing age. It has been established that ethnicity plays a vital role in this. As can be seen above, bone strength decline is more pronounced in white than black females.

Source: Hochberg 2007

In addition to hereditary factors, environmental and lifestyle factors are just as important for bone quality. Chantler et al. (2012) showed that physical activity influences bone strength by comparing white and black South African women using DXA. Even though white women are more involved in vigorous physical activity boosting BMD, black women are more active mainly through walking for travelling purposes and thus presenting a higher BMD. In addition, black women are proportionately heavier than white women resulting in a greater BMD at load-bearing sites (Chantler et al. 2012). Moreover, Chantler et al. (2012) argue that low socioeconomic status, often associated with sub-optimal nutrition, growth delays and low educational level may be the answer to lower lumbar spine BMD in black compared to white women. The lumbar spine is predominantly made of trabecular bone,

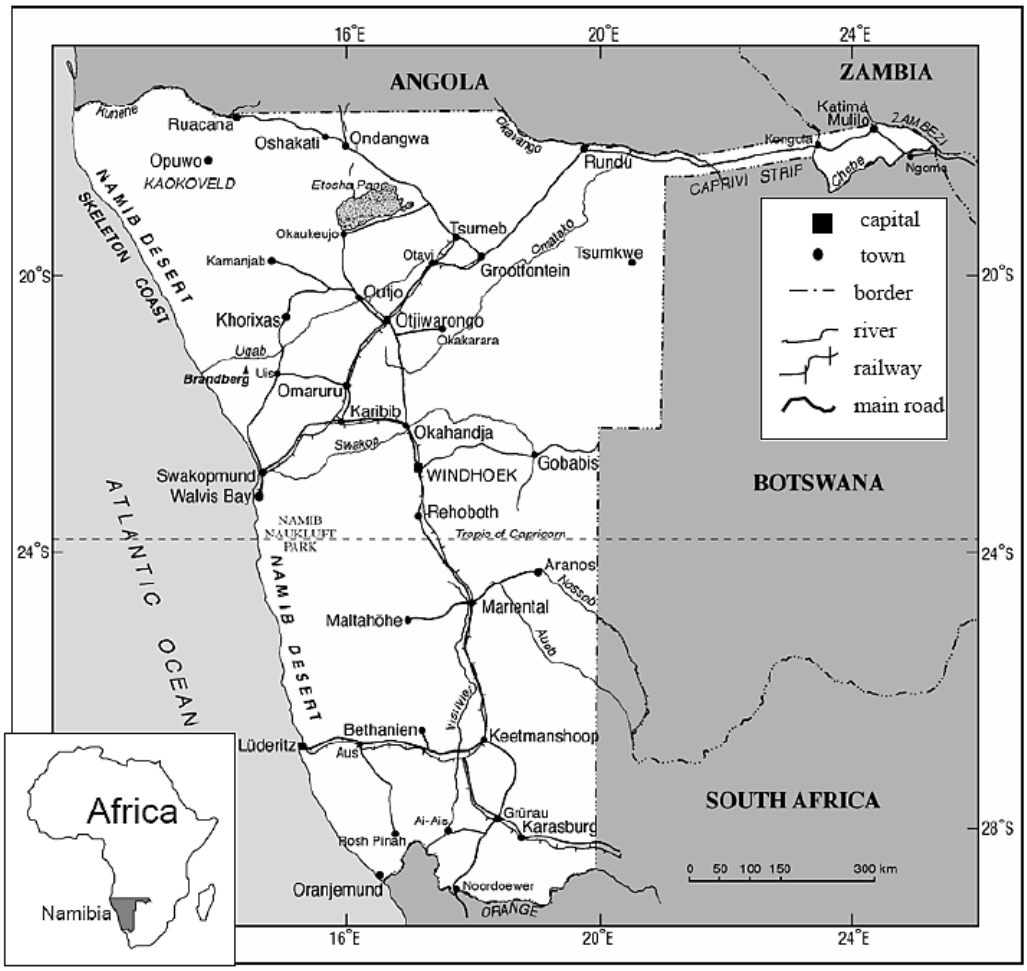
which is strongly influenced by hormonal and metabolic factors. Therefore, a low social economic status is associated with a lower BMD and thus an increased risk of fracture (Chantler et al. 2012, Norris et al. 2008).

Chapter 3 Namibia

1. The Namibian profile

Namibia, the most arid country in sub-Saharan Africa (SSA), lies in south-western Africa covering an area of 824 116 km². Four of its borders are determined by rivers: the northern border to Angola by the Kunene and the Okavango rivers, the most north-eastern part of Namibia, the Zambezi region (previously known as Caprivi strip), to Zambia and Zimbabwe by the Zambezi river and the southern border to South Africa by the Orange river. Botswana borders Namibia in the east, sharing parts of the big Kalahari Desert. On the western side, Namibia's central highlands slope down into the big Namib Desert, the oldest and second largest desert in the world, which fades into the 1 572 km long coastline of the Atlantic Ocean (CIA Factbook 2011).

Figure 26 Map of Namibia



Source: Noongo 2007

The capital city, Windhoek, lies in the heart of Namibia at 1700m above sea level. It is the biggest city of the country, with a population of roughly 350 000 people, 17% of the total population. Nearly all national enterprises have their headquarters in Windhoek. Due to its strategic location and political stability, Windhoek has become a preferred venue for many southern African conferences. Windhoek has also been the first and thus far the only city in the world re-using sewage water by having built huge purifying plants. It is one of Africa's cleanest, most efficient and most modern capitals and the cultural, economic and social centre of the nation (Windhoek City Council).

1.1. The political structure

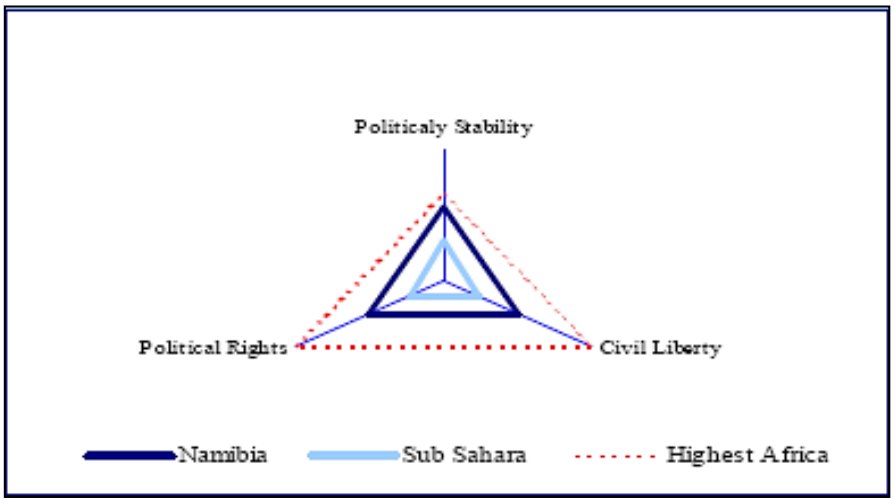
The Namibian constitution was drafted in the late 1980s already and came into force in March 1990 when the country gained Independence from South Africa. It is one of

the most progressive constitutions in the world. It provides for a unitary state with a democratic multi-party system (African Development Bank [ADB 2009]). The executive power rests with the president, prime minister and members of the cabinet.

Cabinet ministers are appointed by the president from among the members of the National Assembly. The legislature is bicameral consisting of the National Council which has 26 members: two chosen from each of the 13 regional councils. The National Council is primarily an advisory body. The second part of the legislature is the National Assembly with 72 seats and members are elected by popular vote (CIA 2011, ADB 2009, WHO 2009). Lastly, the judicial system is a mixed legal system of uncodified civil law based on Roman-Dutch law inherited from South Africa and customary law. The system includes a Magistrate Court, High Court and Supreme Court. The judges for the latter are appointed by the president, but on recommendations from the Judicial Service Commission (CIA 2011, ADB 2009, WHO 2009).

The main political achievement of Namibia since Independence has been the smooth transfer of power from one president to the next. In March 2005 Mr Hifikepunye Pohamba took over the presidency from Dr. Sam Nujoma, showing that multi-party democracy is working in Namibia. In addition, the country continues to show respect for the rule of law and human rights, and allows considerable press freedom. This forms the basis for its stability and progress (ADB 2009). This stability is reflected in Figure 27, a graph by the ADB Statistics Department which depicts that Namibia outperforms SSA in political stability, political rights and civil liberties (ADB 2009).

Figure 27 Political context of Namibia



The above graph by the ADB Statistics Department shows that Namibia outperforms SSA in political stability, political rights and civil liberties. Namibia is seen as one of the top 10 countries in Africa at political, social and economic level.

Source: ADB 2009

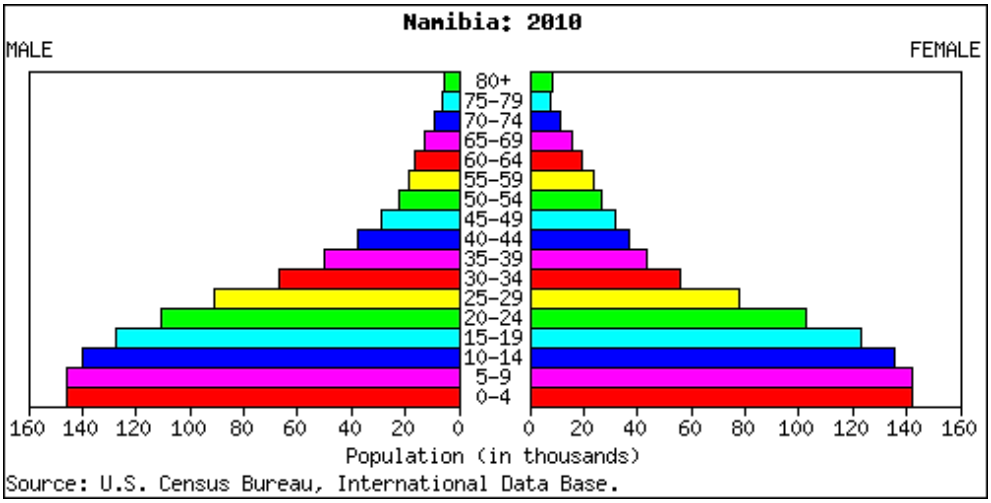
In its annual report the Mo Ibrahim Foundation has placed Namibia in 6th position out of 53 for the past 11 years (exception: ranked 5th in 2007). This rank is based on the Ibrahim Index which uses 86 indicators to measure the effective delivery of public goods and services to citizens of African countries. Data are evaluated in four categories: safety and rule of law, human development, sustainable economic opportunity and participation, and human rights, with which the governance of all African countries can be evaluated. (Ibrahim Foundation 2011).

1.2. The Namibian people

In 2011 the Namibian population counted 2,324 million people with roughly 2.2 persons per square kilometre, making it the second least-densely-populated country in the world (UNDP 2011, World Bank 2011). According to the United Nations Development Programme (UNDP) only 38.6% of Namibians live in urban areas. This sparse and scattered population distribution makes the provision of equitable access to social and health services an administrative challenge (WHO 2009). It is estimated that urbanisation will take place at an average rate of 3.3% per year (CIA 2011). Annual population growth is 1.8-2.6% per year, with the female population being slightly larger than the male population. At birth, life expectancy is 51.6 years: 50.9 for males and 52.2

for females. This places Namibia in position 208 of 221 countries when comparing worldwide life expectancies (CIA 2011). The estimation is 10 years lower than in 1991, when the average life expectancy was 61 years. The drop is mostly due to high mortality rates associated with the HIV/AIDS epidemic and life expectancy is only expected to increase again in 2021 (WHO 2009). Therefore, Namibia has a very young population (Figure 28) with 43% of Namibians being under the age of 15 (WHO 2009).

Figure 28 Namibian population pyramid 2010



The population pyramid of Namibia shows the typical picture of a young population with a low life expectancy.

Source: US Census Bureau

Namibia's population is culturally and ethnically extremely diverse. 87.6% of the people are black, 6.5% are of mixed origin and 6% white: over half of the people belong to the Ovambo tribe, 9% are Kavango, while other ethnic groups include Herero (7%), Damara (7%), Nama (5%), Caprivian (4%), Bushmen (3%), Baster (2%) and Tswana (0.5%). Of the 6% whites in the country approximately two thirds are Afrikaans, one quarter is of German origin and the rest of English origin (CIA 2011, Yikona et al. 2011).

In addition to these ethnical groups, Namibia hosts a large Angolan community comprising mostly refugees, and their descendants, of the Angolan civil war in the late 20th century, while more recent Angolan newcomers have been attracted to Namibia by the economic opportunities and the high standard of living. Over the past decade about 35 000 Chinese have immigrated to Namibia. They are mainly engaged in the

construction industry and retail business, either as low-income workers or wealthy business people (Yikona et al. 2011).

Between 12-15 indigenous languages are spoken in Namibia, including Ovambo (48.5%), Herero (5%), Damara/Nama (11.4%), Kavango and Tswana. English, the official language is only spoken by 7%, while Afrikaans is the common language of most people. German is spoken by 32% showing that the influence of the German Namibians remains inversely proportional to their numbers (CIA 2011, Yikona et al. 2011).

1.2.1. Migration and urbanisation

The world population is rapidly urbanising and so is the Namibian population. The global urban population increased from 13% of total population in 1900 to 29% in 1950 and reached 49% in 2005. It is expected to reach 60% by 2030 (UN 2005). The urban population in Africa was 38% in 2008 and it is projected that Africa will reach an urbanisation level of about 50% by 2020 (Misra & Khurana 2008). According to the ADB, Namibia also presents a rapid urbanisation rate with the highest increase being in the north, where 7.5% of rural dwellers moved into small towns in 2006. The projection for the years 2010 to 2015 is an annual urbanisation rate of 3.3% (CIA 2011). In most instances this rapid urbanisation comes with urban poverty; people live in informal settlements where service delivery is weak and housing inadequate (ADB 2006). For the health consequences of urbanisation the reader is referred to the chapter ‘Diabetes type 2 – The African picture’ (pg 55).

1.3. The social context

Namibia was a protectorate of South Africa before gaining Independence. Economically it benefited greatly from that (good infrastructure, successful exploitation of rich mineral resources and a strong public administration). However, the Apartheid system imposed on Namibia by the South African administration left the country with a highly dualistic society due to its social and economic imbalances (World Bank [WB] 2010). For details on the health system, see section on ‘The Namibian health system’ (pg 108).

1.3.1. Education

One of the biggest development challenges faced by the post-Independence government is the improvement of the education sector. Education was either denied or not provided for to most people before 1990. In those areas where education was provided it was mostly of a very low standard, with quality education reserved for only a very limited percentage of the population. This resulted in a huge skills deficit, which is still impacting negatively on the social and economic development of the country (National Planning Commission (NPC) 2009).

Namibia has managed to increase access to education for its people by increasing spending on education to the extent that it now is among the top eight countries of the world regarding per capita expenditure on education. This has led to great progress in achieving the government's goal to make education accessible to all (NPC 2009). According to the WB Education Statistics Department the spending amounted to 22.4% of total government spending in 2008. Total number of schools increased from 1 584 in 2002 to 1 672 in 2008. This increase is still far from enough, judged from own experiences. Enrolment rates for 2009 were 89.1% for primary school, but dropped to 54.4% for secondary school (WB EdStats 2010). The drop-out rate has been reduced from 15% to 13% from 2007 to 2008 (ADB Group). The expected years of schooling have been between 11.1 and 11.6 years since 1980. However, the actual mean years of schooling do not reach these expectations: in 1980 the average was 4.2 years, in 2000 6.6 years and in 2011 the average years a child went to school in Namibia was 7.4 years (UNDP 2011, WB 2011). With this average Namibia compares favourably to SSA, but lies below the average of its neighbours Botswana and South Africa. Looking at the literacy rate, 93% of young Namibians (15-24 years old) are literate and 88.5% of adults (above 24 years of age) (UNDP 2011, WB 2011).

While there have been great improvements in accessibility of education, the quality of education delivered is still far below acceptable. Despite the middle-income status of the country and the significant resources spent on education, the educational outcomes are poor. Namibia ranks lowest among the countries of the Southern African

Development Community[10] (SADC) in students' performance as monitored by SACMEQ (Southern and Eastern Africa Consortium for Monitoring Educational Quality) (Figure 29) (WB 2007).

Figure 29 SACMEQ Reading and Mathematics Scores, 2000

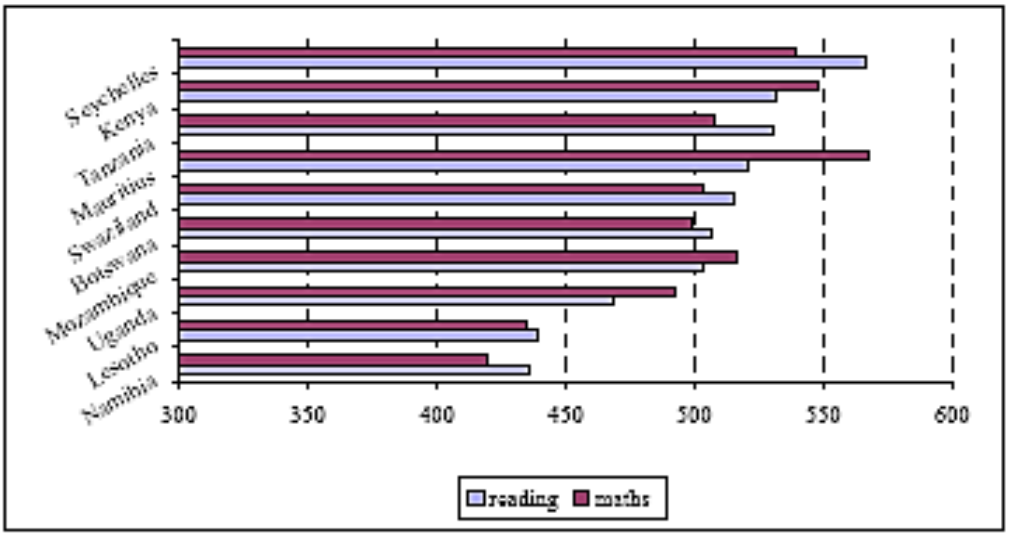


Figure 29 shows that Namibia's school performance is ranked lowest among the SADC countries
Source: WB 2007

According to the National Planning Commission of Namibia the percentage of learners receiving a D[11] or better in their final Grade 12 exams in 2009 was 32.7% for Mathematics, 38.4% for Science and 31.1% for English.

This means that the calibre of the teachers must improve as well as the quality and volume of teaching material and other school facilities. However, it also means that action must be taken by society, parents and caregivers in sending children to school

[10] SADC: an association of 15 countries in southern Africa. Its mission is 'to promote sustainable and equitable economic growth and socio-economic development through efficient productive systems, deeper co-operation and integration, good governance, and durable peace and security, so that the region emerges as a competitive and effective player in international relations and the world economy.' (SADC website).

[11] Namibian school system: twelve years of education including seven years primary school (compulsory) of which the first three years are taught in the mother tongue of the majority of children, after that the language of instruction should be English. Following this are three years junior secondary education and two years of senior secondary education. The Junior Secondary Certificate, an external examination is conducted at the end of Grade 10. At the end of Grade 12 the Namibia Senior Secondary Certificate is taken allowing the scholar to attend a Namibian tertiary institution. Some private schools offer A-levels or the German Abitur, which would allow the scholar to attend international universities (Fischer undated). The marking system is done in letters with 'A' being the best possible mark and 'F' being the worst possible mark.

regularly, establishing home environment conducive to learning and participating in the educational system (NCP 2009).

The higher education is offered mainly by two autonomous institutions: the University of Namibia (UNAM) and the Polytechnic of Namibia (PoN). These offer Bachelors, Masters and Doctoral programmes. The UNAM educates roughly 10 000 students on its Windhoek and Oshakati campuses and in 2005 700 students graduated from the university. The total annual output of the PoN is higher at 2 612 graduates in 2005. Of these, 2 203 hold diplomas and only 409 hold degrees. According to the NCP both institutions are struggling with the lack of sound basic education of its students. In addition, there are four colleges of education for training teachers and two agricultural colleges. The latter offer diploma-level training in agriculture, farming and science (NCP 2009). Twelve vocational training centres exist across the country, providing short-term training programme for youths and adults (NCP 2009).

Unfortunately the poor academic performance shown at school level is also seen at the level of higher education with exceptionally low university completion rates: 20% in science, 35% in humanities and 44% in education (WB 2007). Annual completion rate at the Vocational Training Centres lies at 52.6%, which is shockingly low for basic vocational training courses (NCP 2009). This lack of a skilled and qualified labour force greatly hinders the economic and social progress of country.

Even though significant progress has been made in the education sector, there is still a long way to go to achieve the government's goal of good and equal education for all.

1.3.2. Gender equality and social security

In 1997 the government formulated a National Gender Policy to promote the welfare of women in the Namibian society. It has also signed several international conventions and acts to combat the high rates of gender inequality, discrimination and violence against women. These interventions are slowly showing success, as for example more girls are being enrolled in school and tertiary education establishments, though there is still a big gender imbalance on the political, economic and business decision-making level. However, many of these inequalities have their roots in cultural and traditional perceptions of the role of women in society. In some population groups, women are not allowed to run a business or inherit the husband's property. These traditions make the

tackling of gender inequality an on-going challenge in an ethnically diverse country such as Namibia (ADB 2009).

Looking at the social security for its people, Namibia is one of the few SSA countries that has a social safety net for the elderly, people with disability, war veterans and orphans and vulnerable children. According to the 2001 census Namibia has more than 97 000 children under the age of 15 that have lost one or both parents, and this number is projected to increase to 250 000 children by 2021. These horrendous numbers are mostly a result of the HIV/AIDS epidemic. Even though the government has a safety net for orphans and vulnerable children, these institutions are often under great strain and lack financial back-up. On the positive side, the government has implemented a Social Security Act that provides for sick leave, maternity leave and medical benefits (WB 2009, WHO 2007).

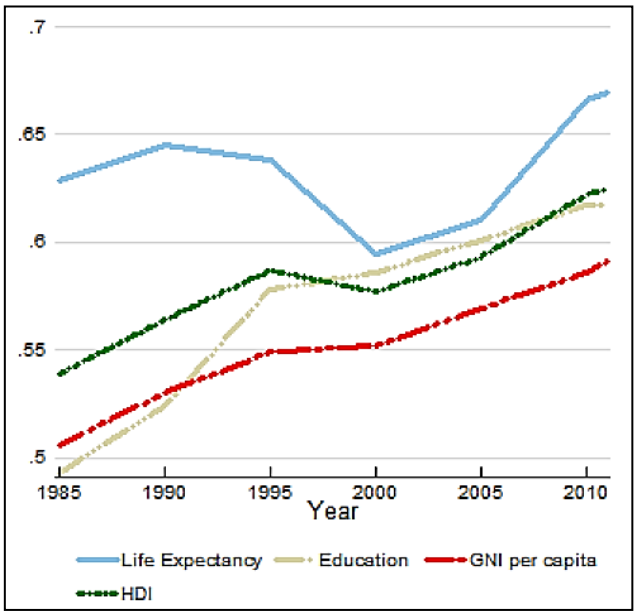
1.3.3. The Human Development Index

The Human Development Index[12] (HDI) is a way to measure development not only by economical means, but by combining three dimensions of human development: life expectancy, educational attainment and income – a decent standard of living (UNDP 2011).

In 2011 Namibia's HDI was 0.625, placing it in the medium human development category. With this index Namibia is in position 120 out of 187 countries and territories in the world (UNDP 2011). Since 1985, Namibia increased its HDI value by 16% (an annual increase of 0.6%). Looking at Figure 30 it becomes obvious that Namibia progressed in each of the HDI indicators over the past years.

[12] The educational dimension is measured by mean years of schooling for adults and expected years of schooling for children. The standard of living is measured by the Gross National Income (GNI) per capita. This index of social and economic development, expressed as a value between 0 and 1, is then published annually in the Human Development Report by the United Nations Development Program. For detailed information on the attainment of data and the calculation of the HDI the reader is referred to the website of the Human Development Reports as part of the UNDP website. The information is available at www.hdr.undp.org.

Figure 30 Trends in Namibia's HDI component indices 1985-2011



When looking at the Human Development Index, which takes life expectancy, educational attainment and income into consideration, Namibia has been improving in the past few years. In 2011 it was ranked number 120 out of 187 countries.

Source: UNDP 2011

Namibia's HDI has always been above the HDI value for SSA, but slightly below the world average and the average for the medium human development category. It compares favourably to its neighbours. For the comparison of the HDI of Namibia, SSA, medium human development category and the world see Figure 31.

Figure 31 Namibia, Human Development Index trends: 1985 - 2010

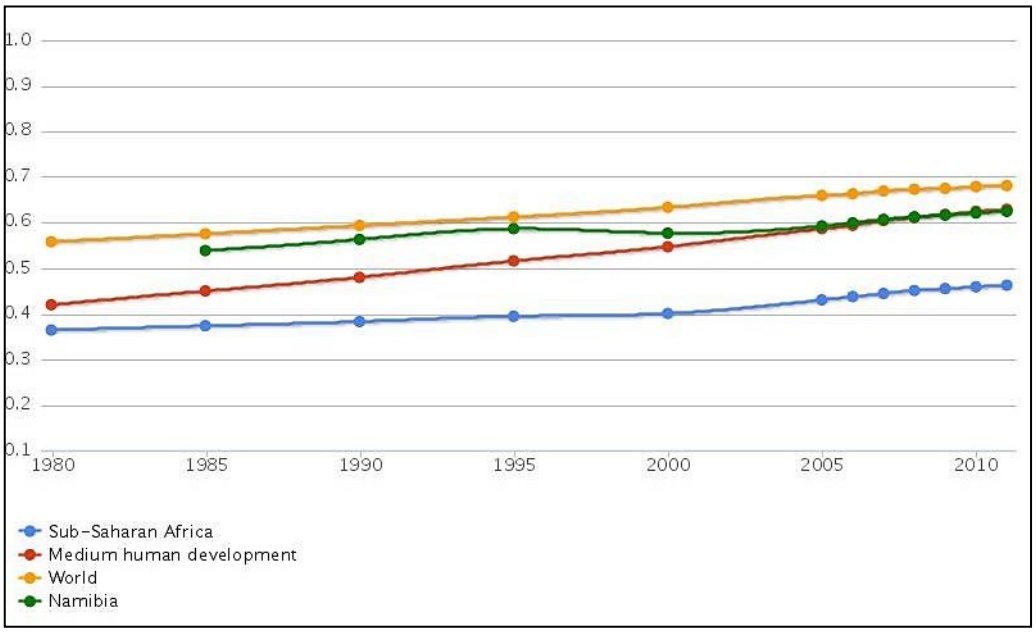


Figure 31 shows that Namibia's HDI lies above that of SSA. However, it also shows that while SSA improved its HDI, Namibia's was stagnant or only improved slightly.

Source: UNDP 2011

The HDI gives a measure of the development of the people of a nation. However, it does not take any inequalities in the distribution of development of the population into consideration. Therefore the inequality-adjusted HDI (IHDI) was introduced. This index takes into account inequalities in all three dimensions by discounting the dimension's score accordingly (UNDP 2011). Consequently, the HDI can be seen as an index of potential human development, while the IHDI is an index of the actual human development. The difference would then be the loss of potential human development (UNDP 2011).

When Namibia's HDI is adjusted for inequality it drops to 0.353, a loss of 43.5%. This is higher than the overall loss of SSA and medium HDI. The main portion is the loss due to inequality in income (Figure 32).

Figure 32 Namibia's IHDI for 2011 relative to selected groups

	IHDI value	Overall Loss (%)	Loss due to inequality in life expectancy at birth (%)	Loss due to inequality in education (%)	Loss due to inequality in income (%)
Namibia	0.353	43.5	21.1	27.8	68.3
Sub-Saharan Africa	0.303	34.5	39.0	35.6	28.4
Medium HDI	0.480	23.7	19.2	29.4	22.3

In order to consider inequalities in education, income and life expectancy within a country the Inequality adjusted HDI (IHDI) was introduced. When this calculation is applied, Namibia loses 43.5 %, mainly due to inequality in income. This IHDI is higher than the IHDI for SSA.

Source: UNDP 2011

Namibia has made great progress in the development of its people, however, as the inequality-adjusted HDI shows, there is still a long way to go until the whole nation will profit from the progress.

1.4. The economical context

The Namibian economy can be roughly divided into two sectors: the more modern market sector producing most of the country's income, and the traditional subsistence sector (US Department of Public Affairs [US DPA] 2011). The majority of the people are engaged in subsistence agriculture and herding, making this the more important sector that determines the day-to-day lives of many. Unfortunately, this branch is highly dependent on the often scare and variable Namibian rainfall (Sherbourne 2010). The formal market is based on capital-intensive industry and farming. Namibia's main earnings originate from a few vital export products in the primary sector[13], including minerals, livestock and fish. The tertiary sector also contributes heavily to the gross domestic product (GDP), reflecting the government involvement in the economy. The contribution of the secondary sector to GDP is only slowly increasing, even though this would greatly increase exports to other countries. However, according to the World Bank, Namibia is still lacking educated and skilled labour force to properly enhance this sector (US DPA 2011, Sherbourne 2010, ADB 2009, WB 2007). Figure 33 shows the contribution of each sector to the GDP.

[13] Primary sector: this sector extracts or harvests products from the earth and includes the production of raw materials and foods. This includes mining, agriculture, fishing, forestry, farming and hunting.
Secondary sector: this sector manufactures finished goods.
Tertiary sector: this sector provides services to the general public and businesses (Rosenberg 2011).

Figure 33 Contribution to GDP by sector

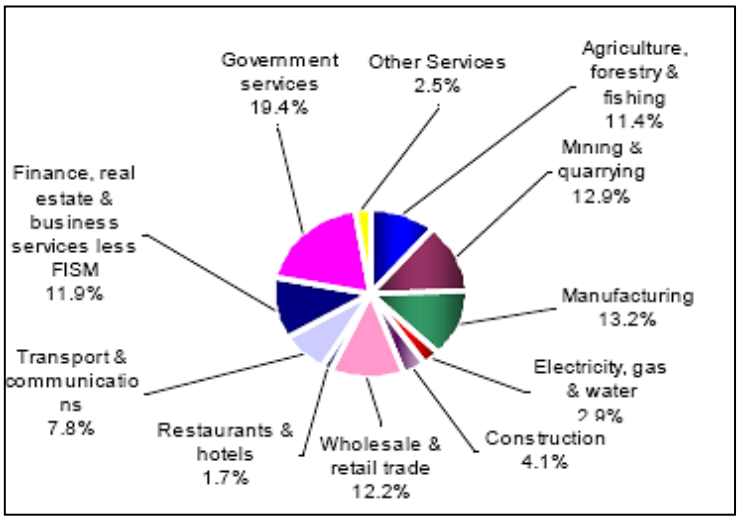


Figure 33 shows how much each sector is contributing towards the country's GDP.

Source: ADB 2009

1.4.1. The mining sector

The economy is mainly resource-based and driven by agriculture, fishing, mining and tourism (Yikona et al. 2011). The mining industry is by far the oldest, its origins dating back to the 16th century, and the largest industrial sector. Mining contributes over 17% of GDP and about 50% of its merchandise exports (Yikona et al. 2011, Sherbourne 2010, ADB 2009). On the other hand though, it employs less than 3% of the labour force due to its weak linkage to other economic sectors. Diamonds are Namibia's most important mineral resource, accounting for more than 70% of its export. After heavy losses of more than half of its exports during the world financial crisis in 2008, the diamond industry is almost back to its pre-crisis production levels of 2 million carats per year (US DPA 2011). The past decade has also seen the sudden rise in the worldwide demand of uranium and Namibia has become the fourth-largest producer of uranium worldwide, representing approximately 10% of the global uranium production (US DPA 2011, Yikona et al. 2011).

Before Independence South African mining companies dominated Namibia's market, however, today the mining industry is internationalised with companies such as De Beers (SA), Rio Tinto (Australia), Anglo American (USA) and further companies from China, France, Israel and the United Kingdom. Unfortunately, the government's new

Epangelo mining company lacks the capital and expertise to keep up with these international mining giants (Sherbourne 2010).

1.4.2. The agricultural sector

Another large sector of the Namibian economy is agriculture. Even though about 80% of the rural population and 35-40% of the total population depend on agricultural activities for a living, the sector contributes only 6% to the national GDP. This reflects low productivity in the sector (CIA 2011, ADB 2009). Subsistence farming is mainly confined to communal land, while commercial farming is spread over the whole country. Cattle farming is predominant in central and northern Namibia, while sheep and goat farming is more prevalent in the arid south (US DPA 2011).

While the growth of the national economy as a whole was on average 4.1% per year, the growth in agriculture was only 1.7% (Sherbourne 2010). The government is trying to enhance this sector by passing policies on loans for subsistence and commercial farmers and by forcing fruit and vegetable retailers to purchase at least 27.5% of their stock from local farmers (US DPA 2011). Other similar policies have been implemented, but according to Sherbourne (2010) none of the government's initiatives to increase the productivity of the sector seems to be bearing fruit. According to Sherbourne (2010) the poor performance can be put down to three characteristics that are absent in other sectors: unclear property rights, limited opportunities for foreign direct investment and government directed production (Sherbourne 2010).

1.4.3. The fishing sector

The Namibian coastline offers great opportunity for the fishing industry as it has an exceptionally high biological productivity (Sherbourne 2010). In 2010, fishing contributed almost 2.7% of GDP making it one of the significant sectors of the economy in terms of employment, export earnings and contribution to GDP (US DPA 2011).

1.4.4. The tourism sector

The potential of the tourism industry was discovered early by the government and the establishment of the Ministry of Wildlife, Conservation and Tourism was one of the first ministries to be established post-Independence. However, it took another 15 years

until the efforts of the government became earnest. The main infrastructure was put into place and efforts were undertaken to make Namibia an international tourist destination (Sherbourne 2010). In prior years, private investors and companies have developed a strong industrial sector. With the help of international donors, communal conservancies and community based tourism[14] has flourished (Sherbourne 2010). The tourism market has been, until recently, mainly dominated by whites and foreigners. In times of severe drought, the conversion of a commercial farm to a hunting or guest farm has saved many a one farmer. Unfortunately, the entry of black Namibians into the tourism market has been extremely slow, but as government support is increasing, so might the interest of black entrepreneurs.

The Namibian government soon realised that the beauty and uniqueness of the Namibian flora, fauna and landscape are of extreme value and thus it has become the first country in the world to include the protection of the environment into its constitution. 14% of the land is protected by the constitution, including virtually the entire Namib Desert coastal strip (CIA 2011).

1.4.5. Economic indicators

Namibia's economy is a small open economy that is closely linked to the South African economy (WB 2007). The World Bank classifies Namibia as an upper middle-income country with a per capita gross national income[15] (GNI) of U$ 4 270 in 2009. This is more than twice the average per capita income of SSA. Nonetheless, this high GNI per capita masks one of the most unequal income distributions in the world (US DP) 2011). According to the CIA Factbook and the newspaper 'The Economist' Namibia has the highest Gini-coefficient in the world. The Gini-coefficient measures the degree of inequality in the distribution of family income in a country (CIA 2011).

The Gross Domestic Product[16] (GDP) was U$ 9,3 billion in 2009 but increased to U$ 12,2 billion by 2011 (WB 2011, Yikona et al. 2011). This puts Namibia well into the

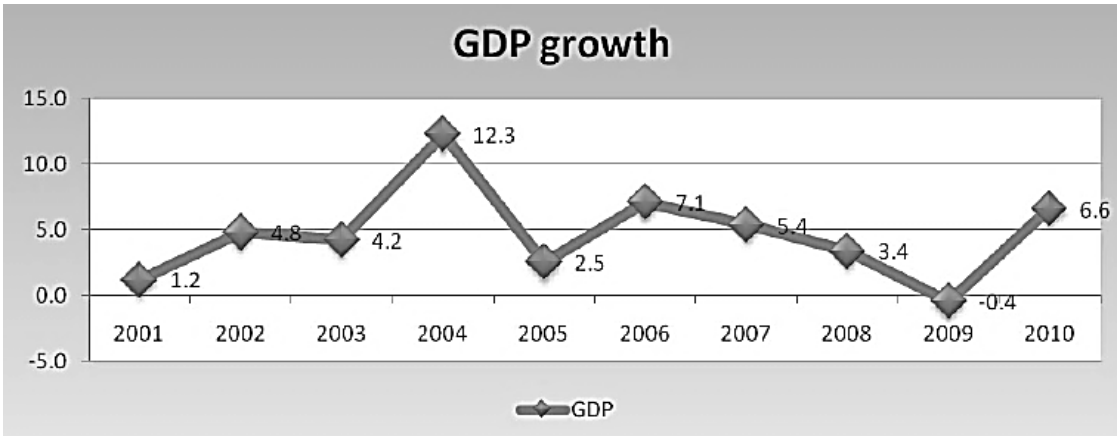
[14] Community-based tourism (CBT): CBT allows the traveller to spend time in the local destined community, learning about the way of life, traditions, culture and the local environment. This brings about financial benefits to the local community and allows for the conservation of the environment and the community structure (Planeterra).

[15] GNI: The GNI is a measure of the income earned, whether domestically or abroad, by Namibian factors of production by its people (CBS 2010).

[16] GDP: the GDP is the total value of goods and services produced within the country less raw materials, and other goods and services consumed during the production process (CBS 2010).

middle when comparing it to other southern African countries. The GDP showed a steady growth over the past years of an average of 4.8% (Figure 34). The financial crisis of 2008/2009 hit Namibia too, although not as hard as might have been expected: before the crisis the annual GDP growth rate projection for 2008-2011 lay at 5.2%, but dropped to almost 0%. This was mainly due to the slowdown in the mining sector. However, since 2009, the annual GDP growth rate has recovered and was at 6.6% in 2010 (CIA 2011, Central Bureau of Statistics [CBS] 2010, ADB 2009).

Figure 34 Namibian GDP growth, 2001-2010



On average Namibia's GDP grew at a steady 4.8% over the past years.

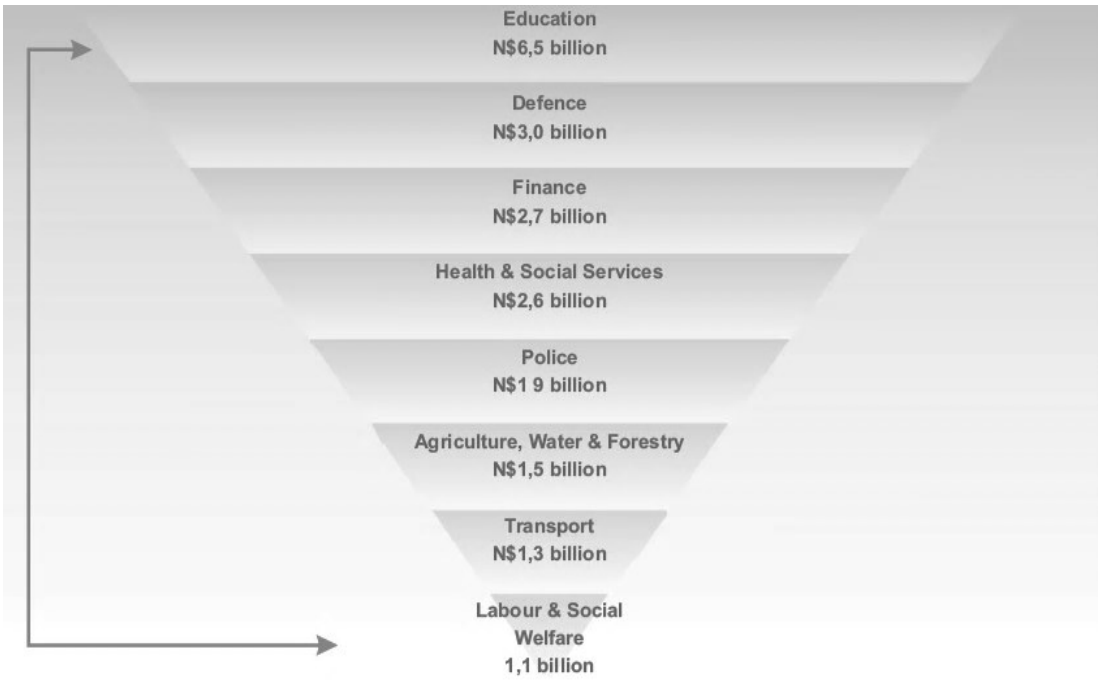
Source: CBS 2010

Each year Namibia's Minister of Finance presents the annual budget. This year, Mrs Kuugongelwa-Amadhila announced a planned budget deficit of 9.8% of GDP, the highest since Independence (Mwinga 2011). The aim is to maintain macroeconomic stability while consolidating economic recovery, creating jobs and improving the welfare of the Namibian people by implementing various new programs (Mwinga 2011).

The Ministry of Education has been allocated the biggest share of the 2011/2012 budget, followed by the Ministry of Defence, Ministry of Finance and Ministry of Health and Social Services. These account for over 51% of government expenditure (Mwinga 2011, Mwinga et al. 2011). It is expected that the Ministry of Finance will become the second biggest spender due to the interest rate on debt repayment by the government. The high spending on the social sectors (education and health) and

economic infrastructure (transport, roads, railways) shows the governments dedication to increase the social and economic development of its people (Figure 35) (Mwinga 2011).

Figure 35 Budget allocation per sector for the year 2010/2011



The largest part of the GDP is allocated to education, with health and social services being on fourth spot. This indicates the government's determination to increase the social and educational development if its people. However, the arrow indicates the large difference between money allocated to education and that allocated to labour and social welfare.

Source: Mwinga et al. 2011

1.4.6. Export, import and Namibia's trading partners

Namibia's economy is still heavily dependent on South Africa. The most important factor is that the Namibian dollar is tied to the South African rand, limiting the scope for independent monetary policies (US DPA 2011). Namibia imports about 65% of its food requirements, of which 70% comes from South Africa, making it heavily dependent on imports from this trading partner (ADB 2009). One-third of its exports is destined for South Africa or transits the country. Since Independence though, great efforts have been made by the government to diversify trading and more goods are now exported to the European Union, United Kingdom, Japan and Canada (US DPA 2011, ADB 2009, WB 2007). Due to this diversification the exports have tripled over the past ten years (CIA

2011). Nevertheless, imports have drastically increased as well, and only once over the past ten years the export rate exceeded the import rate (CBS 2010).

The Namibian market is small in size making the regional economic environment to a sustained economic growth. As such, Namibia is a member of SADC (see pg 92), the Southern African Customs Union (SACU) and several smaller regional programs. These unions have the aim to facilitate trade and join resources, for example the Trans-Kalahari Highway between Namibia, Botswana and South Africa, to enhance regional economic growth. Furthermore, the aim is to achieve a better human development as well as to maintain regional peace (ADB 2009, WB 2007). This opens a regional market of over 350 million consumers to the Namibian economy giving the prospect of diversifying its exports markets (ADB 2009).

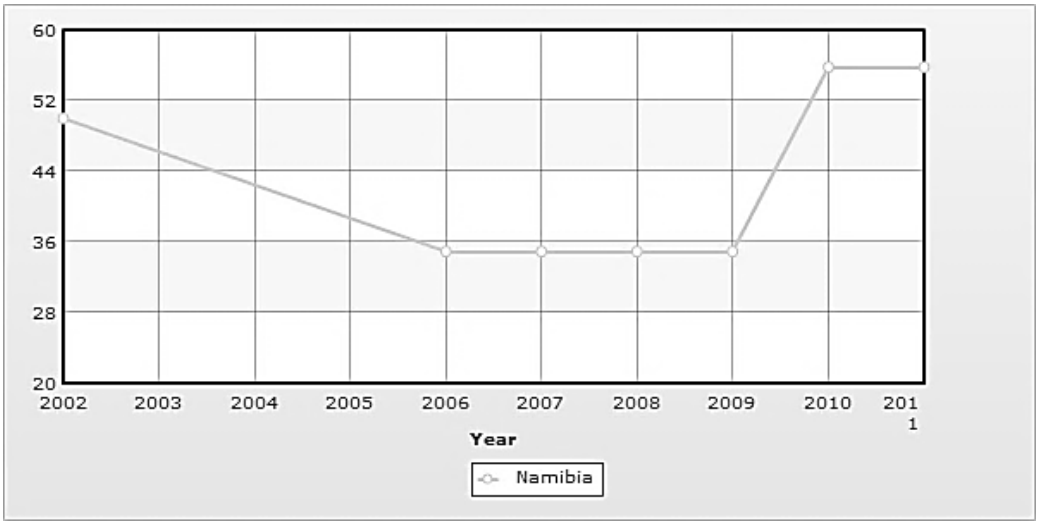
The political stability of the country as well as inviting policies and guarantees for foreign investors has made Namibia attractive for business and investment. An aggressive stance to eradicate corruption by the creation of an anti-corruption commission in 2005, respect for the rule of law and sound macroeconomic policies have ensured a moderate but steady economic growth making Namibia's economy one of the strongest on the African continent (ADB 2009).

However, the challenge of translating the economic growth into the reduction of poverty and unemployment remains ever present. According to the World Bank, the relative prosperity of the country is at risk, should high poverty rates, unemployment and inequality not be reduced in the near future.

1.4.7. Poverty and unemployment

Even though Namibia's GDP is moderately growing and the country is experiencing economic and social development, poverty is still widespread. This is a legacy of the dualistic society created under the Apartheid regime. Twenty-one years after Independence this problem has not been eradicated and poverty is as widespread as ever with over 55% of the population being classified as poor (Figure 36) (CIA 2011).

Figure 36 Population below poverty line (%)



In 2011 over half the population of Namibia was classified as poor by the CIA. Poverty is still widespread in Namibia even though steady increases in the strength of the country's economy are showing. This is due to Namibia's unequal distribution of income (see below).

Source: CIA 2011

The UNDP's 2005 Human Development Report estimated that 34.9% of the Namibian population live on $ 1 per day and 55.8% on $ 2 per day. Poverty is more a phenomenon of the rural areas, rather than the urban areas. However, as more and more people move into town, poverty also takes root here.

As mentioned above, Namibia has a Gini-coefficient of 70.7, making it the country with the most unequal distribution of income in the world (CIA 2011, WB 2007). The Multidimensional Poverty Index[17] (MPI) can also be used to assess the degree of poverty in a country. The most recent estimates available for Namibia refer to 2007 in which 39.6% of the population suffer multiple deprivations and another 23.6% are vulnerable to multiple deprivations as Figure 37 shows (UNDP 2011):

[17] MPI: This index identifies multiple deprivations in education, health and standard of living in the same household and a score is calculated using various indicators (UNDP 2011). If the household deprivations score is 33.3% or greater, all members of that household are multidimensional poor – meaning, not only lacking income but lacking education, health and standard of living.

Figure 37 Namibia's MPI for 2011 relative to South Africa

	MPI value	Head count (%)	Intensity of deprivation (%)	Population vulnerable to poverty (%)	Population in severe poverty (%)	Population below income poverty line (%)
Namibia	0.187	39.6	47.2	23.6	14.7	..
South Africa	0.057	13.4	42.3	22.2	2.4	17.4

Intensity of deprivation: average % of deprivation experienced by the people in multidimensional poverty

Head count: % of population with a weighted deprivation score of at least 33%

MPI value: share of the population that is multi-dimensionally poor, adjusted by the intensity of the deprivations.

Source: UNDP 2011

The government has implemented a number of policies and programs to address poverty including the poverty reduction strategy in 1998, rural and pro-agricultural development policies and land reform programs (ADB 2009).

The high rate of unemployment is another big challenge Namibians are facing. According to the most recent study the unemployment estimate is 51.2%, putting the country on place 192 of 199 countries (CIA 2011, Yikona et al. 2011). The unemployment rate among youths is much higher at 68%, with a higher rate in rural areas and among women as well (Yikona et al. 2011, ADB 2009). Yikona et al. (2011) argue that the underlying reasons for this unemployment are the unequal access and sometimes total lack of access to education. Joblessness among those with post-secondary education is almost non-existent. The lack of skilled labour is also threatening economic growth (WB 2007). In March 2011, the minister of finance announced 30% additional spending over prior years in an attempt to focus on public works and infrastructure to stimulate economic growth and lower the unemployment rate (US DPA 2011).

1.4.8. The Affirmative Action Employment Act and Black Economic Empowerment

The introduction of the Affirmative Action Employment Act in 1998 was an attempt by the government to reduce unemployment and decrease the inequality inherited from the Apartheid regime. The Act stated that equal opportunity in employment should be given to all Namibians, especially those from previously disadvantaged backgrounds

(racially disadvantaged, women and people with disabilities). It further stated that procedures to eliminate discrimination must be implemented (Republic of Namibia 1998). Businesses, retailers and shops had to apply this Affirmative Action Act and a commission was formed to advise businesses and monitor progress of implementation. The Affirmative Action Act was extended by the Black Economic Empowerment (BEE) policy. In theory, this provides for a more equal distribution in the ownership of private-sector firms in favour of previous racially disadvantaged Namibians by including a minimum partnership quote for BEE entities (Yikona et al. 2011). However, instead of reducing poverty and unemployment there is the growing suspicion that the BEE initiative has increased corruption and nepotism and favours politically well-connected Namibians (Yikona et al. 2011).

1.5. Conclusion

In conclusion, it can be said that in the bigger picture Namibia compares well to other African countries. It is a politically stable country with good governance and sound macroeconomic policies attracting increasing numbers of foreign investors. So far, economic growth has been moderate but continuous, and Namibia came out well of the worldwide financial crisis of 2008. Nonetheless, great disparities in income, wealth distribution and education remain. This and the high HIV/AIDS rate threaten to hinder further economic growth. In terms of social development and equality there is a long way ahead for Namibia. Some of the goals set out in the National Development Plan 3 are being achieved, while others remain a challenge. However, Namibians will continue to work hard to achieve Vision 2030[18] (ADB 2009).

[18] Vision 2030: mission of the government to create a fair, caring, committed nation, a democratic political system, competent and highly productive human resources and a healthy, knowledgeable and stable nation (ADB 2009).

2. The Namibian health system

2.1. The early days of the health system

The establishment of the Namibian health services dates back to the 1890s, when two hospitals were built for German soldiers[19], one in Windhoek and one in Swakopmund. In the following years more clinics were built by the Finnish Missionary Society, mostly in the northern part of the country (Ministry of Health and Social Sciences [MoHSS]). In later years, the health-care system was administered by second-tier authorities, divided into eleven different administrations each responsible for a respective region of the country (MoHSS 2008).

There were four characteristics of the newly established health services that were evident from the start and remained until Independence in 1990 (MoHSS report**).** Firstly, there was a continuous increase in the number of doctors in SWA, from nine in 1907 to 324 in 1991. The bulk of this development took place in the centre of the country though, as most whites, as the main recipients of the services, were living either in Windhoek or Swakopmund. Only in later years did the South West African (SWA)[20] administration provide more facilities also in the so called 'native reserves' or 'homelands' to serve the black population. In the beginning, these health services were funded by missionary societies, and the first free-of-charge medical services were supplied in 1935 at missionary hospitals. By 1966 however, the SWA administration subsidised all missionary health services (MoHSS).

The second major characteristic was the great disparity between health services for the white and those for the black population (MoHSS). Percentage wise there were many more and better-quality services available to the whites than to the blacks, which caused, for example, the infant mortality rate to be five to six times higher in the black population (MoHSS). The third main trend of the pre-Independence health services was the lack of preventative disease-control or educational health services. The central approach of the health services was a purely curative approach provided mainly in urban hospitals.

[19] Namibia, then still South West Africa was a German colony from 1884 until 1919.
[20] South West Africa: Until Independence, Namibia was called 'South West Africa (SWA)'.

After the Independence of Namibia in 1990, vast changes took place in the health-care system. The new government inherited a fragmented health-care and social welfare system that needed revision. These changes were first embodied in the policy statement of 1990 and then subsequently in the policy framework of 1998.

2.2. Set-up of the health system

One of the first tasks of the government was to form the Ministry of Health and Social Services (MoHSS) by uniting the eleven pre-Independence second-tier authorities (MoHSS 2008). The MoHSS is now organised in three levels in line with the policy framework of 1998 (see below) (MoHSS 2010). These three levels were introduced to increase the quality and equity of the services and to allow for a decentralisation of the management services.

The central level is the first level, consisting of the ministerial head offices, the offices of the permanent secretary, three departments and seven directorates. The functions of this central level are among others policy formulation, planning and review, strategic planning, legislation, the coordination of services and the performance management (MoHSS 2010). The second level is the regional level consisting of thirteen regional directorates heading the regional management teams and corresponding to the thirteen regions of Namibia. The functions of these management teams are among others the provision of leadership and management support to the region and the districts, the translation of central-level plans and policies into operational plans for implementation at regional and district level, coordination of services and activities to ensure equity and access of all districts, district level supervision and support as well as the management and coordination of stores and logistics (MoHSS 2010). The lowest level of the health-care system is the district level which is in direct contact with the communities. The 34 district levels are managed by medical officers with the following functions: ensuring effective and efficient implementation of regional directed projects and programmes, supporting community based activities, managing district resources and acting as a liaison between regional/central levels and community leaders or other partners in health development (MoHSS 2010).

2.3. Primary health-care approach

One of the most important changes made by the new government was the adoption of the primary health care (PHC) approach according to the Declaration of Alma Ata[21]. This approach has become the fundamental principle for providing public health-care services to the Namibian people (MoHSS 2010). This form of health-care puts great emphasis on equity of and access to health-care at affordable costs for all people (Hall & Taylor 2003). There is also strong focus on the prevention and control of prevailing health problems through education, promotion of proper nutrition, safe water supply and basic sanitation, vaccination, the control of locally endemic diseases, appropriate treatment of common diseases and injuries, and the provision of essential drugs. This should be achieved through strong involvement of the communities by for example community health-care workers, women groups or youth programmes as well as the participation of other ministerial sectors such as agriculture (Hall & Taylor 2003).

While the prevention and cure of common diseases and illnesses take place at the primary level, the curative care of more complex diseases is administered at secondary and tertiary levels, as medical care gets more sophisticated at higher levels. These levels were relatively strong before Independence and were thus either maintained or further strengthened and developed to provide an important national system of referral for the PHC services. Namibia has four tertiary level hospitals: Oshakati Hospital in the Oshana region, Rundu Hospital in the Kavango region and Katutura Hospital in the Khomas region. Windhoek Central Hospital serves as the overall national referral hospital (MoHSS 2000). The Katutura Hospital and Windhoek Central Hospital also act as teaching hospitals (MoHSS 2010).

2.4. Different entities of the health-care system

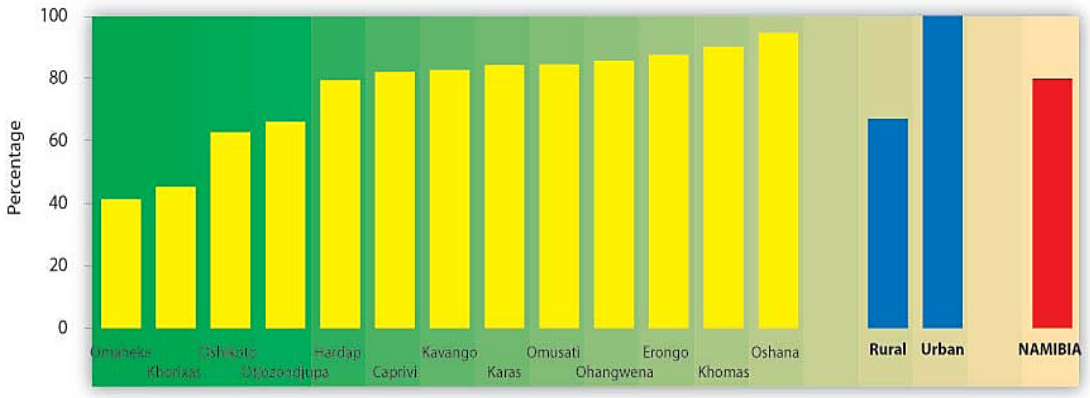
The Namibian health system is a pluralistic entity delivering services through various sectors with the public sector being the main actor (MoHSS 2010). In addition to this, health-care is provided by a large private sector, non-governmental organisations, faith-based institutions, as well as community-based providers and traditional healers.

[21] Declaration of Alma Ata: in 1978 all WHO member countries unanimously adopted a declaration adopting primary health care ‘as the means for providing a comprehensive, universal, equitable and affordable health care service for all countries’ (Hall & Taylor 2003).

2.4.1. The public health-care sector

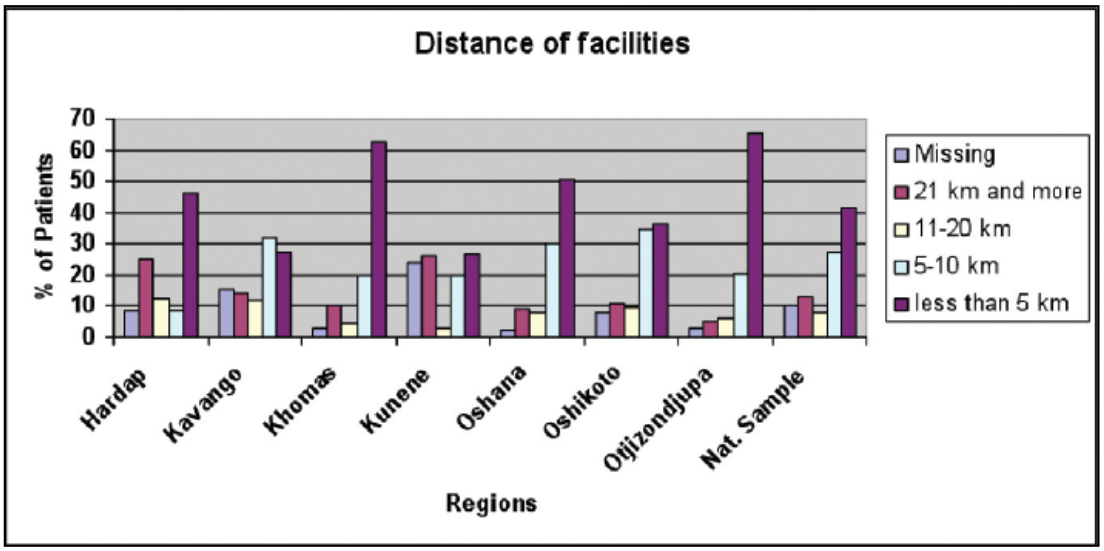
The public health service is made up of a four tier system with approximately 1 150 outreach points, 309 clinics and health centres, 29 district hospitals and four referral hospitals (Brockmeyer 2012, MoHSS 2010). These are distributed across the country with a concentration of facilities in the north, as this is where 60% of the population lives (MoHSS 2000). Despite the fact that the government greatly increased the number of clinics after Independence, the MoHSS estimates that still 21% of the population is living more than 10 km away from a health facility (Figure 38) (MoHSS 2010, MoHSS 2000). In their review report of 2008, the MoHSS published data showing that the situation has not greatly changed since 2000 (Figure 39). The long distances to the nearest health-care facility are mainly due to the vastness of the country being so thinly populated outside the urban centres, especially in the middle and the south of the country (Brockmeyer 2012, MoHSS 2010).

Figure 38 Percentage of people living within 10 km of a health facility in 2000



Source: MoHSS 2000

Figure 39 Distance covered by patients to reach health-care facilities in 2008



The two diagrams above show the percentage of people who lived within 10 km of the next health facility in 2000 and 2008 by region. The MoHSS estimates that even though more clinics have been built, not much has changed since 2000 and more than 21% of people were still living more than 10 km away from the closest health facility in 2008.

Source: MoHSS 2008

The efforts of the MoHSS to steadily improve the health-care of the Namibian people has resulted in the country having the highest number of beds per population (33 per 10 000) in the southern region. As with the health-care facilities though, there is a disparity between rural and urban distribution as well as inter-regional differences. See Figure 40

for details on the distribution of clinics/health-care centres, number of beds and population per clinic in the different regions:

Figure 40 Population and bed correlation to health-care facilities in the different regions

Region	Pop. (2007)	Total Beds	Beds per 10,000 pop	Pop. Per Hospital	Pop. Per Health Centre	Pop. Per Clinic
Ohangwena	251,111	454	***18.08***	83,704	***125,556***	6,975
Omusati	242,885	577	***23.76***	60,721	40,481	6,747
Oshikoto	175,650	567	32.28	87,825	58,550	***10,978***
Oshana	173,893	770	44.28	***173,893***	43,473	***15,808***
Caprivi	87,274	238	27.27	43,637	29,091	3,491
Kavango	268,701	661	***24.60***	67,175	38,386	5,971
Erongo	114,845	413	35.96	28,711	38,282	7,656
Kunene	75,518	250	33.10	25,173	25,173	3,596
Otjozondjupa	155,430	411	26.44	38,858	51,810	***10,362***
Hardap	69,072	349	50.53	34,536	17,268	5,756
Karas	73,954	355	48.00	24,651	24,651	5,282
Khomas	274,957	1531	55.68	***137,479***	***137,479***	***39,280***
Omaheke	75,102	195	25.96	75,102	75,102	6,259
National	**2,038,392**	**6771**	**33.22**	**58,240**	**46,327**	**7,692**

The table shows the distribution of clinics/health-care centres, number of beds and population per clinic in the different regions. Great disparities can be seen between urban and rural as well as inter-regional distributions of health-care.

Source: MoHSS 2008.

2.4.2. The private sector

Another major contributor to delivering health-care to the Namibian people is the private sector. There are 844 private health facilities registered in Namibia of which 13 are hospitals, 75 are clinics, eight are health centres and 557 are medical practitioners. These are concentrated mainly in the urban areas of the Khomas and Erongo regions (MoHSS 2010).

2.4.3. Faith-based institutions, NGOs and traditional healers

Faith-based institutions and Non-governmental Organisations (NGO) are also providers of health-care, and their significance has greatly increased over the past years. They are making a great contribution to the reduction of mortality and morbidity in the country by supplying mainly community-based health-care. Here they play an important

role, firstly by providing care in the communities and secondly by encouraging and training community volunteers. One such example would be the training of volunteer workers to care for chronically ill patients or to educate women on the importance of women's health and ante/postnatal care (MoHSS 2010, MoHSS 2008).

The WHO estimates that 80% of the people of Africa still use traditional medicine to meet their basic primary health-care (Kasilo et al. 2010). And even though traditional healers are still playing an important role in Namibia, especially in remote rural areas, little appreciation for their work is given by the various health-care providers (MoHSS 2010). According to the MoHSS, more effort should be made to include these healers into the system of care as they are often the first port of call and still enjoy great trust by many people (MoHSS 2011, MoHSS 2008).

2.5. The workforce of the health-care system

Looking at the workforce of the health-care system, Namibia is above the benchmark of the WHO (2.5 health workers per 1000 population) with 3.0 health workers per 1000 population (MoHSS 2010). However, there is a marked disparity between the workforce of health workers in the public and the private sector (Figure 41). While the private sector employs 72% of all doctors in Namibia and has a ratio of 8.8 health workers per 1000 population, the public sectors barely reaches a ratio of 2.0 health workers per 1000 population with a chronic shortage of doctors and nurses (MoHSS 2008). According to the report by the MoHSS on national health, 26.9% of posts in the public sector are vacant and the system relies heavily on the recruitment of expatriate doctors. Lengthy recruitment processes for government positions, salary scales not being correlated to level and years of training, no appropriate staff appraisal system and the lack of an appropriate policy on allowances are, according to the MoHSS 2010 just some of the reasons discussed for the high vacancy rates in the public sector.

Figure 41 Distribution of health professionals in the public and private sectors

Professional Category	Health Workers registered during 2006/07	No in Public Health Sector		No in Private Sector	
		No	Percentage	No	Percentage
Doctors	774	216	28	558	72
Registered Nurses *	2989	1626	54	1363	46
Enrolled Nurses *	2761	1884	68	877	32
Dentists	90	11	12	79	88
Pharmacists	239	27	11	212	89
Pharmacist Assistants	137	65	47	72	53
Occupational Therapists	48	15	31	33	69
Environmental Health Officers*	140	37	26	103	74
Environmental Health Assistants	58	37	64	21	36
Social Workers *	250	76	30	174	70
Orthotists	14	4	29	10	71
Orth. Technician	26	26	100	0	0
Radiographers	109	27	25	82	75
Radiographic Assistants	62	32	52	30	48
Total	**7697**	**4063**	**53%**	**3634**	**47%**

*No in private and other Gov-sectors than health sector

Source: MoHSS 2008

Furthermore there are great disparities in the distribution of health workers between urban and rural areas, with as many as 76.4% of doctors, 89% of dentists and 98.5% of physiotherapists working in urban areas (Figure 42) (MoHSS 2008). No special incentives for retaining staff in remote areas are in place resulting in less willingness of the employees to either remain in or move to rural areas. This results in a high workload and therefore a high attrition rate in the rural public sector.

Figure 42 Urban/Rural distribution of health workers

Professional Category	Total no. registered 2004/2005	Urban		Rural	
		No	Percentage	No	Percentage
Doctors	598	457	76.4	141	24
Nurses (Registered and Enrolled)	6214	3,767	61	2,378	39
Dentists (Dental Assistants included)	113	101	89	12	11
Pharmacists (Pharmacist assistants included)	288	198	68	92	32
Physiotherapists	68	67	98.5	1	1.5
Occupational Therapists	30	28	93	2	7
Environmental Health Officers (Env. H Assistants included)	240	107	45	133	55
Social Workers	270	230	85	40	15
Psychologists	68	67	98.5	1	1.5

Source: MoHSS 2008

The training and education of health workers takes place at various institutions. In the past doctors, pharmacists and dentists had been trained outside the country, but with the establishment of a national medical school at the University of Namibia (UNAM) in 2010, more health workers are now trained in Namibia. Registered nurses, radiographers and social workers are also trained at UNAM, while the Polytechnicon of Namibia offers courses for environmental health officers and medical laboratory technicians. One national health training centre and four regional health training centres are available to educate enrolled nurses, pharmacy assistants, radiographers and environmental assistants (MoHSS 2010). In order to further increase the workforce, the MoHSS awards bursaries and financial assistance to students who cannot afford tertiary education.

2.6. Financial aspects of the Namibian health system

2.6.1. Health-care funding

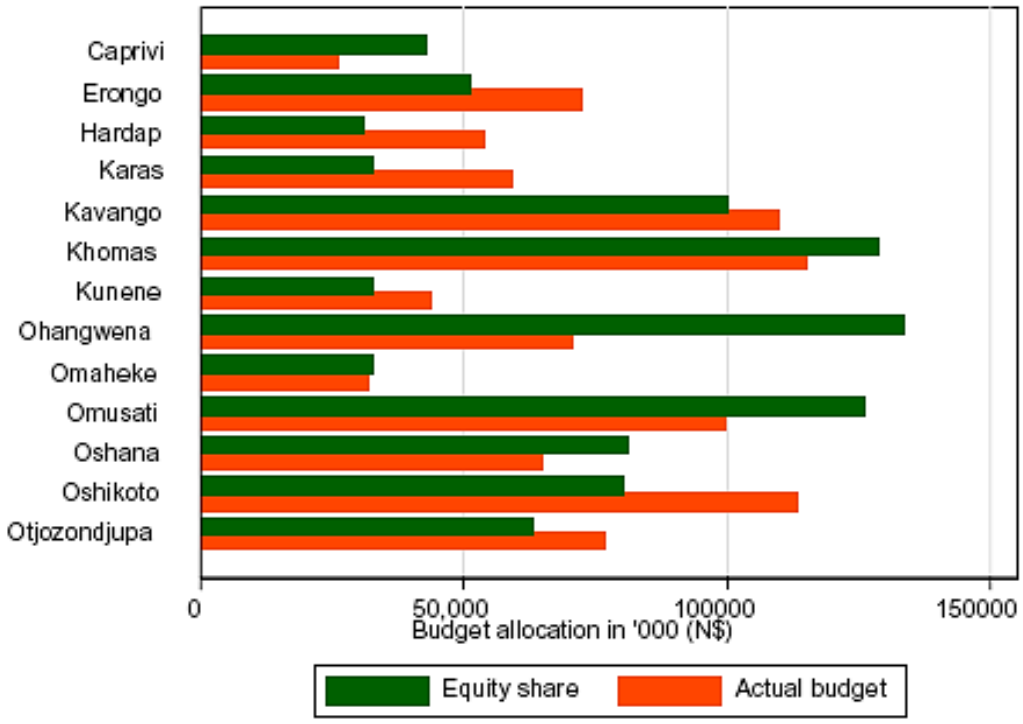
The financing of the Namibian health system comprises a mixture of public and private contributions. The public system, predominantly funded through general taxation, provides universal coverage. Namibia's total health expenditure as a percentage of GDP has averaged 6.7% (N$ 1 264, appr. €120) comparing favourably with other countries in the Southern and Eastern African region. Government spending on health as a percentage of total government spending has averaged 12.2% over the past years, with a high of 13.5% in 2010 (MoHSS 2010).This is the highest in the region, however, it still falls short of the Abuja Declaration[22] stating that African governments should spend 15% of their funds on health by the year 2015 (MoHSS 2008).

Taking the PHC principles as the basis, the Namibian government has made 'equity' one of the main guiding principles in allocating health-care resources. This is done in order to improve health-care for the poor and disadvantaged and to even out pre-Independence disparities (Zere et al. 2007). In addition, the government's Poverty Reduction Strategy (PRS) commits it to reduce the inter-regional health expenditure per

[22] Abuja Declaration: In 2001 the members of the African Union pledged to increase government spending on health to at least 15% by 2015. In 2011, only Tanzania had reached this goal, 26 countries increased their spending but were still short of the 15% (including Namibia) and nine countries reduced their spending since 2001 (WHO 2011).

capita by distributing resources appropriately. However, Zere et al. (2007) state that this re-allocation of resources is not yet taking place effectively (Figure 43), so that poorer regions are still left behind in the improvement of their health-care services. One of the main reasons for this is that budgeting is still based on historical policies, rather than disease-burden orientated and needs-based concepts (Brockmeyer 2012, Zere et al. 2007).

Figure 43 Equity share vs. actual budget for the financial year 2000/2001



Source: Zere et al. 2007

The private sector, funded largely by employees and employers contributions, adds 25% to health-care spending. However, the proportion of health financing from both the government and the private sector has been declining over the past years. The proportion of contributions by international partners, largely targeting special programmes, NGOs and civic organisation has increased from 3.7% in 2000 to 19.7% in 2005 (MoHSS 2008). For the most part these funds are managed and distributed by the donors or the NGOs.

2.6.2. Fees and health insurance

The fees patients have to pay vary between the different levels of health-care and between the private and public sector. The fees in the public sector range between N$ 4 (appr. €0,40) at clinic level to N$ 30 (appr. €3) at the level of national referral for state outpatient visits. The increase of the fees at higher health-care levels aims at encouraging people to use the primary health-care facilities, thus helping to decongest the district and referral hospitals (MoHSS 2008). Exempted from the payment of user fees are vulnerable groups such as children under five and pregnant women as well as the use of preventative and promotive services. The fees having to be paid at private health-care facilities are much higher and vary greatly.

Namibia does not have a national medical-aid scheme, which means that 1,5 million Namibians, 85% of the population, who cannot afford private health insurance rely on the primary health-care setting at the above mentioned rates and often horrendous services (see 'Challenges faced by the MoHSS', pg 121) (Brockmeyer 2012).

The private health industry is driven by a medical insurance system similar to that of western countries. There are several medical-aid funds, including the Public Service Employee Medical Aid Scheme for all civil servants (Brockmeyer 2012). Payment to these medical aids is either done by the employer or privately and ranges from N$ 1000 per month upwards according to the coverage chosen, allowing for total coverage of outpatient and inpatient costs. However, even the cheapest schemes offered are often too pricey for low-income workers, resulting in 38% of the Namibian workforce (200 000 of 530 000) not being insured (Brockmeyer 2012).

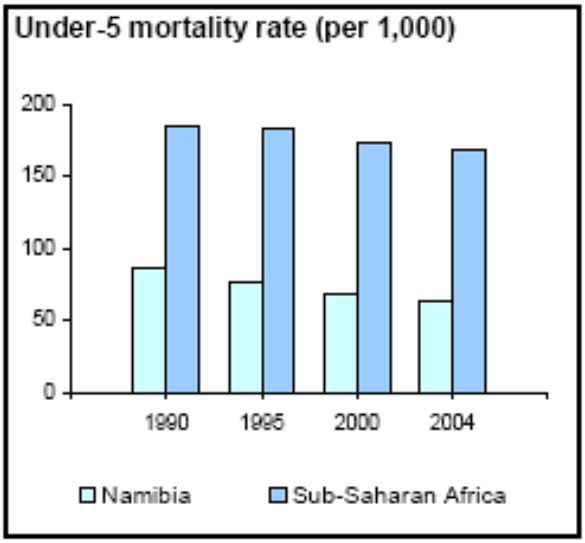
2.7. Epidemiological profile

2.7.1. Indicators of health status and health-care delivery

Looking at the epidemiological profile of the health status of the Namibian people, the country compares favourably to other countries of Sub-Saharan Africa (SSA) in most key indicators (MoHSS 2008). The infant mortality rate lies at 46 per 1000 live births and the under-five mortality rate at 69 per 1000 live births compared to a rate of 94 and 157 respectively in SSA (Figure 44). According to the health report 2000 by the MoHSS, the top five causes of child mortality are acute respiratory infections, gastroenteritis, malnutrition, HIV/AIDS and malaria. It was found that 17% of children

were underweight and 4% severely underweight, while one-third of the Namibian children were found to be stunted and 10% severely stunted (MoHSS report 2008).

Figure 44 Under-five mortality rate Namibia and SSA



Source: World Bank 2007

The maternal mortality rate however lies at 449 per 100,000 live births, which is almost double the rate than 1992. The main causes for such a high maternal mortality rate are haemorrhage, eclampsia, obstructed labour, sepsis and HIV/AIDS, combined with a drastic lack of emergency obstetric care. Delayed referrals and absence of surgeons for caesarean sections further aggravates the situation (MoHSS 2008). Looking at adults in general, in 2007 the main causes for adult inpatient mortality were HIV/AIDS, diarrhoea, pulmonary TB, pneumonia and other respiratory diseases (Figure 45) (MoHSS 2008).

Figure 45 Top 10 causes of adult inpatient death in Namibia, 2007

Rank	Cause of Death	No. of Deaths	% of all Deaths
1	HIV	1608	24.76
2	Diarrhoea	1269	19.54
3	Pulmonary TB	1092	16.82
4	Pneumonia	990	15.24
5	Other Respiratory system disease	332	5.11
6	Heart failure	310	4.77
7	Anaemia	263	4.05
8	Malnutrition	217	3.34
9	Malaria	209	3.22
10	Hypertension	204	3.14
	Total	**6494**	

Source: MoHSS 2008

2.7.2. The HIV/AIDS epidemic in Namibia

Namibia has been hit hard by the HIV/AIDS epidemic. The first case in the country was reported in 1986 and the epidemic grew rapidly thereafter until 2000, reaching a high of 35% in 2000, since when a stabilisation and decline in the infection rate was detected (MoHSS HIV/AIDS 2008, MoHSS 2008). The disease has been classified as the disease with the highest national public health priority. A health survey conducted in 2007/2008 showed that the prevalence of HIV among the adult population only (15-49 years) was 15.4%. The estimated rate of new infections lies at 39 new infections per day (MoHSS HIV/AIDS report 2008). According to sentinel surveys conducted at birth-clinics the rate of infected pregnant women lies at 20% with great disparities between the different regions (31.7% in Katima Mulilo and 5.9% in Aranos) (MoHSS 2010).

In 2003 Antiretroviral (ARV) treatment was introduced in Namibia by the government and the HIV/AIDS epidemic has become a manageable chronic disease since then. Currently there are 86 539 people on an ARV treatment plan, which is 84% of the eligible population. These include 5 900 children under the age of 14 years (MoHSS 2010). In addition, prevention of mother to child transmission (PMTCT) has been successfully implemented at almost all target sites. However, the utilisation of voluntary counselling and testing services is at 25% very low in the adult population. Prevention of transmission has been prioritised as the main strategy to combat the

epidemic. This is focussing amongst others on achieving changes in sexual behaviour (reduce age of sexual debut, multiple partnerships and intergenerational sex), PMTCT, HIV counselling and testing and increasing male and female condom use (MoHSS HIV/AIDS report 2008).

2.7.3. Non-communicable diseases in Namibia

Over the past few years, lifestyle related health problems and NCD such as hypertension, DM and chronic obstructive pulmonary disease are increasingly becoming a public health problem and important causes of morbidity and mortality in the country (MoHSS 2010, MoHSS 2008). Health facility based data indicate hypertension and DM as the first and second cause of disability among adults, while the death rate due to NCD has increased from 5% in 2005 to 8% in 2007 (MoHSS 2008). According to the MoHSS, the reason for such an increase in NCD is the rapid modernisation taking place in Namibia and the negative health impact this is having on poor and affluent people alike (MoHSS 2010).

2.8. Challenges faced by the MoHSS

Demographic and health surveys (DHS) were conducted in 1992, 2000 and 2006 by the MoHSS, firstly to set up goals and draw strategic plans on how to improve the health-care sector for the whole Namibian population and secondly to analyse trends in essential key indicators (infant mortality rate, under-five mortality rate, maternal mortality rate). There was a great improvement in the key indicators between 1992 and 2000; however the DHS conducted in 2006 showed a decline of the health status of the Namibian people (MoHSS 2008).

One of the huge challenges faced by the health-care providers is the vastness of the Namibian country and its people being so widely dispersed. This causes accessibility problems for many patients, 13% of whom have to travel more than 21 km to reach the nearest health-care facility. In many regions there is a lack of transport to cover these distances or to ensure an adequate referral system between the different levels of care (MoHSS 2008). In order to overcome these challenges, outreach clinics were established by the MoHSS, but many of these services are unfortunately not functioning optimally, again due to a lack of transport to various remote areas. The government has trained over 5 000 community health workers, but there are no clear structures to

support their work in the community thus resulting in the breakdown of many community based health-care services. Furthermore, volunteer workers in the communities have no incentives and do not receive adequate support from the communities and health workers, thus this system as well is failing in many areas (MoHSS 2008). Especially in remote areas, many health facilities are poorly maintained due to inadequate funding, failure of material and poor supervision. In addition, these facilities often lack clean water, sanitation and electricity (MoHSS 2008).

There is, at the moment, no coordinated system to regulate the use and management of ambulance services, and a lack of funds hampers the maintenance and replacement of ambulance vehicles. The lack of funds further hinders the acquisition of sufficient vehicles. Only very few ambulance drivers in Namibia actually have the skills to attend to patients in an emergency pre-clinical situation (MoHSS 2010). Namibia is also lacking a national public health laboratory. Currently, all analyses by the public sector are done by the National Institute for Pathology (NIP), an autonomous entity.

The public health sector suffers under a great workload due to chronic staff shortages. Therefore, a high attrition and burn-out rate of the health workers are seen, reducing the services given to patients. Many regions and districts do not offer any in-service training for their staff and continuing education to improve health-care is greatly limited (MoHSS 2008). The chronic shortage of staff, especially doctors, in the public sector results in many patients not receiving adequate and sometimes lifesaving treatment (MoHSS 2010).

Looking at the management levels of the health system, a great lack of coordination and interaction between divisions and between vertical levels has been noted, according to the MoHSS. Plans, activities and programmes are not discussed at all levels, policies are implemented without the knowledge of the management or policies are drafted without ever being implemented (MoHSS 2010, MoHSS 2008). The supervision at different levels was found to be very unsatisfactory, and especially at district level there is often a complete lack of supervision and support for the health workers. This does not allow for services to be optimised (MoHSS 2010, MoHSS 2008).

The above-mentioned points show the scope of challenges the Namibian government and especially the MoHSS is faced with. No easy task. However, great improvements

have taken place since Independence to ensure health-care for all Namibians and the Namibian government is working continuously to further improve the health-care system.

3. The Ovahimba

3.1. History of the Kunene region and the Ovahimba

The history of the Ovahimba tribe goes back a few hundred years and is marked by times of war, drought and flight, but also by times of peace, pastoralism and animal husbandry while moving around in the north of Namibia and south of Angola.

The Bantu-speaking people travelled southwards from what appears to be central Africa in the 16th century. Among these people, a group then called the Herero, settled in the present Moçamedes Province of southern Angola. In the 1760s this part of Angola was drawn more and more into the transatlantic slave trade with its often associated violent conflicts and social disruption. This caused the Herero people to travel further southwards, first to the grassy plains north of the Etosha Pan. Here a strong presence of Ovambo people forced the Herero to turn westwards towards the more arid and mountainous Kaokoland (Bollig 2002, Malan 1974). The Herero people lived here for two centuries until repeated attacks and cattle raids by the neighbouring Ovambo people brought about another southwards movement of the Herero people to their present location in central Namibia (Bollig 2006, Malan 1974). A small number decided to stay behind though, and became known as the Ovahimba. Thus, according to the elders of the Ovahimba, the origin of their people is a small mountain called the *Okarundu Kambeti* in the mountainous area north of Ruacana from which their forefathers travelled south until they reached Kaokoland (Bollig 2002).

3.1.1. Early days in southern Angola and northern South West Africa

The Ovahimba, also sometimes called the Kaokoland-Herero[23], adopted a lifestyle of pastoralism and animal husbandry, roaming the north-western parts of Namibia in search of water and grasslands for their cattle; a nomadic lifestyle many Ovahimba still lead today. Unfortunately, the peace could not be maintained for long. During the years 1850 to 1870 marauding groups of Swartbooi and Topnaar Namas, having immigrated from the Cape Province (South Africa), raided most of the Ovahimba cattle. These so-called 'Oorlams commandos' were well-armed as they had already traded cattle for weapons from the European settlers. Thus the Ovahimba, especially due to their

[23] Kaokoland lies in the north-western part of Namibia, bordering the Kunene river in the north and the Atlantic ocean in the west. It is part of the Kunene region, which extends further south. The Ovahimba, however, reside mostly in Kaokoland only (Figure 47).

extended living space, were not able to offer much resistance. The old traditions are filled with detailed accounts of what was named 'The gun of *Kaukumuha'* painting a picture of continuous raiding, brave resistance and heavy bloodshed. By 1880, most Ovahimba had fled to Angola to seek refuge with family and friends (Bollig 2002, Malan 1974, Malan 1973, von Koenen, undated).

Figure 46 Map of Southern Africa

A map of southern Africa, showing the present-day countries through which the forefathers of the Ovahimba people moved during their migration to south western Africa. Angola and Namibia can be made out and it is here that the Ovahimba people live. During times of war, the Ovahimba took refuge in southern Angola. Available at: www.map-of-africa-com.

In Angola the refugees came into contact with the Portuguese colonialists, who were boosting their country's economy by establishing commercial hunting businesses, large agricultural farms and sugar-cane plantation. Here, many Ovahimba men found work to earn money in order to buy guns and household goods and to restock their herds. By 1890 the Portuguese colonial army was the single most important employer for the Ovahimba men, who were working as mercenaries (Bollig 2006). After the devastating Rinderpest epidemic in 1897, when almost 90% of cattle died, the Ovahimba became even more dependent on working for the Portuguese. The refugees were soundly involved with the growing colonial economy, not only through their labour, but also through trading. However, after the liberal revolution in Portugal in 1910, the Angolan military administration was changed to a civil administration and there was no need for mercenaries anymore (Bollig 2002, Bollig undated). Gathered around a young Tswana man called Vita, the Ovahimba had managed to attain some weapons and a considerable

amount of cattle by helping the Portuguese army with their 'punitive expeditions' against revolting locals. After the news about Germany's defeat in World War I reached south Angola and after having restocked their herds considerably, the Ovahimba moved back to Kaokoland (Bollig 2002, Malan 1974).

Not all Ovahimba had fled to Angola during the raids by the Oorlams commandos. Some stayed behind and having lost all their cattle had to turn to hunting, gathering and keeping small livestock, such as sheep and goats. This gave them the name 'Tjimba' derived from the word *onjimba-ndjimba* meaning 'aardvark', an animal which digs in the ground to find food. The name 'Tjimba' had a rather derogatory connotation in earlier days (Malan 1974). Tjimba often worked for Himba[24] or Herero people herding the cattle. A poor Tjimba who achieved prosperity could become a Himba (or Herero) and a not hard working Himba or Herero could become a Tjimba. Even though the Himba-Tjimba division still exists today, the difference between these two groups has subsided (von Koenen, undated).

3.1.2. The Kaoko region under South African rule

When Germany had to hand over SWA/Namibia as a protectorate to South Africa after World War I, the South African government immediately ran an extensive disarmament campaign in the region, taking all weapons from the pastoralists. In 1923 then, the Kaokoland was divided into three smaller reserves to be governed by three different chiefs, who would act as middlemen between the people and the South African administration. Until that time the Ovahimba had never had any traditionally legitimised chiefs. Thus, C.H.L. Hahn, Native Commissioner for Ovamboland and Kaokoland from 1923 to 1947, had to appoint three chiefs. People had grouped themselves around three men to whom they paid allegiance and loyalty and it were these three men that Hahn made chiefs: Kakurukouye, Muhonakatiti and Vita Tom, giving the latter predominance (Bollig undated, Hihanguapo 2000). The colonial power was further strengthened by police patrols and tribal authorities. Besides maintaining strict control over the people in the Kaoko region, another aim was to isolate the region from the central part of the country. In order to achieve this, pass-laws and new laws were implemented and new

[24] Himba: Himba are a sub-group of the Ovahimba. They form the largest group within the Ovahimba society and the two names are often used interchangeably (Malan 1974). We will use the term 'Ovahimba' unless the specific 'Himba' sub-group is meant. For other sub-groups within the Ovahimba society see 'The people of the Kunene region and Kaokoland' (pg 130).

boundaries drawn: interior boundaries between chiefdoms were established. The Kunene river, acting as a border to Angola, was strictly controlled and a boundary between the Kaokoland and neighbouring Ovamboland was installed. These greatly hindered the movement of the nomadic Ovahimba and their herds and active trading with the Ovambo and the people of southern Angola, became very difficult (Bollig 2006, Hihanguapo 2000, Rizzo 2000).

In the late 1920s, a major part of southern Kaokoland was cleared. People living there were forcefully resettled to other parts of the region in order to create a major buffer zone between Kaokoland and the commercial farms further south[25]. In addition all trade, national (Ovamboland) and international (Angola), involving livestock products was categorically prohibited. For every movement of their herds, the Ovahimba had to apply for a permit. Every visitor had to undergo a lengthy process of applying for a visa. In this way Kaokoland was successfully isolated from the rest of the country and its neighbours, and livestock movement, important for pastoralism, was almost impossible. By the late 1940s the effects of the isolation policy started to show in that clear borders between the Kaoko groups were visible, most economic activities had come to a halt and the people were forced into subsistence farming (Rizzo 2000). C.H.L. Hahn ensured that all the laws were abided by and harsh punishments, for example the shooting of a whole herd of cattle, were carried out (Bollig 2006, Rizzo 2000). According to Bollig it was not only the trading relations and settlements that the Ovahimba lost, but also vital grazing grounds for their herds, especially in times of drought. In 1939, the region was hit by a devastating drought, but the Ovahimba were not allowed to take their cattle to the wetlands of the Kunene river which had until then been a last resort in times of little rain.

The infamous 'Odendaal commission'[26] recommended that development in Namibia could only be achieved by ethnical separation of the various population groups. It described Kaokoland as 'an especially underdeveloped, isolated region with its economy based solely on livestock husbandry'. Furthermore, the commission described

[25] Creating this buffer zone called the 'red belt' was done to protect commercial farms further south from any animal diseases coming from the Kaoko region and furthermore to exclude the pastoralists from trading in the rest of SWA. Until then, the pastoralists had a great share in the cattle trading of SWA.

[26] The commission, officially known as 'Commission of Enquiry into South West African Affairs', was named after its chairman Fox Odendaal. It was established by the South African Apartheid administration in order for it to study Namibia and look for ways to improve the country's development.

the people as 'lazy and unwilling to participate in the country's economy' (Botha)[27]. For more information on the Odendaal report the reader is referred to the article by Dr. Christo Botha 'The Odendaal Plan: "Development" for colonial Namibia'.

3.1.3. The fight for freedom in the Kaoko region

Until the early 1970s, Kaokoland was isolated from the rest of SWA, but things started to change when the South West African People's Organisation (SWAPO) and the Peoples Liberation Army of Namibia (PLAN) started building up a base in southern Angola. From here, these organisations, as the main opponents to the South African Apartheid regime planned a second attack line. Although the actual war between SWAPO and PLAN fighters on the one side, and the South African Defence Force (SADF) and the *koevoet* fighters[28] on the other, took place in southern Angola, it was taken into Kaokoland when SADF established three bases in Opuwo (the regional capital), Okongwati and Ehomba to check the advances of the guerrillas. Pastoralists were forcefully resettled near these stations to avoid guerrilla support to the freedom fighters and *koevoet* fighters recruited heavily among the young Ovahimba men (Bollig 2006, Bollig 2002, Rizzo 2000). Many of the Ovahimba families were struggling dearly with the huge loss of cattle during the preceding drought and thus joining the *koevoet* units was a way for Ovahimba men to cope. Other times they were taken as hostages by the PLAN and SWAPO fighters. Many roads in Kaokoland and southern Angola were scattered with landmines and soon grazing movement and nomadic routes were restricted for fear of personal safety (Bollig 2006).

3.1.4. Further hardship in the region

Not only war and isolation made life difficult for the people of Kaokoland, but the repeating droughts affecting Namibia every few years also left their mark on the people and their livestock. The first drought mentioned in the Ovahimba oral traditions is the *Ondjara oya Katurambanda* – 'The year of pounding the leather clothes' in 1915, when food was so scarce that the preparation of skins and hides as food was the last resort to prevent death by hunger. In 1929/1930 and 1932/1933 this was followed by the 'Famine

[27] Please note that this is a summary of the Odendaal report on the Kaokoland and its people. It does in no way represent our view.

[28] *Koevoet* fighters were paramilitary fighters known for their harsh and brutal methods of training their fighters and bringing down their enemies.

of Licking the knife' – *Karasaruvyo*, in 1941 'The Famine of chasing away the Hungry' and in 1946 by the 'Famine of eating the Horse' – *Kariekakambe.* During these last two droughts, when permission for any movement within Kaokoland had to be attained by the regional administration, the latter did not give permission for free movement, neither for lifting the ban on bartering with the Angolans nor using the Kunene area as grazing ground for the cattle (Bollig 2006). The next drought hit Namibia in the late 1950s early 1960s and lasted for four years. It is called 'The drought of Omasitu and Tjimbundu' in the Ovahimba oral traditions, and 50% of cattle died in that drought. The worst drought was yet to come. In 1981 disaster struck Kaokoland, when the effects of the violent conflict, the isolation and a severe drought added up to kill 90% of the Himba cattle – between 110 000 and 16 000 (Bollig 2006). This time, Kaokoland became an emergency zone and famine relief was handed out by the government and the International Red Cross.

3.1.5. The Kaoko region after Independence

When Namibia gained Independence in 1990, the region could open its borders again, except for the southern border of Kaokoland which still requires a three months quarantine for any livestock trading across this border for fear that highly infectious animal diseases (such as foot and mouth disease, bovine pneumonia) could spread to the rest of the country. However, cattle can be taken to the abattoir in Oshakati and of all the cattle now slaughtered at this abattoir 49% come from the Kaoko region. Other major development projects had been planned for the region mainly in the area of mining, livestock marketing and the building of a huge hydro-electric dam. Some were successful, others were not successful or, as in the case of the hydroelectric dam, were not implemented (Bollig 2006). In addition, boreholes were sunk for clean drinking water and watering places for the cattle were built across the area at strategic points. This was already started in the 1960s and 1970s when the South African administration started modest developments in the area, such as the named boreholes and watering places, as well as the first government hospital and primary school. These development efforts were further expanded after Independence in 1990. For example, great efforts have been made to introduce mobile schools and outreach clinics, the success of which is unfortunately still outstanding in many areas (Bollig 2006).

Kaokoland and northern Kunene region were the topic of many international discussions among environmentalists, anthropologists, economists and engineers in what has become known as 'The Epupa Project'. In 1995, the Namibian government drew up a plan to build a huge hydroelectric dam in the Kunene valley which would free Namibia of its electric dependence on neighbouring countries and meet its increasing demands for electricity. The project would supply job opportunities for 3000 Namibians, and schools and health-care facilities would be built in the area. In short: there would be great economic and social development taking place in the area (Cultural Survival 2008).

On the downside however, the dam would flood an area of 380 km^2 of arable land used by the semi-nomadic Ovahimba people as their grazing routes, especially during the dry seasons. This would force the Ovahimba to settle down, and rob them of their centuries' old traditions and customs of moving around. Soon overgrazing would also become a huge problem. Furthermore, many of the sacred sites and ancestral graveyards of the Himba would be flooded (Cultural Survival 2008). It will be outlined later in the text that the Ovahimba have a very strong bondage with their ancestors, and a lot of fortune and misfortune as well as daily activities of the living are directed by the interaction with the ancestors. Therefore, flooding the graves would be disastrous to the Ovahimba society. Beside the detrimental effects on the people of Kaokoland, the planned dam would also cause great damage to the wildlife of the area. Not only would beautiful landscapes be lost, but several fauna and flora species already endangered now would then be lost forever and further species would become endangered (Cultural Survival 2008, Tarr 2007).

So in 1999 environmentalists joined Ovahimba leaders to gain worldwide support for their cause. After great efforts made, the World Bank sponsored an investigation into the social and environmental impacts of the planned project, and the final report concluded that the dam should not be built without the agreement of the local people. This, and the fact that the Namibian and Angolan governments cannot agree on specifics of the project, have caused it to be stopped. Nevertheless, every now and then the issue would be raised again, but until now this has not been successful (Cultural Survival 2008, Tarr 2007).

3.2. The Kunene region – Kaokoland

3.2.1. The Kunene region and its neighbours

The Kunene region lies in the north-western part of Namibia (Figure 47). In the north, the Namibe Province of Angola is separated from the Kunene region by the Kunene river, one of the few perennial rivers in Namibia. On the eastern border lies Ovamboland, a large area comprised of the Ohangwena, Omusati, Oshana and Oshikoto regions, populated mainly by the Ovambo people. In the south the Kunene region borders the Otjozondjupa and Erongo regions with Otjiwarongo and Swakopmund as the regional capitals respectively. The Atlantic Ocean forms the western border of the Kunene region.

Figure 47 Map of Namibia, highlighting the Kunene region in the north-west

This map of Namibia indicates it provinces and the neighbouring countries. Circled in red is the Kunene region, the province where our research study was conducted. More specifically, the study was done in the area between Opuwo and Epupa. Available at www.commons.wikimedia.org.

The Kunene region (Figure 47) comprises six constituencies: Outjo, Kamanjab, Khorixas, Sesfontein, Opuwo and Epupa, with the town Opuwo as the regional capital. The region in this form only exists since 1992, when the Epupa and Opuwo constituencies, until then known as ‘Kaokoland’ or ‘Kaokoveld’ where incorporated under the administration of the Kunene region. However, the terms ‘Kaokoland’ or ‘Kaokoveld’ are still widely used to describe the area north and north-west of Opuwo, and especially the Ovahimba people living here still adhere to this name (Bollig 2006).

For this reason the name Kaokoland/Kaokoveld is used throughout this paper to describe the northern Kunene region.

3.2.2. The people of the Kunene region and Kaokoland

The southern area around the towns of Khorixas and Fransfontein is also known as the 'Damaraland', as most people living here are Damara or Nama people. Obviously, these are not the only two ethnic groups represented in the area. By now people from all over Namibia have moved into the region, however this number is rather small. Looking more closely at the Kaokoland population it is mostly made up of Himba, Tjimba and Tjimba-Herero, collectively known as Ovahimba and all genetically belonging to the Herero. Since the Himba group is by far the largest, the terms 'Himba' and 'Ovahimba' are mostly used interchangeably for the inhabitants of the area. Zemba, Hakaona and Thwa as well as several southern Angolan ethnicities are also represented in the Kaoko population, however only in small numbers (Malan 1974).

According to the census of 2001, 68 735 people or 3.76% of the total Namibian population lived in the Kunene region, which makes up almost 14% of the land area of the country. Therefore, the area is sparsely populated with a density of only 0.6 persons per km^2 compared to a national density of 2.6 persons per km^2. Of those people, 75% live rurally and only 25% live in towns or villages (National Planning Commission [NPC] 2007). The annual population growth rate of the region lies at 1.9%, which is lower than that of the rest of the country. However, when looking at census data it is important to note that no ethnic affiliation has been made. According to Bollig (2006) it is mainly the townships that are growing rapidly in the area. Opuwo is growing at 7% per annum, mainly with immigrants from neighbouring regions such as Ovamboland or post-war southern Angola. When looking at the Ovahimba people only, the growth rate is much lower at less than 1% per annum (Bollig 2006). A possible reason for these low fertility rates could be the relative high prevalence of sexually transmitted diseases (STD) in the area. Even though STDs are becoming less due to the availability of antibiotics, it is still expected to have a great impact on fertility (Bollig 2006).

3.2.3. Household set-up in Kaokoland

Another reason for the below national average growth rate in the Kunene region is because especially young people are leaving in search of work in other parts of the country. Unfortunately, this greatly reduces the prospects of local economic development, and the Kunene region is becoming more and more dependent on transfer payments back to family members (NPC 2007). The regional employment rate lies at 77.2%, which is higher than the national average of 68.9%. On the other hand though, average income per household is much lower than the national average. Despite this 'high' employment rate, more than half of the population in the Kunene region was rated as poor (41%) or very poor (11%) in the 2001 census (NPC 2001). Looking at these figures, it might come as no surprise that the percentage of severely stunted children (too small for their age) in the Kunene region lies at 10%, having increased from 6.4% in 2000 (MoHSS 2008). In addition, access to basic household services is scarce in the region; 80% of households have access to clean drinking water, however, almost 10% of these have to walk more than one km to the water source, while more than two thirds of the inhabitants live without sanitary toilets and only 22% of people have electricity in their homes (NPC 2007).

When the households were asked during the Regional Poverty Assessment about levels of education the general answer was: no, poor or incomplete education and no training (NPC 2007). This is also reflected in the statistics on education in the Kunene region: 40% of people above the age of 15 have never attended school with Kaokoland (Opuwo and Epupa constituencies) showing a percentage of 64, which is much higher than in the other constituencies. The literacy rate lies at 59% for the region, compared to a national average of 81%. Almost three-quarters of 7-13 year olds are attending primary school; however this number is dropping to 35.3% attendance of 14-18 year olds to secondary school (MoHSS 2000). Again though, the Kaokoland area shows a much lower percentage than the rest of the region: in the Opuwo constituency only 51% of 6-15 year olds are attending school while the number is 26% in the Epupa constituency (NPC 2007). To analyse the reasons for this low level of education would be beyond the scope of this paper, however it should be mentioned that the poor education and lack of training are seen as one of the major reasons of the poverty of the region by its population (NPC 2007).

3.2.4. Health-care in Kaokoland

The access to health-care is made difficult by the vastness of the area and the low population density. In the Health and Social Services Review 2008, the Ministry of Health and Social Services (MoHSS) outlined the health-care in the Kunene region: there are 21 clinics and three health centres in the Kunene region, both of which do not have any beds but rather treat patients on an outpatient basis. Clinics are usually run by nurses only, and even the health centres do not always have a doctor present. Outreach teams are supposed to serve the far away villages, however these are rather unreliable. Such is the case in the Namatanga community, where the distance to the next clinic is 41 km, but the outreach team only visits the community very seldom (MoHSS 2008, NPC 2007). In addition to the clinics and health centres, there are three hospitals in the region: Opuwo, Outjo and Khorixas with a total of 250 beds. Unfortunately, the health services are further hampered by the chronic shortage of staff, medication and other resources. Despite this, the Kunene region shows an above national average life expectancy of 57 years for females and 50 years for males (NPC 2007).

3.3. Kaokoland – a detailed picture

As mentioned above, the Kunene region and especially Kaokoland is a very sparsely populated area. In the following, a more detailed description of the Kaokoveld area and landscape will be given. This is the area, where the fieldwork was done.

Figure 48 Map of Kaokoland in the Kunene region

The map shows Kaokoland in north-western Namibia forming part of the Kunene region. The research study was conducted in the area in and around Opuwo, Okongwati and Epembe.

Source: www.arroukatchee.fr

3.3.1. Geographical outline of Kaokoland

The Epupa and Opuwo constituencies, together known as Kaokoveld or Kaokoland, lie in the north western part of Namibia (Figure 48). It is in this area that all of Namibia's geographical and ecological characteristics come together. The vast bush and grass savannahs of the eastern Kaokoland are interspersed with small hills, while the western parts present shrub and grass savannahs with high mountain ranges. The mountain ranges, interspersed with large open plains, slope down further westwards to the Namib Desert and its Skeleton Coast on the Atlantic Ocean, forming the western-most border of Kaokoland. Through the open savannahs as well as through the mountain ridges, large and small, dry river beds find their way. Only from October to April, when enough rain has fallen, do these rivers carry water for a few days at a time. The only perennial river is the Kunene, which flows westward towards the Atlantic Ocean and forms the northern border between Kaokoland and Angola. These episodic

and perennial rivers do, however, supply great sources of underground water and sometimes lush vegetation in times of water scarcity as the rainfall in this area can be very irregular. An average of 300 mm a year is recorded in central Kaokoland, while the eastern part is more semi-arid and the western part, heading towards the desert becomes more arid with an average rainfall of only 100-150 mm per year (Bollig 2006, von Koenen undated).

3.3.2. Homesteads, villages and towns in Kaokoland

Across the landscape little villages of extended families are scattered, sometimes only four to five km apart, sometimes 50 to 100 km apart. The villages usually consist of three to five households and serve as the main homestead – *onganda* (see section 'Traditional lifestyle of the Ovahimba', pg 138 for detailed information on various homesteads). Contrary to what might be expected, there are no shops to be found in most of these villages. Aside from these small rural villages, larger villages, comprising 40-200 households, can also be found. In the area where the fieldwork took place such larger villages were Okongwati, Etanga or Otjondeka. The houses, some of which are still build in the traditional Ovahimba style, are scattered around a small number of shops, such as a grocer, a bar or a supermarket. These villages normally also have a clinic and a police station serving the whole surrounding area.

Larger towns in Kaokoland are Opuwo, as the regional capital, and Epupa as the most northern town of the region. Opuwo has a population number of about 21 000 people and naturally a larger number of shops, a hospital, health centre, a clinic and several guest houses and hotels, as it serves as the main hub when travelling through Kaokoland. However, as described above, the poverty rate is high and the level of education is low (NPC 2007). Many people interviewed during the fieldwork for the Kunene Regional Poverty Profile complained of high alcohol consumption in the many shebeens[29] that can be found in Opuwo and other towns. Unfortunately, the sight of Ovahimba people selling their livestock below market price in order to buy alcohol is not a rare one. Alcohol abuse is wide spread and greatly contributes to poverty, disruption of family relationships (valued extremely high in the Ovahimba society) and the endangerment of the Ovahimba culture and lifestyle (NPC 2007).

[29] Shebeen: an illegally run bar

Figure 49 Opuwo – The capital of the Kunene region

A windy day in Opuwo

The pictures above give an impression of the town of Opuwo, the capital of the Kunene region. This is where the urban part of the research study was conducted[30].

3.4. Traditional lifestyle of the Ovahimba

Many Ovahimba have moved into the towns or bigger villages over the past few decades. Despite the urban influences some, nonetheless, honour the old beliefs and traditions of their forefathers. The extent of this varies greatly between families of course. However, there are still many Ovahimba who live in rural areas and even though changes are taking place in these communities, many still adhere to the old traditions

[30] All the photos of this study were taken by, and are the property of, this author. None of the photos of this study may be used or published without the permission of this author.

and cultural beliefs. An outline of the lifestyle and belief system will be given here, as the comparison between the rural and the urban life and its effect on the health of the people is the paramount question of our research study. In addition, we believe that when doing and presenting a study done in a community which is so different from western cultures, it is indispensable to get a certain understanding and familiarisation of the people and their way of life.

3.4.1. The homesteads of the Ovahimba

The Ovahimba people lead a nomadic lifestyle, since they have four different homes between which they move according to the season. Firstly there is the *onganda*, the semi-permanent main settlement of the household which is inhabited during the rainy season (Figure 50). Ideally, this homestead is built on ancestral grounds, an area where the father(s) of the headman are laid to rest (Van Wolputte 2009). The presence of his fathers' graves will give the headman the right to use the grazing land and watering sources. In addition, it will allow the household to be in the vicinity of their ancestors which is important in times of plenty - to thank the ancestors - and in times of disaster, drought or any other misfortune – to ask the ancestors for forgiveness or for help (Van Wolputte 1998). There will be more than three households in the vicinity as well as reliable water sources and gardening opportunities (Bollig 2006). Secondly, there can be villages with fewer households in the area and less opportunities for gardening but with very good water resources. As with the above mentioned villages, there will be ancestral graves in the proximity. The presence of these graveyards makes these two types of homesteads semi-permanent settlements (Bollig 2006).

Figure 50 The *onganda* – the semi-permanent main settlement of the village of Ombaka

The *onganda* of the village of Okamwe

The pictures above show the homesteads of Ombaka and Okamwe. These are semi-permanent settlements, because the graves of the ancestors of its inhabitants are in close proximity. Since Ovahimba people have a strong bondage with their ancestors, they will always return to this place. In both villages people were recruited for the rural group of the study.

The cattle posts (*ohambo*) (Figure 51) or dry season settlements are mobile settlements which change their locations according to the availability of pasture and

water and are far less elaborately built. In the last months of the dry season (September to December) most households move all their pregnant cows to these areas to ensure that the cows have enough fodder when calving starts, while the other cattle are being taken care of by the young men (Bollig 2006). It is between these cattle posts and the villages that the Ovahimba with their herds move back and forth. More time is spent in the homestead, especially by the women and married men of the family. After the rains have come, the whole household, including all cattle, will spend three to four months together in the homestead. Before the pasture is depleted in the area of the homestead, the young unmarried men (*ovandato*) start taking the oxen, heifers and non-lactating cows to the fourth settlement, the cattle posts of the oxen (Bollig 2006). These are very non-permanent settlements, often consisting of not more than a blanket over a small tree to give shelter, shifting according to pastures available and usually located somewhere in the mountains.

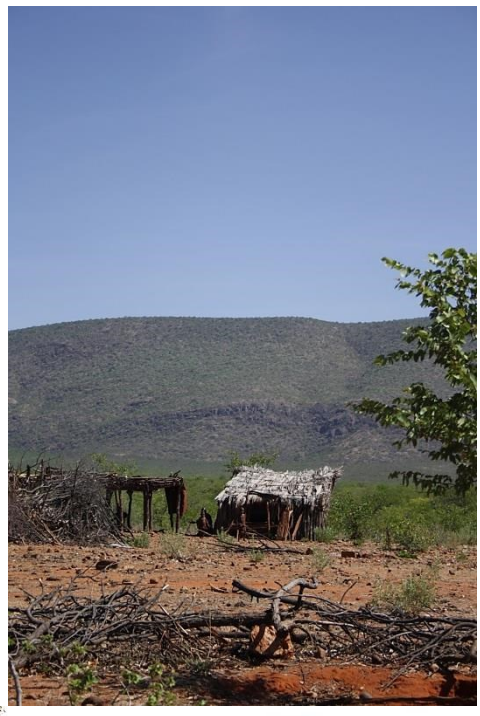


Figure 51
The *ohambo* – dry season settlement

The *ohambo* homes are mobile settlements built during the dry season and the location can easily be changed according to the availability of pasture and water for the cattle. Especially the pregnant cows will be herded into these areas to ensure enough fodder when birthing. Most of the household will travel with the animals.

The use of specific grazing areas is agreed upon by the headmen. Certain settlement areas are associated with specific gardening and dry season pastures, therefore the same households often move together and share the same areas (Van Wolputte 2009, Bollig 2006). Often the movements of a household are the same as those of their ancestors, especially because grazing rights and wells are transmitted through the patrilineage – from father to son. In times of drought, however, one would turn to matrilineal relatives for help ('The double-descent system of the Ovahimba', pg 146) (Van Wolputte 1998).

3.4.1.1. *Onganda* – the main homestead

The *onganda*, the rainy season settlement, is seen as the main homestead because the household will always return here until the settlement is deserted upon the death of the head of the family. It is also the place where personal belongings are kept and where all major ceremonies and celebrations take place (Van Wolputte 2008, Van Wolputte 1998). A homestead is founded by a married man picking out a tree or shrub that will give shade to the calves of the herd. Around this, an inner thorn bush enclosure is constructed (*otjiuunda*) the entrance of which faces towards the rising sun in the east. The senior wife or matriarch will construct her house with its entrance facing towards the entrance of the inner enclosure. This will be the grandhouse (*ondjuo onene*) (Van Wolputte 2009, Jacobsohn 1988). The line between the two entrances is called the *omuvanda* and should not be crossed by strangers coming to the village for the first time, by women carrying things on their head from outside of the homestead, for example wood or water. Also, a married woman who has not yet given birth will not cross the *omuvanda* in her parents-in-law's homestead (Van Wolputte 1998). A lot of daily activities within the homestead will centre directly or indirectly around the *omuvanda*: it indicates where the ancestral shrine will be built, where animals will be slaughtered, where meat and other foods will be cooked, and where ceremonies will be held. (For more details on this topic, the reader is referred to the habilitation of Steven van Wolputte, Of Bones and Flesh and Milk published by the Catholic University of Leuven in 1998.) There are usually four different fires in a homestead: one for cooking porridge or other foods, one for cooking meat, one in front of the house for warmth and comfort, and one for ceremonial and ritual purposes, the ancestral fire (*okuruwo*).

When standing inside a house looking out, the right side is called the 'side of the firewood', and this where the other wives of the headman will build their huts (*ondjuuo*) in order of seniority as well as other members of the same patrilineage living in the homestead. It is also on the right side of every hut that the 'male-cooking' fire is situated, where meat will be cooked. The left side is called the 'side of the calabashes', and this is where matrilineal relatives will construct their huts. Each woman will construct further needed dwellings for her household, like a storage floor or an *omuvanda* (gathering place with shade) on the 'side of the calabashes' of her hut. This is also where the 'female-cooking' fire is situated for everyday cooking. The wife of a

full brother will erect their hut on the opposite side of the main hut. All entrances will face towards the inner enclosure.

A homestead is made up of a headman and his wife/wives with their children. Often one or two of his sons with their families remain in the homestead and sometimes a younger brother and his wife/wives and an older family member. Normally, a village comprises more than three such homesteads spread over a larger area (Van Wolputte 2009, Van Wolputte 1998, Jacobsohn 1988). However, the structure of households is very dynamic: a woman will return to her father's homestead during the later stages of pregnancy until some time after having given birth, divorce rates are high among the Ovahimba, visiting one's relatives for several months is common, and a brother will take a deceased brother's wife and her children into his household. All these situations bring about a constant rearrangement of the households.

3.4.1.2. Changes in the homestead during the time of mourning

All the huts and the inner enclosure are surrounded by an outer thorn bush fence with several entrances. The main entrance to the homestead faces west. This outer enclosure as well as constructions used for ceremonial purposes is constructed by the husband, while all huts and dwellings inside are built by the women. The outer enclosure will be destroyed upon the death of the head of the household, while the huts will be destroyed later. Only if it was the explicit wish of the deceased that the family will remain where his homestead was, will there be an exception to this. The outer thorn bush will then be destroyed, but rebuilt after the time of mourning, which usually lasts for one to two years. Normally, after the time of mourning, the huts will be destroyed and the eldest son, now head of the family, inherits all belongings of the deceased especially his *oruzo* cattle (holy cattle) and the ancestral fire. Should he be married, he is now able to found his own homestead according to the above mentioned traditions (Van Wolputte 1998). During the time of mourning, the women as well as the men will loosen their ornaments and certain pieces of clothing as a sign of bereavement. Removing or loosening items from the head or neck shows mourning for both matrilineal and patrilineal relatives. The specificity is shown by loosening ornaments on the left arm and leg or right arm and leg when mourning a matrilineal relative (*eanda*) or patrilineal relative (*oruzo*) respectively (Van Wolputte 1998, Crandall 1991, Kuvare 1977). The funeral is a devotional

ceremony in which the whole household, the men, the women and the cattle and other livestock, play a part. If the deceased was a man of high standing (*omhuhona*) several holy oxen will be slaughtered to provide decorations for the grave (Figure 52).

Figure 52 A graveyard of the Ovahimba

The picture shows a graveyard in the area of Ombaka village. The horns stuck on the long pole are horns from holy cattle, showing the recent burial of a man of high standings.

After the year of commemoration, happening for both deceased men and women, there will be another ceremony, marking the end of the mourning period. At this time the question of inheritance will be raised: in case of the death of a woman, a woman of high social standing from a friendly *eanda*[31] will lead the procedure. All the woman's bowls, dishes and ornaments will be given to her eldest daughter while her cattle will be given to her eldest son. In the case of the death of a man, his cattle will be inherited by his brother (see below) and his bowls by his wife or wives. The brother will also marry the wife/wives and care for them and their children, however if they wish to return to their father's homestead they may do so (Kuvare 1977). Should the deceased have been the head of a household it is at this ceremony that his heir is finally decided upon and he will be formally introduced at the ancestral fire as the rightful successor of the deceased (Bollig 2006).

[31] *Eanda*: a decent group from the maternal side

3.4.2. The bond with the ancestors and the double-descent system

3.4.2.1. The *okuruwo* - the holy fire

The ancestral fire is the link between the living and the deceased. It is not a contact point between all the living and dead, but only between ancestors who belonged to that fire during their life and the current keeper of the fire, normally the oldest living member of the patrilineage. He will officiate at all functions and ceremonies taking place at the *okuruwo* and will make contact with the ancestors as representative of his household. It is the *okuruwo* that makes the reconcilement between fortune and misfortune possible and ever so often an ox will be ceremonially slaughtered to ask for ancestral forgiveness or support. Upon his death, this task will be given to the now eldest living member of the patrilineage (Crandall 1991). It becomes obvious that the relationship between the living and the dead is very close in the Ovahimba culture, and it would not be possible to live without the blessing of one's forefathers. For this reason, it only happens rarely that Ovahimba people will turn to their God (*Mukuru*) in prayers or ceremonies, as it is believed that God does not interfere much with affairs on earth (Bollig 2006). This belief system makes it so important that homesteads be erected near the graves of the ancestors. Whatever changes have happened in the Ovahimba culture or whatever conditions have struck the people, the continuation of the ancestral fire and the respect for the ancestors are still paramount concerns as it is said that 'living where there is no fire is tantamount to living like animals in the bush' (Crandall 1991).

3.4.2.2. The double-descent system of the Ovahimba

Another very important feature in the Ovahimba culture is the double-descent system, meaning that each person within the Ovahimba society belongs to a matrilineal (*eanda*) and patrilineal (*oruzo*) descent group. No group is put above the other, no group is more important than the other one. They both cover different areas of the culture and traditions and have different functions within the social and political realm of the society (Crandall 1991).

(1) Matrilineage

The membership of an *eanda* is obtained by birth and will not change during one's lifetime. This descent group is non-totemic and non-residential, and because a woman

will move to her husband's homestead after marriage, the members of a matriclan are dispersed over wide areas (Malan 1973). Matriclans are not confined to the Ovahimba, but are also found in other ethnic groups in Namibia, northern West Africa and Angola. There are six different matriclans in the Ovahimba culture, all of which originate from one common ancestress whose name cannot be remembered. She had two daughters, the elder of which had four daughters herself. A beautiful story about each daughter and daughter's-daughter led to the foundation of each *eanda* (Crandall 1991, Malan 1973).

The importance of the *eanda* can be seen in various areas. Firstly, it provides each member with a vast number of relatives, even if often unknown to each other. A high degree of solidarity and privilege is associated with each *eanda,* so that one can expect unconditional hospitality from the members of the same matriclan. This has proven very important in times of draught or disaster when many Ovahimba turned to their matrilineal relatives outside the affected area for help (Van Wolputte 1998, Malan 1973). Secondly, the bulk of wealth in livestock is controlled by the *eanda* as most animals are inherited matrilineally, i.e. the cattle of a deceased man will be inherited by his brother (of the same mother) and in absence of the latter, by his sister's son. A young boy will get a heifer as a present from his maternal uncle to be able to build up his own herd one day. Thirdly, the matriclan is important in selecting a spouse as Ovahimba preferably marry a cross-cousin, since this constellation allows for a good *ongura*[32]. Lastly, the matriclan can also bring misfortune: direct matrilineal relatives, for example a mother's brother, can easily bewitch a person or an entire homestead (Van Wolputte 1998, Malan 1973).

(2) Patrilineage

The patrilineages, on the other hand, are residential entities as they are based on the need to live by an ancestral fire. Membership is acquired at birth, though women will adopt the patriclan of the husband when getting married. This is celebrated in a ceremony in which the newly wedded woman is introduced to the rules and obligations within her new patriclan by her in-laws. These rules and obligations are specific to each patriclan and consist amongst others of certain taboos, favourite colours for cattle,

[32] *Ongura*: working together

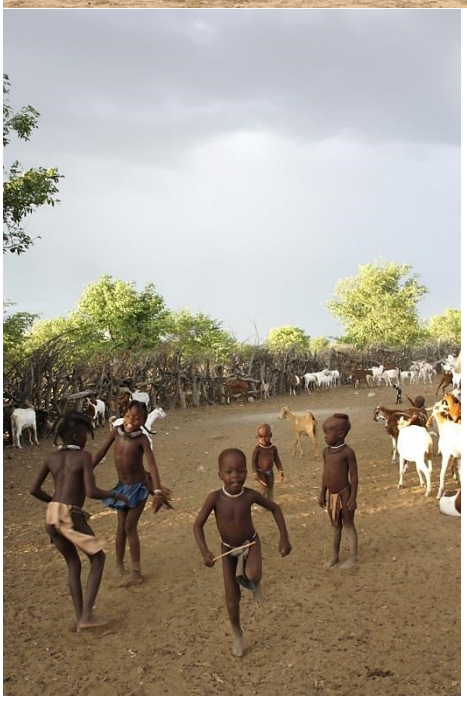
procedures of cutting up a sacrificed animal or the way the hair of small children is shaven (Bollig 2006, Van Wolputte 1998, Malan 1973).

As mentioned above, the oldest member of the patriclan is the keeper of the ancestral fire and conducts all ceremonies and rituals. Upon his death, this duty is passed on to his eldest son. He will also inherit the *oruzo* cattle, which are of great spiritual value and thus need to remain attached to the ancestral fire. The milk and meat of these cattle may only be used by direct male, patrilineal descendants of the deceased. If this rule is violated, the wrath of the ancestors, and especially the recently deceased man, will be drawn upon the homestead (Crandall 1991). In addition, grazing and watering rights are transmitted patrilineally; the area is laid down by the journey of the ancestors, which has led the descendants to the place where they are residing now (Van Wolputte 1998).

3.4.3. Livestock of the Ovahimba

It has become obvious that cattle and livestock play a very important role in the Ovahimba society. Especially cattle are seen as wealth and lead the hierarchy of livestock, followed by sheep and then goats. Small livestock, such as sheep and goats, are rather kept for milk, meat and as exchange items to barter for maize meal, alcohol, clothes and other goods (Bollig 2006). While cattle and goats are milked, sheep are never milked but rather kept for meat. The cattle herds are tended to by the young men, and the herding of small livestock is done by boys and girls in the vicinity of the homestead. This marks an important step in the lifecycle of both boys and girls, as they are now not seen as small children any longer, but old enough to be able to tend to the herds. Another important step is when the girl is old enough to go through the ‘ceremony of setting the hair’ (see below), and she will now no longer herd the livestock but be instructed in domestic duties as she is slowly becoming a woman (Van Wolputte 1998).

Figure 53 Livestock of the Ovahimba



Above: The boys are now old enough to tend to the goats and sheep in Okamwe village. An important step in the growing up of Himba children.

Below: Children playing after bringing in the goats and sheep to the *onganda* in the evening.

Almost all ceremonies and rituals within the Ovahimba society are associated with the ceremonial slaughtering of at least one ox. The father of the bride is presented with cattle by his future son-in-law or his father. The women, and sometimes the men too, anoint their bodies with butterfat from specific cows. The father of a woman who has just given birth is presented with a heifer or an ox by his son-in-law.

At birth the father will give his child a heifer. However, not all offspring of the heifer will belong to the child. A rather complicated set of rules, at least for an outsider, ensures that the gross of the cattle belong to the headman. A wealthy headman can have

herds of between 800 to 2000 heads of cattle, which will then give him a high social and political standing, he might now be called an *omuhona*[33]. With such wealth also comes the responsibility to donate or loan livestock to poorer matrilineal relatives. Even though this is required by the rules of solidarity within the matriclan, the loaning of cattle is often done to gain more power and political influence (Bollig 2006). The importance of cattle does not only lie in the accumulation of wealth, but also in the spiritual value of the animals. Almost all ceremonies taking place within the Ovahimba society include the slaughtering and offering of at least one ox at the ancestral fire or the ancestral graves. This is done to honour and pay tribute to the forefathers and thus prevent their anger being drawn upon the homestead.

Young boys begin by herding the cattle belonging to their father or their maternal uncle. They can now either borrow a cow from their father or uncle to start their own herd, and an agreement of how many offspring will belong to the young boy will be made. Sometimes the father or uncle will present the boy with a cow for his work. Building an own grand herd of cattle this way is a rather lengthy process for young men, therefore real wealth will only be achieved once the maternal uncle will have died and bequeathed all cattle to the, by then, generally grown-up nephew (Van Wolputte 1998). Bollig (2006) shows that men over 70 years of age own almost 100% of their herds, while men at the age of 45 only own 55% of their cattle while 45% is borrowed. This is also why a young man will remain dependent on his patriclan until a relatively high age. He will, for example, be dependent on his father to pay the bride price in cattle for his future wife. A woman can also own a small herd of cattle, given to her by her matrilineal relatives. Neither her husband nor her father will have any say over these cattle (Van Wolputte 1998, Kuvare 1977).

There are two major subcategories within the Ovahimba herds: the 'cows of the butter calabash' – *ozongombe onzondugwa* and the 'cows of the firesticks' – *ozongombe ozondumehupa*. Milking is only done by female members of the same patrilineage as the head of the household. She has to cover her head, if not with one of the headdresses typical to Ovahimba women, then at least with a piece of plastic, paper or mopane leaf. She squats down on the left hand side of the cow, in a posture similar to that when giving birth. While milking, she will mutter the cow's name. Each herd category has its

[33] *Omuhona*: big man or chief

own specific milking utensils used in a particular way. Some are carved by the head of the homestead and some are braided by the women. No milk is drunk uncultured except by little children, who are especially given the first milk produced by a cow after having given birth, because this is seen as very powerful (Van Wolputte 1998).

The milk of the 'cows of the calabashes' will be used to make butter and buttermilk, by churning the milk in a calabash until it separates (Figure 55). The buttermilk is consumed while the butter is cooked into butterfat and kept in a pair of horns (*ozonya*) from a cow or ox that has been slaughtered ceremonially. The one horn contains butterfat mixed with aromatic herbs and ground red ochre (*otjize*) used to anoint the body of the woman and the married man (see below for the meaning of this custom). The other horn contains a mixture of more roughly grounded herbs, pounded coal of the mopane (a local tree) and butterfat, used to anoint the neck of the woman's husband and her smaller children (Van Wolputte 1998).

Figure 54 Cattle of the village of Omuhonga

A herd of cattle outside the research tent in the village of Omuhonga.

Figure 55 Ovahimba women churning the milk in calabashes

A woman churning milk in a calabash slung from a tree, while watching her children play. The milk separates into buttermilk, which will be eaten, and butter, which will be used to anoint the body.

A young woman shaking the calabash (see below for the meaning of wearing her hair down in front).

The ‘cows of the firesticks’ can be further subdivided into a group of cows or heifers belonging directly to the ancestors (chosen at the first commemoration ceremony), another group associated with a specific myth and a particular set of rules and responsibilities to obey in order not to offend the ancestors and several more subgroups for various self-chosen patriclans. Thus the ‘cows of the firesticks’ are associated with the ancestors and the patriclans of the homestead. The milk of these cows will yield the

curdled milk known as *omaere*. *Omaere* is obtained by keeping the milk in a calabash for several days to ferment and turn sour. It is then offered to the head of the household for tasting by his wife or his daughter. Only then will the *omaere* be drunk by other members of the household (Bollig & Gewald 2000, Van Wolputte 1998, Kuvare 1977).

3.4.4. Dietary habits of the Ovahimba

Milk and its products play a vital role in the diet of the Ovahimba. Soured cow's milk (*omaere*), soured goat's milk and buttermilk, add considerably to the fat and protein uptake of the Ovahimba. A large amount of butterfat, yielded from butter when cooked, is stored in leather sacks or metal containers to serve as a nutritional source, rich in proteins and fats for the meagre months of the year. It is then cooked with maize into porridge (Bollig 2006, Bollig & Gewald 2000). During the rainy season maize is planted in the gardens. Once harvested the maize is stored and when needed ground to a fine meal and cooked with water. When buttermilk or *omaere* is added it results in the staple food of the Ovahimba: porridge (*ovisema*). This is usually cooked twice a day on the fire towards the 'side of the calabashes'. Sometimes it might be cooked with milk and is then seen as a delicacy. Should a household run out of maize, small livestock is exchanged for bags of maize either in other villages or in Opuwo. Other produce grown on the communal agricultural land includes millet, sorghum, pumpkins and sometimes beans. The harvest is mostly not substantial, since wild animals and livestock will break through the thorn bush fence and eat the crop. In addition, the mostly arid weather does not allow for more agricultural foods to be grown. However, even if oly in small amounts, it allows for a welcome variety in the diet (Bollig 2006, Van Wolputte 1998, O'Keefe et al. 1988).

Meat is not eaten regularly and is highly dependent on the wealth of the homestead. Normally only goats and sheep are slaughtered purely for meat. Even when slaughtering a sheep a reason will be found to address the ancestors, thus making a ceremony, however small, to kill the animal. According to Galvin & Little (1999), who made an analysis of dietary intake and nutritional status of pastoralists in 1999, the Herero diet (closely related to Ovahimba) consists of 55% maize and cereals, 31% milk and milk products, 16% meat and fat and 7% wild foods, sugar and oil. This shows that 86% of the Herero diet is made up of porridge. These figures are a mere average and it must be

said that the energy intake varies greatly among pastoralists, as food production and consumption is very sensitive to variations in climate, ecology, health and social and political conditions (Galvin & Little 1999). O'Keefe et al. (1988) found that the intake of vegetables and fruit was almost non-existent in rural Herero people in the dry months of the year, which lasts for about 8-9 months. Furthermore, it was found that the caloric intake of pastoralists lies well below the recommended daily intake (RDI) of the WHO, even in times of plenty. This exhibits a great difference to urban populations, where caloric intake often greatly exceeds energy requirements (Galvin & Little 1999).

When studying the people of north-western Namibia and southern Angola, it becomes obvious that on the one hand there is a great ethnic and social cohesion. This is marked for example by the immediate solidarity shown towards foreigners from the same matriclan[34], the frequency of interethnic marriages or the bartering system between various groups[35]. On the other hand though, great efforts are being made to visualise ethnic differences within the societal structure. Various forms and colours of beads and jewellery, different hairstyles and ways to dress are used to show the belonging to a specific ethnic group (Bollig 2006). Since our fieldwork has taken place mainly within the Himba community, a brief outline of their traditions will be given.

3.5. Traditions and appearances of the Himba

3.5.1. Anointing the body with red ochre or coal

Probably the most eye-catching custom of the Himba is the anointment of the body with a mixture of butterfat, aromatic herbs and ground red ochre – *otjize* (Figure 56). From the 'ceremony of turning around the hair', carried out at the menarche of a young girl, a woman will anoint her body every (other) day with the red butterfat except when ill or when menstruating. When travelling, in preparation for a ceremony or when her lover will come to visit, the woman will put on an extra bit of ochre to look especially beautiful. She will first smear her belly, then her breasts and arms followed by the hair, neck and back and finishing with the legs. Men and unmarried boys/men will smear their neck with the butterfat, herbs and coal mixture made by their wife, mother or

[34] Hospitality is shown towards all foreigners, but hospitality towards matrilineal relatives reaches further

[35] Himba and Kuvale are known for their knowledge of pastoralism, the Hakahona are said to have great healing and ritual powers while the Twa are impressive iron-workers and potters

sister. Only sporadically does a husband smear his body with *otjize,* for example when travelling (Van Wolputte 1998).

Figure 56 Himba women and man showing the traditional anointment of the body

These two women from Ombaka anointed their bodies with *otjize* before coming to visit the researcher's camp. The body is anointed every day, however, when travelling, for a ceremony or any other special occasion, extra care is given to the anointment.

Headman Watireiki of Ombaka. His neck is smeared with coal, herbs and butterfat and he is wearing the typical thick collar and necklace representing the strength of the bull. His head is covered by a piece of cloth, showing that he is married. The smallest necklace, which is brown and white, is made of special beads showing that he is either the father, brother or husband of twins (see below for the meanings).

The butterfat has to originate from the cattle of the husband or father, and a man will use only butterfat churned and ochre or coal ground by his senior wife or daughter. This gives a very strong sense of belonging, of joining women and men, the matriclan and patriclan as well as the cattle of the homestead together. It combines the life-giving capacities of the herds and the ancestors to the human skin within the realm of a household (Van Wolputte 1998). In smearing the body with butterfat, be it mixed with ochre or coal, the Himba pay respect to their ancestors and the coming about of the cultured world. In the oral traditions it is said that a long time ago the Ovahimba did not have cattle. Then the forefathers left to the country of the *OvaMwira* and they brought back with them the cattle they had robbed. Seeing how the calf drinks from the cow's udder, they decided to milk the cow. Forgetting the milk in the basket it turned into soured milk (*omaere*), which could then be eaten. When leaving for another village the calabash containing the milk was carried on a stick and through the swinging turned into butter. But some fathers were killed in the land of the *OvaMwira*. To remember those ancestors and the introduction of the cattle into Himba society, and with that the coming about of the cultured world, the people anoint their bodies with butterfat (Van Wolputte 1998).

3.5.2. From birth to adulthood

In addition to the smearing of the body there are numerous other ways in which the Himba show their ethnic identity or mark the stages in the lifecycle of its members. When a woman is pregnant, she will spend the last few months at the homestead of her parents. After the child has been born, the mother will remain in seclusion in the house of her mother until the umbilical cord has fallen off. The child, until then only called *okapuka* – small wild animal – will be given a name when the mother emerges from the house in a naming ceremony. Sometime after that the husband will come to fetch his wife and newborn child and present his father-in-law with an ox. From an early age onwards the child wears a small collar and a necklet and its hair is shaven in transverse stripes. After the ceremony of the circumcision, the boy's hair will be shaven so that a circle of hair will remain on the top of the head (Figure 57). This will grow into the

ondato tail[36], marking the young boy or later young man as an *omundato* (bachelor) (Figure 57).

At the age of 18-20 years the *ondato* tail will be opened and braided into two different plaits: the sign that the young man is now ready and intending to get married. During the wedding ceremony the tails are opened and the young man is presented with a piece of cloth (*ondumbo*) that every married man wears over his hair (Van Wolputte 1998, Kuvare 1977).

[36] *Ondato* tail: a tail of hair growing down the back of the head

Figure 57 The stages of growing up of Himba boys/men

Top left: The hair of boys is shaven into transverse lines, after circumcision it will be shaven into a circle, growing down to the back (top right). A necklace is worn from an early age on. Bottom: The *ondato* tail, growing after the ceremony of circumcision, shows that the young man is still a bachelor. Only once it is opened and braided into two different plaits does the man show his intention of getting married. A young man from Ombaka village shows his *ondato* tail.

It is only through marriage that a man acquires fatherhood. If he has children born before he is married, the children will belong to the mother and he will only be

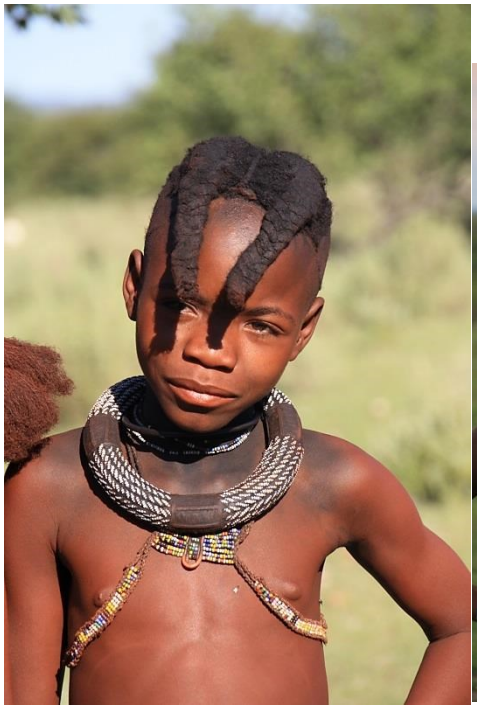
recognised as the father once he is married to a woman. For clothing, the men will wear a piece of cloth tucked into a loin belt and various ornaments. Attending to the neck is very important for Himba men, as the strength of a bull lies in his neck. Identifying with the bull, the neck gives a man his strength; therefore he will anoint it with butterfat blackened by mopane coal and wear a thick collar. The collar and various other ornaments, like belts, arm and leg bracelets, will be exchanged or further amplified during specific stages of the lifecycle, for example circumcision, first or second marriage and when becoming a headman. It is also these ornaments and the *ondumbo* that are loosened during the time of mourning (Van Wolputte 1998, Kuvare 1977).[37] Upon the death of a man, his ornaments might be given to his sons, but because they actually belong to his *eanda* (matrilineage) they should be given to his brothers or sisters of the same mother (Kuvare 1977).

The rituals and ceremonies young girls and women will experience during their lifecycle are numerous and therefore only a few will be highlighted here. For detailed information on the customs, rituals and ceremonies of the women and men of the Himba, the reader is referred to the writings of Steven van Wolputte and Silas Kuvare.

At the age of four or five a young girl will receive the 'feast of setting the plaits'. A sheep will be ceremoniously slaughtered and the fat of the intestines divided upon the heads of the girl and all the women present. They will then return to their hut, where they will spend the night and the next day. Afterwards the fat, having been worn on the head by the young girl, will be cooked and eaten by the girl (the *oruhe* ceremony). This is also when her transverse stripes on the head are shaven off and from now on she will grow the *ozondatu* hairdress: two plaited braids hanging in front of her face with a high shaven hairline (Figure 58). At this ceremony, her necklace will also be changed so as to be corresponding to the now growing *ozondato* hairdress.

[37] *Ondumbo*: piece of head cloth

Figure 58 Young girls showing the traditional hairstyle and jewellery



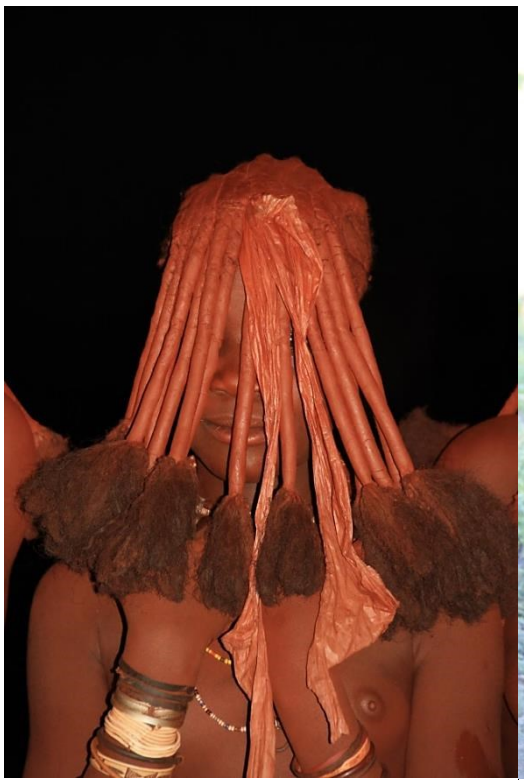
Young girls of Okamwe village with their traditional *ozondatu* hairdress.

Young girls of Ombaka village making necklaces from the maize kernels and grinding it for cooking. From an early age the girls are instructed either by their mothers, sisters or older girls in the art of making jewellery.

Between now and the next major ceremony, the girl will be called one day by her father and asked to sit down opposite him. Without much preamble another man will hold onto her arms, while her father will pull out all four lower incisors. A piece of cooked meat will be pressed on the wound so that it will not get infected. Young boys will go through this ritual before they start growing their *ondato* tail. It is said that the 'teeth go out at night to eat cow dung' and therefore they are taken out. Later in life both men and women might have their middle upper two incisors filed to an upside down 'V' because it 'looks more beautiful' (Van Wolputte 1998).

The next two ceremonies taking place within a young girl's life are the 'ceremony of setting the hair' and the 'ceremony of turning around of the hair'. During the first ceremony the *ozondatu* tails will be opened and braided into several long plaits, the *ozongise* braids. These are made to fall in front of the face of the girl (Figure 59). She will now also start to anoint her body with butterfat and red ochre, including her hair, and she will be slowly incorporated into the female household duties. The girl will go through her menarche in a shelter outside of the village. When she returns, her father will give her a sheep and the 'ceremony of the turning around of the hair' will take place. The *ozongise* braids will from now on be worn to the back and she will wear the sheepskin back apron that all women wear (*ombanda*), signalling that she has reached womanhood (Figure 59). Again, her ornaments will also be exchanged (Van Wolputte 1998).

Figure 59 Himba women and their traditional hairstyle and dress



Above left: A young girl with her *ozongise* braids falling to the front, showing that she will reach puberty soon. From now on she will be instructed in the household duties.

Above right: a dancing woman wearing the typical sheepskin back apron.

Left: the daily clothes of a woman.

Usually some time after this ceremony, the ceremony marking her entrance to adulthood will take place. The father will give his daughter her *erembe* crown, *oruvanda* headdress and *omihanga* anklets. These are the most important objects of female adulthood and the young woman is now entitled to have sexual relationships. As

with the other three ceremonies, this is accompanied with the ceremonious slaughtering of an ox or several sheep and the *oruhe* ceremony[38] (Van Wolputte 1998, Kuvare 1977).

Figure 60 Two young Himba women showing the traditional headdress

Two Himba women wearing the traditional *erembe* (left) or a leather skin (right) covering the head. These are the daily *omarembe* crowns, worn once a girl has reached womanhood. More elaborate *erembe* head crowns will be worn on special occasions. From when a girl reaches womanhood, she will always cover her head, be it an *erembe* crown (left), a piece of leather (right) or sometimes just a mopane leaf.

The *erembe* crown is made from the skin of a newly born lamb and sewn into what looks like four pairs of horns (Figure 60). A woman normally has two *omarembe* crowns, one for special occasions and one for daily use, as she is required to cover her head when entering the inner enclosure to milk the cows, when leaving the homestead or when visitors are present, and one for special occasions. The *oruvanda* headdress is made of metal beads and thin iron wire beautifully put together to what looks like a network, smeared with coal or red ochre and ending in a tail of black horse hair which will hang down at the back (Figure 61).

[38] *Oruhe* ceremony: the ceremony where the girl wears the fat of the slaughtered ceremonial animal on her head. She will sleep with it for a night and then cook and eat the fat.

Figure 61 Himba women in Okamwe village

Left: A traditionally dressed woman of Omuhonga village, note her *omihanga* – metal bead anklets. These are given to the woman by her father and will be worn for the rest of her life. She will remodel them on several occasion, for example she will add a leather strap once she has born two children. Right: A woman displaying her *oruvanda* headdress – representing the tail of a horse and worn for beauty.

The third female attribute given to a young woman by her father are the two metal bead anklets (*omihanga*). These are metal beads tied together with two single leather straps. The woman will wear these for the rest of her life; however she will remodel and widen them over time: after the birth of her second child she is allowed to work two leather straps into the anklets, representing her status. In addition, large and high anklets are seen as a token of wealth and prestige. When the anklets are taken off for repair, a plastic or leather strap will be tied around the ankles as a substitute (Van Wolputte 1998, Kuvare 1977). Should a woman be infertile or unmarried, she can wear specific clothes and jewellery once her sister is entitled to wear those items.

Pregnancy also presents an interesting stage for Himba women. During the last months of the pregnancy the woman will return to her father's village, ideally it would also be the village of her mother, where she will slowly lay off her ornaments and jewellery. She will give birth behind her mother's house squatting towards the east as

that is where the sun is rising: were life comes into being. If it is an exceptional birth, like twins, a breech position or the child was conceived before the previous child was weaned, the mother's mother will present each of the family members with a special necklace, *omutombe*[39]- which will be worn by all family members for the rest of their lives. This necklace should never be removed, not even during mourning, when all other jewellery is taken off or loosened.

[39] *Omutombe*: see Figure 56 (pg 152) where headman Watireiki is wearing a *omutombe* necklace, because his wife is one of a twin.

Figure 62 Himba women of Ombaka village

Women of Ombaka displaying the traditional dress and make-up of the Ovahimba people.

Women of Ombaka displaying the traditional dress and make-up of the Himba people.

Besides the above mentioned customs and rituals, items and ornaments the Himba wear numerous other clothing items, headpieces, necklaces, bracelets and anklets to accentuate their beauty and show the stage, and sometimes also emotions, of their current situation. In the Himba culture dressing up is understood as 'building one's body properly' (Van Wolputte 1998). The items that are worn strongly identify the people, not only with their ethnic grouping but also with their social standing, their wealth, their homestead, family, husband, wife and children. Rituals and ceremonies are performed to bring people together and celebrate different stages in life.

The late Dr. von Koenen probably had the most in-depth knowledge of the Himba culture as an outsider since he and his wife spent a considerable time of their life within the Himba society. In one of his presentations on the Himba years ago, he had already remarked that the society was changing. Western clothes are replacing hand-made leather clothes, ancestor worship is starting to lack its previous intensity, and more and more young people have the ambition of leaving the homestead for a few years to live in the city. But the threat to the culture of the Himba does not only come from within, but mostly from outside.

PART B CLINICAL RESEARCH

Chapter 4 Material & Methods

1. Preparations in Germany

In order to be familiar with the equipment and procedure of examination, the research staff was instructed in the routine procedure as well as the troubleshooting events of machines and examination techniques used. An instruction on the use of the body impedance analysis (BIA) machine was given by Mrs. Bettina Kann, endocrine nurse at the endocrinological department of the university hospital. Mrs. Bauer, a staff member of the department of gynaecology, gave a detailed instruction on the use of the Achilles+ for bone ultrasound measurements. In addition, we collected saliva and blood samples from fellow students. These samples were then analysed by Mrs. Elisabeth Bothe, a staff member of the Endocrinological laboratory of the University hospital, to evaluate whether the technique of salivary collection was satisfactory. An instruction on the use of the Diasolab machine was given by Mr. Thakur of Diaglobal Berlin. Mrs. Jutta Schick, diabetic assistant in the endocrinological department, instructed us on the use of the DCA Vantage HbA1c machine. The anthropometrical measurement techniques and the questionnaire were discussed in detail by the study supervisor and the student.

Most of the equipment and reagents used were bought in Germany and air-freighted to Namibia by Transworld Cargo. This was done due to the fact that medical machines are not commonly on sale in Namibia, but rather in South Africa. However, the acquisition of equipment in Germany allowed for our training.

2. Participant information and informed consent

Participants of the Ovahimba tribe in Opuwo and surrounding rural villages were recruited for the study. Recruitment was done in accordance with the Declaration of Helsinki and permission was given by the Committee of Ethics of the Philipp's University of Marburg (Appendix A), the Committee of Ethics of the University of Namibia (Appendix B) and the Namibian Ministry of Health and Social Services (MoHSS) (Appendix C).

We made an oral explanation of the study locally in August 2010. Following this, Professor Dr. Dr. PH Kann as the principal investigator of our study, gave an in depth

explanation to the participants before the research began in September 2011. The scientific background, the design of the study, possible benefits, actions on the participant as part of the study, criteria for drop-out or exclusion and the privacy of data were outlined and a copy of this information given to the subjects (Appendix D). Questions by the participants were answered. After 24 hours, the participants willing to partake in the study were asked to sign a consent form (Appendix E). In case of illiteracy of the participants consent was given by fingerprint. For these participants, there was a detailed oral explanation of the study and its procedures.

None of us researchers speak the local language Otjiherero fluently, therefore two guides, Mr. Elia Jimmy Tolu and Mr. Hafeni Philipps of Onkwele Tours, were hired as interpreters and Kaokoland specialists to assist in the study. Further assistance was given by Mrs. Elisabeth Bothe, medical technical assistant of the endocrinological laboratory of the University of Marburg as well as Dr. Stephan Flache, surgeon from the University Hospital of Leipzig. All participating parties were carefully instructed in their area of the fieldwork. Special attention was given to the necessity of confidentiality on all aspects concerning the collected data, results of the examinations and any other issues concerning the participants.

Figure 63 Explanation of research study to Chief Hembinda in Ombaka

Supervisor of the study, Professor PH Kann (left), explaining to chief Hembinda (far right) the scientific background, design and possible benefits of the study, the criteria for drop-put or exclusion from the study, and the privacy of data. The translation was done by Mr. Elia Tolu (middle) and Mr. Hafeni Philipps (far left).

Figure 64 Discussion of logistics with one of the headman of Ombaka

Interpreter Mr. Elia Tolu (left), researcher Dr. Stephan Flache (middle) and headman of Ombaka (right) discussing location and water supply.

3. Recruitment, inclusion - exclusion criteria and drop-out

We established two groups: The members of ‘Group 1’ were recruited from the Ovahimba ethnic group living in towns (Figure 65). A town was defined as a conglomeration of houses with at least one shop present. Only people who had been living in a town continuously for the past three years were recruited for the study. Sixty people from the town Opuwo participated in this group. Recruitment was done by the interpreters at Sunday church services, on the streets or by word of mouth.

Figure 65 Participants in Opuwo

Participants of the urban group after receiving their results paper (left). Interpreter Mr. Elia Tolu talking to two participants of Group 1 in the waiting room (right).

The members of ‘Group 2’ were recruited from the same indigenous ethnic group, leading a traditional lifestyle in rural areas of Namibia (Figure 66). This included participants leading a nomadic lifestyle or living in a fixed area that is at least 50 km away from the nearest village or town. The diet consisted of foods, which had been gathered, grown or hunted by the participants or a member of the family. Any person who had lived in a village or town for more than six months in the past was not recruited for the study. Three villages, Ombaka, Omuhonga and Okamwe, were chosen according to former work done by the interpreters in the areas. After we introduced ourselves and the study design to the chief and headmen and obtained their consent, recruitment was started in the chief’s homestead after which people from neighbouring homesteads were recruited. In total, 63 people participated in this group.

Figure 66 Participants in the villages

Participating Ovahimba women of the village of Omuhonga (rural group) waiting their turn.

Men and women between the age of 30 and 80 of the same indigenous ethnic group who were capable of giving consent to partake were included in the study. Exclusion criteria applying to both groups were an inability to give consent due to language difficulties or lack of comprehension for the project. Any participant with a missing or withdrawn consent was also excluded from the study. Furthermore, people could not take part if they had a history or known diagnosis of HIV/AIDS or tuberculosis, known pregnancy or were taking any 'western' medicine[40].

Participants were excluded from the study in case the investigator had found any medical reasons to do so. In addition, participants were allowed to resign from the study, regardless of the reasons, if it was his/her wish (Declaration of Helsinki). The exclusion of a participant was noted, and the reasons for the exclusion clearly stated. Once a participant was excluded from the study for any reasons whatsoever, it was the

[40]Western medicine: any medication produced by a pharmaceutical company

aim to replace the latter by a new participant in order to achieve the desired number of participants.

It was expected that the recruitment of participants for Group 2 would be more difficult than for Group 1. Therefore the aim was to recruit Group 2 (village group) first and then find matched pairs when recruiting participants for Group 1 (town group). Matching criteria would have been gender (identical to the partner of Group 2) and age (+/- 3 years to the partner in Group 2). However, due to a drought hitting the area just before our fieldwork began causing the semi-nomadic rural Ovahimba to travel to greener pastures and limited time opportunities on our part, it was not possible to adhere to this. Therefore, Group 1 was recruited first during the 2011 Namibian winter season. The recruitment of Group 2 had therefore been adjourned to the rainy season of February and March 2012. The village people returned to their more permanent homestead during this time as enough rain had then been falling and allowed the cultivation of fields, and watering and grazing of the animals.

Unfortunately the rains stayed away in the rainy season of 2011/2012 (normally December to April) and therefore mostly women were present at the homesteads. Therefore more women than men were recruited to partake in the study.

4. Location set-up

In Opuwo, the local Lutheran Church and Dhimba Translation Project agreed to let a room for the research project (Figure 67). In addition, a fridge was rented to keep the reagents and saliva samples cooled. The participants were asked to arrive at the church by 7 o'clock in the morning, after which the procedure of examination began as described below.

Figure 67 Set-up at the church in Opuwo

In the town the fieldwork was conducted in a small room rented from the local church. In the centre the participant is performing the Chester step test, before and after which the blood pressure and heart rate were measured. On the left Dr. Stephan Flache and on the right researcher Anneke Voigts.

In the villages of Ombaka, Omuhonga and Okamwe a suitable location within good distance of all homesteads was chosen. All necessary equipment, including tables, chairs, tents, water canisters and the research equipment, was transported in a horse trailer to the chosen location (Figure 68). An army tent was erected in which the examination took place. Electricity was supplied by a generator and once again a fridge had to be rented for the cooling of the reagents and saliva samples. In addition, a toilet tent was erected to allow for some privacy for the participants (and ourselves). Water was fetched from the local waterhole after permission had been obtained from the chief.

Figure 68 Set-up in the villages

All research equipment, tents, machines and the team's camping equipment were transported in a horse trailer.
Interpreter Mr. Elia Tolu.

Our food was prepared on an open fire – the research tent and assistants' tent are in the background.

5. Procedure of examination

5.1. Saliva samples and cortisol measurements

The day before the examination (day -1), the participants were asked to collect a saliva sample at sunset (approximately 7 pm) for the determination of cortisol levels. Ten minutes before the sample taking the mouth was rinsed out with water after which no more eating or drinking was allowed until after the sample taking. With the help of a straw 2 ml of saliva without foam (half a tube) was filled into a polypropylen tube (Figure 69).

Figure 69 Collection of saliva samples at sunrise in the village of Ombaka

Participants collecting saliva samples for the analysis of cortisol concentration at sunrise and sunset. This was done to examine a possible effect of cortisol on the presence of a disorder of glucose metabolism as well as the metabolic syndrome.

Collection of saliva samples at sunset in Opuwo

Participant in Opuwo (urban group) collecting saliva for the determination of cortisol levels at sunset. This was done to assess a possible effect of cortisol levels on the primary research question: disorder of glucose metabolism: no/yes.

The participants were asked to abstain from any food or drink except water from sunset of day –1 to sunrise of day 0 (12 hours). An intake of food and drink normal for the participant should have preceded this.

On arrival at the research location at 7 am the following morning the subjects name and date of birth were recorded and a research identification number allocated to each subject. In cases where subjects did not know their date of birth, an estimate of the age was given by the interpreters and the participant, and recorded as born on 01 January of the suggested year.

Once the participants confirmed that no food or drink had been taken in for the previous 12 hours, they were asked to collect a second saliva sample adhering to the same procedure as above. The saliva samples were cooled at the location and afterwards transported to Farm Voigtskirch, where they were kept frozen until the transport to Germany. The analysis of the saliva samples was done by Mrs. Elisabeth Bothe at the laboratory of the Division of Endocrinology & Diabetology at the University Hospital of Marburg. The measurements were done using Gamma coat™ Cortisol kits LOT 127952 made by the company Dia Sorin INC in Northwestern Avenue, Stillwater, USA. The counter used for measuring the cortisol level was a LB 2111 by the company Berthold in Bad Wildbad, Germany. The control measurements were done using Bio-Rad Lyphocheck, Immunoassay Plus Control Trilevel LOT 40250 made by the company IBL in Hamburg, Germany. If the value was below 10% of the lower measuring threshold set by the manufacturer (0.05 µg/dl), the value was recorded as 0. Therefore, any value below 0.045 µg/dl was recorded as 0.

5.2. Capillary blood samples – glucose, total cholesterol, HDL/LDL-Chol

Following this, 80 µl of capillary blood was taken from the participant's finger (Figure 70). This was used to determine the concentration of glucose, total cholesterol and LDL/HDL-Chol. Before the blood was drawn the participant washed his/her hands after which the place of the finger prick, the tip of the middle or ring finger, was disinfected using cutaneous disinfectants. After the area had dried sufficiently, the examiner opened the pack of materials in front of the participant so that the latter was affirmed of the sterility of its contents.

The finger prick was done using Safety Lancets super blade 1,5 mm, 1,6 mm LOT R3D650H9 by the company Sarstedt in Nuremberg, Germany. The first drop of blood was discarded. The following drops of blood were collected in 10 µl Capillary Ringcaps LOT 842322 by Hirschmann in Eberstadt, Germany for the measurement of glucose and

total cholesterol concentrations. A Minicap Sodium 32 mm/60 µl LOT 840724 by the company Hirschmann in Eberstadt, Germany was used for the collection of capillary blood for the measurement of LDL/HDL-Chol. At the end of the procedure a plaster was stuck onto the respective finger and the signs of a possible infection were explained to the participant.

Figure 70 Taking capillary blood during examination procedure in the village of Omuhonga

Researcher Anneke Voigts (left) taking capillary blood from a participant of the rural group (right). Capillary blood sample were taken to determine the glucose metabolism, fat metabolism, haemoglobin levels and HbA1c of the participants.

Working at the Diasolab solar machine in the village of Omuhonga

Researcher Anneke Voigts (left) using the Diasolab solar machine to determine various parameters of the glucose and fat metabolism or the haemoglobin levels of the participant (right).

The capillaries were emptied into the reagents using a Micropipetter by Hirschmann in Eberstadt, Germany. The glucose concentration was measured using a Glucose 142

starter reagent with buffer LOT 31137 by Diaglobal GmbH in Berlin, Germany. The cholesterol concentration was measured using a Cholesterin 142 starter reagent with buffer LOT 30138 by the same company. The HDL-Chol concentration was measured using a HDL 321 starter reagent with buffer and precipitating agents LOT 33131 by the company Diaglobal GmbH in Berlin, Germany. The measurements were done with a vario-photometer version 5.5 by the company Diaglobal GmbH in Berlin, Germany. For the measurement of HDL-Chol, the centrifuge DC by Diaglobal GmbH in Berlin, Germany was used as well as a 500 µl Transferpette (pipette) with 500 µl pipette-points by the company Brand GmbH + Co KG in Wertheim, Germany. The vario-photometer, centrifuge, pipette and the safety lancets were all part of a Diasolab machine (Figure 71). This is a solar powered miniature laboratory designed by Diaglobal GmbH in Berlin, Germany to be used in rural areas.

Figure 71 Diaglobal machine and reagents

The Diasolab solar machine is a solar powered tool used in our study for the determination of the parameters of the glucose and fat metabolism as well as the haemoglobin levels of the participants.

Table 3 Equipment, reagents and expendable items used for the examination

Machine	Parameter measured	Reagents used	Expendable items used
	Cortisol in the saliva		Polypropylene tubes
Counter LB 2111	Cortisol in the saliva	Gamma coat™ cortisol LOT 127952	
Diasolab machine, vario-photometer 5.5, centrifuge	Glucose	Glucose 142 starter reagent with buffer LOT 31137	Safety lancets super blade 1,5 mm LOT R3D650H9, 10 µl Capillary ring caps LOT 842322
	Cholesterol	Cholesterin starter reagent with buffer LOT 30138	Safety lancets super blade 1,5 mm LOT R3D650H9, 10 µl Capillary ring caps LOT 842322
	Triglycerides	Triglycerides 142 starter reagent LOT 27139	Safety lancets super blade 1,5 mm LOT R3D650H9, 10 µl Capillary ring caps LOT 842322
	Haemoglobin	Haemoglobin 342, Sodium Lanryl Sulfate 2,08 mmol/l LOT 47137	Safety lancets super blade 1,5 mm LOT R3D650H9, 10 µl Capillary ring caps LOT 842322
	HDL/LDL	HDL 321 starter	Minicap Sodium 32

Machine	Parameter measured	Reagents used	Expendable items used
		reagent with buffer and precipitating agents LOT 33131	mm/60 µl LOT 840724
DCA Vantage Analyser	HbA1c	HbA1c cassettes DCA Systems LOT 0957041	
Multifrequency Analyser B.I.A. 200-M	Body impedance analysis		Bianostic AT electrodes LOT 114033
Achilles+ 2415 Lunar	Quality of bone		
Boso blood pressure device	Blood pressure		
	Protein, glucose in urine		Combur 10 Test M urine sticks

The table lists name, make, LOT number and use of machines, expendable items and reagents used in the research study.

5.3. Oral glucose tolerance test

Thereafter, the participant was asked to complete the first phase of the oral glucose tolerance test (OGTT) and drink a solution of 75 g of pure glucose dissolved in 250 ml of water. This test is commonly used for the diagnosis of disorders of glucose metabolism. The results were interpreted according to the guidelines of the WHO 2006 (available at: http://whqlibdoc.who.int/publications/2006/9241594934_eng.pdf). The guidelines of the Society of Endocrinology, Metabolism and Diabetes of South Africa (SEMDSA) for diagnosis of DM correspond to the WHO guidelines and were therefore also used (SEMDSA 2009). In 2013 the SEMDSA published its latest guidelines for diagnosis and treatment of DM, which also include definitions for DM, impaired

glucose tolerance (IGT) and impaired fasting glucose (IFG) (SEMDSA 2013). These correspond to the WHO guidelines (available at: http://www.semdsa.org.za/images/guideline_2013_new.pdf):

1. Manifest DM

Fasting glucose	≥ 7.0 mmol/l (126 mg/dl)
or	
2-h plasma glucose*	≥ 11.1 mmol/l (200 mg/dl)

2. Impaired glucose tolerance - IGT

Fasting glucose	< 7.0 mmol/l (126 mg/dl)
and	
2-h plasma glucose*	≥ 7.8 and < 11.1 mmol/l (140 and 200 mg/dl)

3. Impaired fasting glucose – IFG

Fasting glucose	6.1 to 6.9 mmol/l (110 to 125 mg/dl)
and	
2-h plasma glucose*	< 7.8 mmol/l (140 mg/dl)

* 2 hours after the intake of the 75 g glucose load

Participants showing a FG of > 126 mg/dl were not asked to complete the OGTT as this value constitutes manifest diabetes (according to the WHO/SEMDSA guidelines applied in our study) and the intake of the glucose solution could cause a threatening hyperglycemia. All other examinations were carried out as planned. The participant was advised to neither eat nor drink anything nor do any strenuous physical activity for the next two hours until the OGTT has been fully completed.

5.4. Anthropometrical measurements

After the intake of the glucose solution the anthropometrical parameters were established. The height was measured with the shoes off by a scale drawn onto the wall

(in town) or onto a tent pole (in the villages). The weight was established using manual scales. The waist circumference (WC) was taken just above the iliac crest and the hip circumference was taken on the level of the major trochanter using a tape measure. For the weight, waist and hip recordings the participants were asked to remove any excess clothing (Figure 72). The body mass index (BMI) was defined as the quotient of weight in kilograms and the square of height in meters, expressed as kg/m².

Figure 72 Anthropometrical measurements

Participant in the village of Ombaka: Interpreter Hafeni Philips taking the weight measurement of a participant (left) as part of the anthropometrical measurements. Supervisor Professor PH Kann measuring the WC (right).

5.5. Body impedance analysis

Once the anthropometric measurements were completed, the body fat composition was measured using the BIA. The participant was asked to lie down straight on a bed on the back. The back of the right hand and foot were cleaned using cutaneous disinfectant and electrodes of the make Bianostic AT LOT 114033 made by Data Input GmbH in Darmstadt, Germany were attached: one electrode across the wrist in line with the styloid process of the ulna, one electrode across the middle of the metacarpophalangeal

joints of the middle and index finger, one electrode across the middle of the inner and outer malleolus and one across the proximal joints of the second and third toe. The electrodes were then connected to the machine with cables. The participant was asked to lie still. The body fat composition was measured using a Multifrequency Analyser B.I.A. 200-M made by Data Input GmbH in Darmstadt, Germany. Back in Germany, the obtained data was analysed using the NutriPlus software of Data Input GmbH, designed for this specific purpose (Figure 73). Assistance was given by Mr. Johannes Käsebieter of Data Input GmbH.

Figure 73 Measuring the body impedance analysis

Left: Interpreter Mr. Elia Tolu taking down the BIA values of a participant used to determine the body composition of the participant.
Right: Mrs. Elisabeth Bothe doing a BIA measurement on a participant of Ombaka village.

5.6. Bone ultrasound measurements

The determination of the sonometrical parameters of the calcaneus was done subsequently in order to determine the bone quality of the participants. The parameters used in this examination were the broadband ultrasound attenuation (BUA) as well as the speed of sound (SOS) and the stiffness index (SI) in the calcaneus. The machine used was an Achilles+ 2415 Lunar manufactured in Wisconsin, USA. The data were

analysed and stored on a Toshiba Satellite 4080 XCDT Laptop from Japan using the software Achilles+ 350. The participant was sitting on a chair in front of the machine. After the participant's left foot was cleaned and disinfected appropriately, the leg was placed on the machine's leg splint so that the lower leg rested comfortably in the leg splint and the toe holder was placed between the first and second toe. The participant was then asked to keep the leg still until the machine had completed the measurements (Figure 74). The T-score was not taken into further statistical analysis as this parameter is best used for the diagnosis of osteoporosis, which was not the aim of our study. The Z-score on the other hand is best used when the bone ultrasound of young people is assessed and the study cohort has a wide age range. Therefore, the Z-score was analysed in our study.

Figure 74 Bone ultrasound measurement

Left: Researcher Anneke Voigts conducting an osteosonometry measurement on a participant of the village of Ombaka. Right: chief Hembinda of Ombaka village having the osteosonometry measurement done. The osteosonometric measurements were done to assess the bone ultrasound of the participants.

5.7. Urine sample

The participant was also asked to give a urine sample at some point during these procedures. The urine was analysed for the concentrations of albumin and glucose with

Combur 10 Test M urine sticks made by the company Roche in Grenzach-Whylen, Germany.

5.8. Questionnaire

At the end of these procedures the participant was asked to complete the questionnaire (Appendix F). In the case of illiterate participants, the interpreters posed the questions to the participants and completed the questionnaire on their behalf (Figure 75). The questionnaire addressed the participant's level of education, family medical history, presence of cardiovascular risk factors, history of chronic diseases, current medication for chronic diseases as well as physical activity and dietary habits.

Figure 75 Completing the questionnaire

Interpreter Mr. Elia Tolu completing the questionnaire (Appendix F) with a participant of Ombaka village. The questionnaire covered education, diabetes in the family, other chronic illnesses of the participant, work, physical activity and dietary habits.

Once two hours had passed since drinking the glucose solution, the participant was called in again to complete the OGTT.

5.9. Capillary blood samples – glucose, triglycerides, haemoglobin, HbA1c

Capillary blood was taken and emptied into the reagents again according to the same procedure as described above. The glucose concentration was determined using the same material and methods as described above. The WHO and SEMDSA guidelines

used in this research are for glucose measurements done from venous blood. In order to make the collected data compatible, the conversion formula published in the SEMDSA guidelines 2009 was applied (SEMDSA 2009):

plasma glucose (mmol/l) = 0.102 + 1.066 x capillary blood glucose (mmol/l)

For the measurement of total triglycerides 10 µl of capillary blood was put into Triglycerides 142 starter reagent LOT 27139 made by Diaglobal GmbH in Berlin, Germany. Using the obtained values of the fat metabolism, the Friedewald formula was applied to calculate the LDL-Chol concentration (Friedewald et al. 1972):

LDL-cholesterol = total cholesterol – HDL-cholesterol – (triglycerides/5)

The reagent used for the determination of the haemoglobin concentration was Haemoglobin 342, Sodium Lanryl Sulfate 2,08 mmol/l LOT 47137 made by the same company as above. In addition, a drop of capillary blood was collected to determine the HbA1c concentration in HbA1c cassettes DCA Systems Siemens LOT 0957041 made by Healthcare Diagnostics Inc. Tarrytown, USA. The measurement was done in the Siemens DCA Vantage Analyser by Healthcare Diagnostics Inc. in Tarrytown, USA.

Following the determination of concentrations of various parameters in the capillary blood, the BP was taken on the left arm of the participant (Figure 76). Two consecutive measures were obtained with a manual BP device made by Boso in Jungingen, Germany and the average value recorded. In addition, the heart rate was taken at the radial artery. The participant was then asked to climb up and down a 30 cm high step for five minutes according to the Chester step test developed by Sykes et al. (2004). After five minutes the BP and heart rate were taken again adhering to the same procedures as above (Figure 76).

Figure 76 Measuring the blood pressure and doing the Chester step test

Left: Dr. Stephan Flache taking the blood pressure of a participant of Okamwe village. The blood pressure and heart rate were taken before and after physical exercise in the form of the Chester step test. Right: Participant of Omuhonga village doing the Chester step test.

5.10. Diagnosis of the metabolic syndrome

The metabolic syndrome (MetS) was diagnosed according to the definition of the Joint Interim Statement (JIS) (Alberti et al. 2009). In addition, the ethnic-specific cut-off for WC suggested by Prinsloo et al. (2011) was applied. Therefore, a participant was diagnosed with the MetS if any three of the following five components were present: high WC > 94/80 cm (for men/for women), high triglycerides > 1.7 mmol/l, low HDL-Chol < 1.0/1.3 mmol/l (for men/for women), high SBP > 130 mmHg and/or DBP > 85 mmHg, high fasting glucose (FG) > 5.6 mmol/l[41].

5.11. Discussion of results

Once all examinations had been completed and the findings recorded, a results paper (Appendix G) with all findings was compiled for the participant. The results were then

[41] Capillary blood glucose data were transformed to venous plasma glucose using the SEMDSA 2009 conversion formula (pg 186) to agree with the definition of the MetS.

explained in detail to the participant and recommendations given where needed (Figure 77). The participants were encouraged to ask questions, and all questions were answered to the best of our abilities. At the end all participants were given a blanket as gestures of thanks and the village inhabitants were given tea, coffee and maize meal.

Figure 77 Discussion of results in Opuwo and Omuhonga

Once all examinations were done and results determined each participant received a form with all the test results (Appendix G). The results were discussed in detail with each participant after which the participant was given the opportunity to ask any additional questions. Interpreter Mr. Elia Tolu (left), participant of the urban group (middle back), supervisor Professor PH Kann (far right), researcher Anneke Voigts (front right).

Once all examinations were done and results determined each participant received a form with all the test results (Appendix G). The results were discussed in detail with each participant after which the participant was given the opportunity to ask any additional questions. Participant of Omuhonga village (left), researcher Anneke Voigts (middle), interpreter Mr. Hafeni Philipps (right).

5.12. Quality control

In order to assure a consistent quality of data collected, quality controls were performed for the examinations requiring the use of machines and/or reagents. This was done every seven days or whenever the location of the research team changed. All control values were within the range given by the manufacturer. Furthermore, the procedure of examination was monitored on site by Professor Dr. Dr. PH Kann, supervisor of the research study, and laboratory assistant Mrs. Elisabeth Bothe from the Endocrinological Laboratory of the Philipp's University of Marburg.

5.13. Statistical analysis

The statistical evaluation was performed in co-operation with the Institute of Medical Biometrics and Epidemiology of the Philipp's University in Marburg. A consultation was given by Dipl.-Math. Dr. Sebastian Irle in July 2010. Problems, including the limitations of validity of the study regarding the statistical reliability resulting from the size of the groups, were discussed in length. These problems result from the extremely thin colonisation of Namibia and the small number of traditionally living indigenous Namibian populations groups. Once the data were collected, the statistical evaluation was done in consultation with Ms Hanna Daniel of the above mentioned institute.

A Standard Software (SPSS for Windows) was used for analysis and interpretation. Before the entry of the data of each participant, the data set was checked for correctness, completeness and plausibility. Looking at the statistical power reliability, a larger number of participants would have been preferable. However, the recruitment of more participants per group was impossible due to organisational reasons and time constraints.

In a first analytical step, a descriptive analysis of the data was performed. Nominal variables were evaluated using Fisher's exact test. A two-sided t-test was applied to the continuous variables with the null-hypothesis of equal mean values in both groups (mean average, median, standard deviation, minimum, maximum 25^{th} and 75^{th} percentile). For the calculation of the statistical power, a prevalence of 5% was taken as the basis.

The primary variables were:

- Disorder of glucose metabolism (DM type 2 or IGT or IFG): no/yes

Secondary variables were:

- Anthropometry (height, weight, hip and waist circumference, BMI)
- Blood pressure before (lying down for 5 minutes) and after physical exertion (5 minute step test, 40 steps/minute)
- Heart rate before (lying down for 5 minutes) and after physical exertion (5 minute step test, 40 steps/minute)
- Venous plasma glucose concentration at the points of time of withdrawal of blood for the OGTT[42]
- HbA1c concentration in the capillary blood
- Concentration of total cholesterol, LDL-Chol and HDL-Chol and total triglycerides in capillary blood
- Protein concentration in spot-urine
- Glucose concentration in spot-urine
- Haemoglobin concentration in the capillary blood
- Body impedance analysis (fat mass [in kg], fat mass [in %], lean body mass [in %])
- Cortisol concentration in saliva (day -1: at sunrise and at sunset)
- Metabolic syndrome (diagnosis according to the JIS criteria: if any three of the five individual components are present [pg191]): yes/no

  Individual components:

  High WC (> 94/80 cm (for men/for women)): no/yes

  High triglycerides (> 1.7 mmol/l): no/yes

  Low HDL-Chol (< 1.0/1.3 mmol/l (for men/for women)): no/yes

  High BP (systolic > 130 mmHg and/or diastolic > 85 mmHg): no/yes

  High fasting glucose[43] (> 5.6 mmol/l): no/yes

[42] The WHO and SEMDSA definition use venous plasma glucose, therefore our data from capillary blood glucose were transformed applying the SEMDSA 2009 conversion formula (pg 186).

[43] Capillary blood glucose data were transformed to venous plasma glucose using the SEMDSA 2009 conversion formula (pg 186) to agree with the definition of the MetS.

- Framingham risk score (gender, age, LDL-Chol, HDL-Chol, blood pressure [systolic and diastolic], DM, smoking) (Wilson et al. 1998)
- Acoustical properties of the calcaneus (broadband ultrasound attenuation, speed of sound, stiffness index, Z-score)
- Dietary and physical activity habits (including smoking, questionnaire, descriptive analysis)

In the first step of statistical analysis, the primary endpoint (proof of a disorder of glucose metabolism: no/yes) and its individual components (DM, IGT, IFG) were statistically evaluated as a comparison between the two groups using the Fisher's exact test. The secondary endpoints were analysed using either the Fisher's exact test in case of nominal variables (prevalence of the MetS and its components) or a two-sided t-test in case of continuous variables (cortisol concentration, FRS and acoustical properties of bone). For the calculation of the statistical power, a prevalence of 5% was again seen as being significant. The variables were evaluated in a group comparison. The cortisol area under the line (AUL) was calculated for the overall cortisol exposure during the day and a comparison done between the two groups using the Wilcoxon rank-sum test. When calculating the relative decline of cortisol, values reported as 0 had to be excluded, as these would greatly distort the results. However, it must be noted that due to the exclusion of these values, the results become statistically unstable.

In a second step of statistical analysis, a logistical regression model was used to adjust the data of anthropometrical characteristics, glucose metabolism, fat metabolism, BIA, cortisol homeostasis and the MetS for 'age' and 'height'. This was necessary, because the analysis of the baseline data showed a statistically significant difference of these parameters between the two study groups (Table 4, pg 199). There was no need to adjust the data for gender as $p = 1$.

Furthermore, a Mann-Whitney-U test was applied to the data of the disorder of glucose metabolism, MetS and cortisol concentration to assess the mean cortisol concentrations in the saliva of those participants in whom the respective disorder/syndrome was present and those in whom the disorder/syndrome was not present. In order to further assess the cortisol homeostasis a Pearson's correlation was applied in a third step of statistical analysis. This was done to examine the correlation

between the cortisol AUL and the metabolic parameters (WC, triglycerides, HDL-Chol, BP and FG) and the cortisol AUL and bone ultrasound measurements (BUA, SOS, SI and Z-score).

For further analysis of the bone ultrasound measurements it must be mentioned that the Z-score is already adapted for ‘age’ and ‘sex’ as confounders in the initial measurement, however, this is not the case for the BUA, SOS and SI data. Furthermore, ‘weight’, a target parameter in the analysis of glucose metabolism, had to be taken into consideration as an additional confounder when analysing bone ultrasound, even though just missing statistical significance in the first step analysis. Therefore, in a second step of statistical analysis of the bone ultrasound measurements a linear model was applied to adjust the BUA, SOS and SI data for ‘sex’, ‘age’ and ‘height’. In a third step of analysis, a linear regression model was applied to adjust the data for ‘sex’, ‘age’, ‘height’ and ‘weight’. At the same time, a linear regression model was used to adjust the Z-score data to ‘height’ in a second step of statistical analysis. In a third step of statistical analysis, the Z-score data were adjusted for the confounders ‘height’ and ‘weight’, also using a linear regression model.

Additionally, the Pearson’s correlation was applied to determine a possible correlation between the bone ultrasound data and the cortisol AUL, the consumption of milk and the walking time. For the calculation of the latter, ‘walking time’, originally a nominal variable had to be changed to a metric variable to allow for a clearer indication of a correlation between these two variables.

Chapter 5 Results

The primary question looked at in our research was whether the change of lifestyle and modification of social environment may be associated with a risk for diabetes type 2 in the Ovahimba, an indigenous Namibian population group. We hypothesised that Group 1 will have a higher prevalence of disorders of glucose metabolism than Group 2. Furthermore, the diurnal cortisol concentrations and the cortisol decline were examined and the prevalence of the metabolic syndrome (MetS) and the 10-year cardiovascular risk according to the Framingham risk score (FRS) were investigated. Lastly, the acoustical properties of bone of the Ovahimba was measured.

1. Study group and anthropometrical data

A total of 123 people partook in the study. Two groups were formed: Group 1 (urban, $n = 60$) living in a town or village and Group 2 (rural, $n = 63$) living in the rural areas of north-western Namibia. Table 4 shows the anthropometrical characteristics of the study population by group.

Table 4 Anthropometrical characteristics of study population, per group

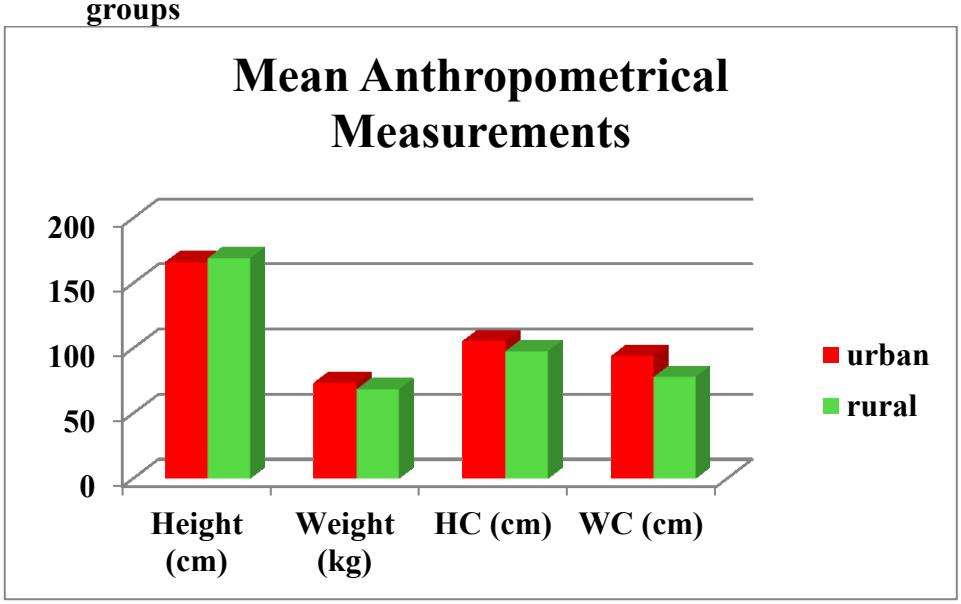
Characteristic	urban	rural	p-value	p_{a+h}-value[44]
n	60	63		
Sex	Female: *n* = 42	Female: *n* = 44	1	
	Male: *n* = 18	Male: *n* = 19		
Age (years)	46.3 ± 11.3	51.1 ± 12	0.025	
Height (cm)	166.0 ± 8.1	169.2 ± 7.6	0.025	
Weight (kg)	73.4 ± 17.3	68.5 ± 11.2	0.064	0.013
Hip circumference (cm)	105.5 ± 14.1	97.7 ± 10.2	< 0.001	< 0.001
WC (cm)	94.1 ± 17.4	78.0 ± 12.6	< 0.001	< 0.001
BMI (kg/m²)	26.6 ± 6.2	24.2 ± 4.4	0.014	0.042
Systolic blood pressure at rest (mmHg)	123.0 ± 20.2	109.4 ± 16.4	< 0.001	< 0.001
Diastolic blood pressure at rest (mmHg)	81.7 ± 13.7	74.8 ± 10.3	0.002	< 0.001
Systolic blood pressure after exercise (mmHg)	154.9 ± 27.3	137.8 ± 20	< 0.001	< 0.001
Diastolic blood pressure after exercise (mmHg)	86.0 ± 12.3	82.4 ± 9.8	0.080	0.018
Heart rate at rest (bpm)	69.8 ± 11.3	69.1 ± 12.5	0.738	0.805
Heart rate after exercise (bpm)	99.8 ± 21.2	89.2 ± 20.6	0.007	0.075

The table outlines the anthropometrical data of the participants including age, sex, weight, height and hip and WC. In addition, it shows the SBP and DBP and the heart rate taken before and after exercise. Data are mean ± SD; p-values are for comparison between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

[44] p_{a+h}-value: is the comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'. These parameters showed a statistically significant difference between Group 1 and Group 2. There was no need to adjust for gender, as p = 1.

Group 1 consisted of 42 women and 18 men with a mean age of 46.3 ± 11.3, while Group 2 consisted of 44 women and 19 men, presenting a slightly higher mean age of 51.1 ± 12 (p = 0.025). Participants of the rural group were taller than participants in the urban group (mean 169.2 ± 7.6 vs. 166.0 ± 8.1 cm; p = 0.025), while Group 1 tended to be heavier with a higher hip and waist circumference (WC) (mean weight 73.4 ± 17.3 vs. 68.5 ± 11.2 kg; p = 0.064, p_{a+h}-value = 0.013; hip circumference 105.5 ± 14.1 vs. 97.7 ± 10.2 cm; p = < 0.001, p_{a+h}-value < 0.001; WC 94.1 ± 17.4 vs. 78.0 ± 12.6 cm; p = < 0.001, p_{a+h}-value < 0.001). Furthermore, the urban group presented a maximum and minimum hip circumference of 140 cm and 69 cm respectively compared to 115 cm and 59 cm in the rural group (Figure 78).

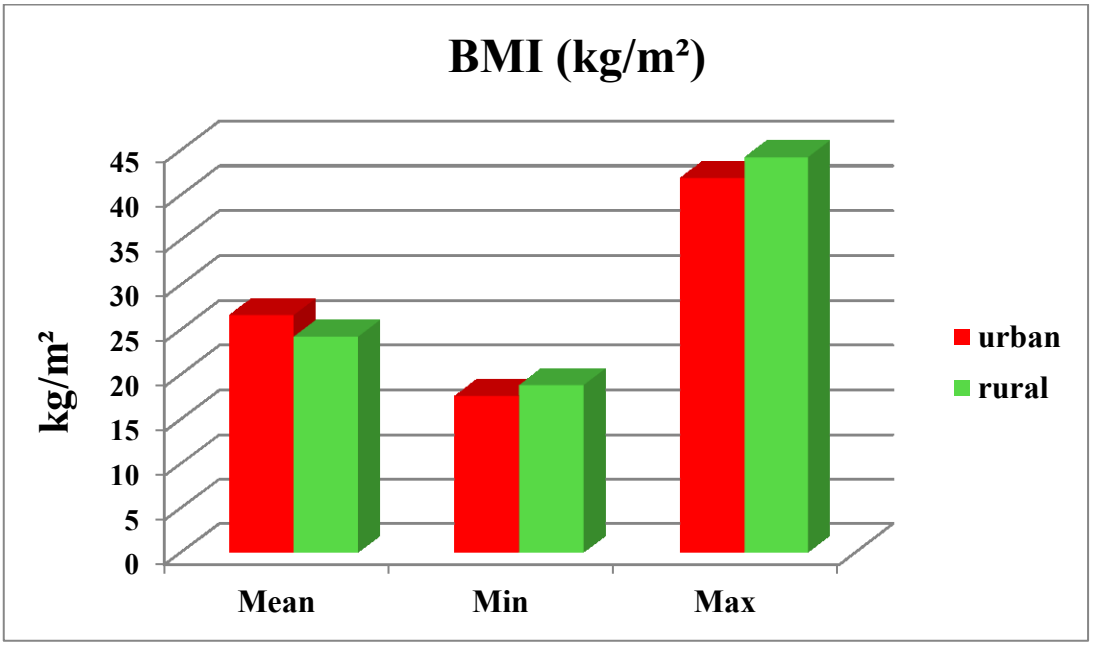
Figure 78 Comparing the mean height, weight, HC and WC of both groups



The diagram shows the mean anthropometrical measurements of the participants per group. HC = hip circumference; WC = waist circumference.

Looking at the body mass index (BMI) (Figure 79), Group 1 had a markedly higher mean BMI of 26.6 ± 6.2 kg/m² with a maximum of 41.9 kg/m² and a minimum of 17.6 kg/m² compared to participants of Group 2 who had a mean BMI of 24.2 ± 4.4 kg/m² (p = 0.014, p_{a+h}-value = 0.042) with a maximum of 44.2 kg/m² and a minimum of 18.8 kg/m².

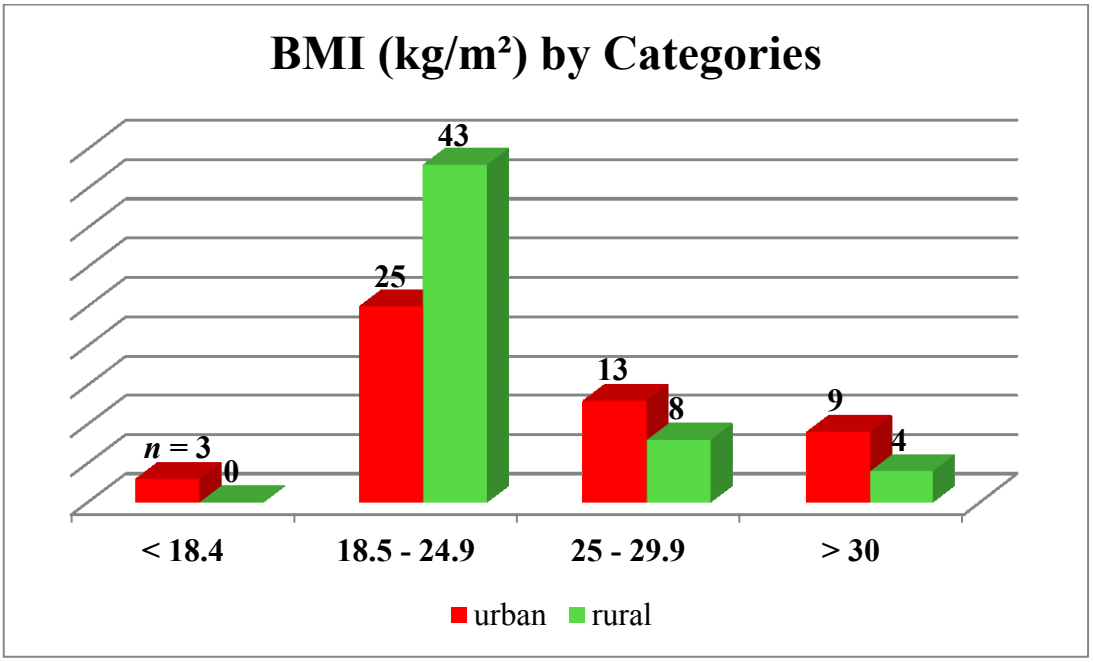
Figure 79 Comparing mean, minimum and maximum BMI, per group



The diagram presents the mean, minimum and maximum BMI of the participants per group.

Using the definition of the World Health Organisation (WHO) for obesity and overweight (BMI > 25 kg/m²) this amounts to 55% of participants of the urban group being overweight/obese and 32% of rural participants being overweight/obese. The data were categorised into four groups according to the WHO: underweight: BMI < 18.5 kg/m², normal weight: BMI 18.5 – 24.9 kg/m², overweight: BMI 25 – 29.9 kg/m² and obese: BMI > 30 kg/m² (Figure 80).

Figure 80 BMI by categories according to the WHO

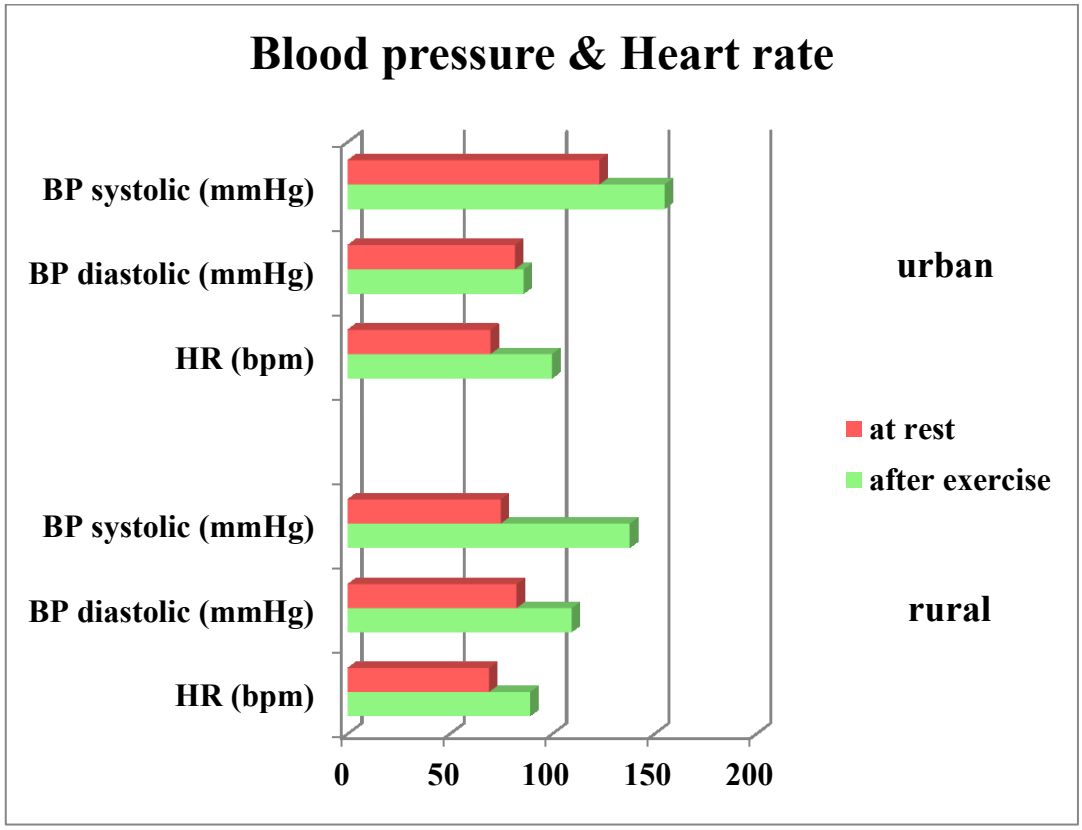


The participants were classified into different weight categories according to the definition of the WHO: underweight: BMI < 18.5 kg/m², normal weight: BMI 18.5 – 24.9 kg/m², overweight: BMI 25 – 29.9 kg/m² and obese: BMI > 30 kg/m²; n = number of participants.

Measuring systolic (SBP) and diastolic blood pressure (DBP) at rest, mean values of 123.0 ± 20.2 mmHg and 81.7 ± 13.7 mmHg were determined in Group 1, while in Group 2 values of 109.4 ± 16.4 mmHg systolic and 74.8 ± 10.3 mmHg DBP were measured (SBP $p < 0.001$, $p_{a+h} < 0.001$; DBP $p = 0.002$, $p_{a+h} < 0.001$) (Figure 81). After completing the Chester step test the values for SBP and DBP were as follows: urban group 154.9 ± 27.3 mmHg systolic and 86.0 ± 12.3 mmHg diastolic; rural group 137.8 ± 20 mmHg systolic and 82.4 ± 9.8 mmHg diastolic (SBP $p < 0.001$, $p_{a+h} < 0.001$; DBP $p = 0.080$, $p_{a+h} = 0.018$). While the mean values of the heart rate at rest showed no significant difference (69.8 ± 11.3 vs. 69.1 ± 12. bpm; $p = 0.738$, p_{a+h}-value = 0.805) there was a significant difference in the mean heart rate after exercise (99.8 ± 21.2 vs. 89.2 ± 20.6 bpm; $p = 0.007$, p_{a+h}-value = 0.075). In Group 1 four participants smoked and six used snuff, while in Group 2 nine smoked and 20 used snuff[45].

[45] Snuff: according to the website www.snufftobacco.co.uk, snuff is a preparation of tobacco which is either powered and inhaled through the nose or ground and then placed between the cheek and the gum.

Figure 81 Mean BP and heart rate before and after exercise, per group



The SBP and DBP and heart rate were measured before and after exercise. The diagram shows the measurements per group. bpm = beats per minute.

2. Glucose metabolism

The oral glucose tolerance test (OGTT) was performed in order to assess the glucose metabolism of the participants. Table 5 shows the data of the OGTT. Furthermore, the OGTT was done to answer the primary question of the research, whether a disorder of glucose metabolism is present or not.

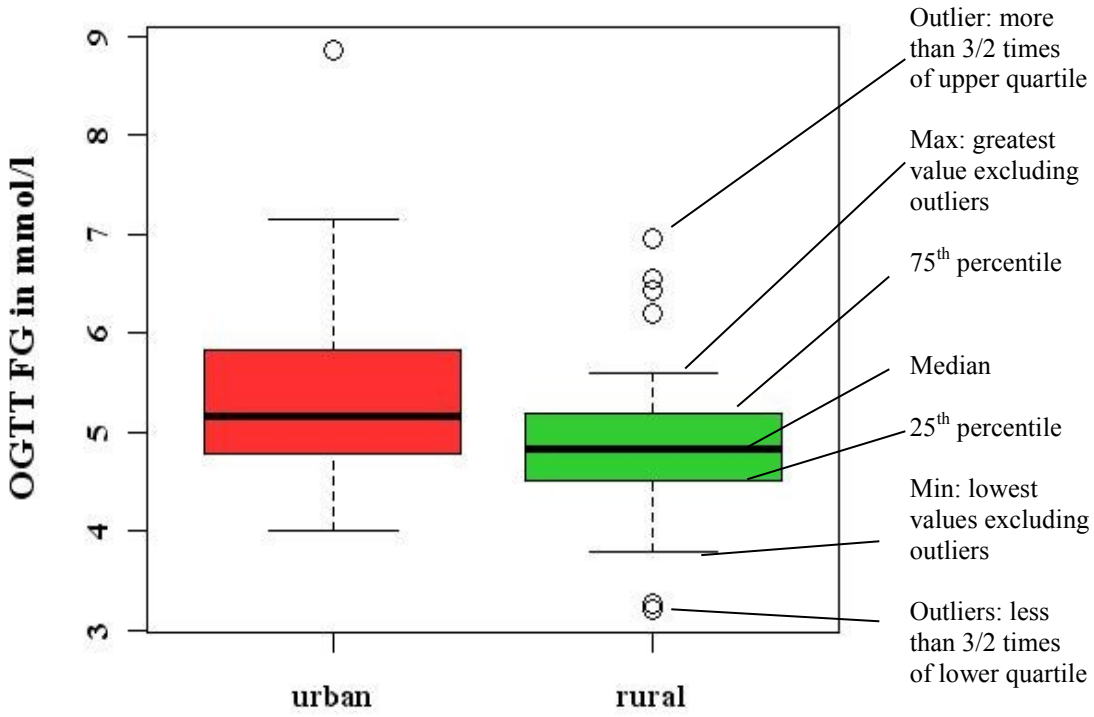
Table 5 Characteristics of glucose metabolism per group

Variable	Grp	*n*	Min	Max	Mean ± SD	Median	q_1	q_3
OGTT FG (mmol/l)	urban	60	4.0	8.9	5.3 ± 0.8	5.2	4.8	5.8
	rural	62	3.2	7.0	4.9 ± 0.7	4.8	4.5	5.1
$p < 0.001$	all	122	3.2	8.9	5.1 ± 0.8	5.0	4.7	5.4
$p_{a+h} < 0.001$								
OGTT 2h-Glc (mmol/l)	urban	59	4.6	10.6	6.7 ± 1.4	6.3	5.8	7.3
	rural	62	3.7	10.1	6.0 ± 1.3	5.8	5.4	6.5
$p = 0.002$	all	121	3.7	10.6	6.3 ± 1.4	6.1	5.5	7.0
$p_{a+h} = 0.004$								
HbA1c	urban	60	4.9	7.4	5.7 ± 0.5	5.6	5.3	5.8
	rural	63	4.8	6.1	5.5 ± 0.3	5.6	5.4	5.7
$p = 0.080$	all	123	4.8	7.4	5.6 ± 0.4	5.6	5.3	5.8
$p_{a+h} = 0.061$								

The OGTT was performed to assess the glucose metabolism of the participants. The above table presents the results of this test as well as the associated HbA1c measurements. The capillary blood glucose values were converted to venous plasma glucose values using the SEMDSA 2009 conversion formula (pg 187) to make the data compatible to the WHO and SEMDSA definitions. *n* = number, min = minimum value, max = maximum value, SD = standard deviation, $q_1 = 25^{th}$ quartile, $q_3 = 75^{th}$ quartile, FG = fasting glucose, 2-h Glc = 2 hour glucose. p-values are for comparison between Group 1 and Group 2; p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

As is evident from Table 5 and Figure 82, urban participants presented a mean fasting glucose (FG) of 5.3 ± 0.8 mmol/l, with rural participants presenting the value of 4.9 ± 0.7 mmol/l, showing a statistically significant difference between the groups ($p < 0.001$, $p_{a+h} < 0.001$). Furthermore, a minimum value of 4 mmol/l in Group 1 and 3.2 mmol/l in Group 2 as well as a maximum value of 8.9 mmol/l and 7 mmol/l in Group 1 and Group 2 respectively, were measured.

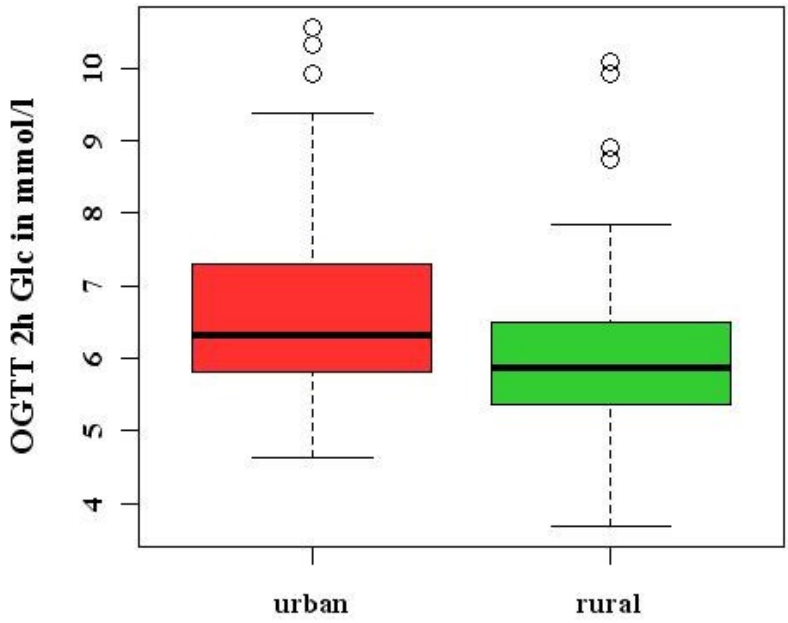
Figure 82 OGTT fasting glucose, per group



The diagram outlines the result of the FG measurements taken as part of the OGTT performed by the participants. The FG concentration was taken after an overnight fast. The capillary blood glucose values were converted to venous plasma glucose values using the SEMDSA 2009 conversion formula (pg 187) to make the data compatible to the WHO and SEMDSA definitions.

Looking at the 2-h Glc value of the OGTT (Figure 83), similar significant differences could be found between Group 1 and Group 2: the urban group had a mean value of 6.7 ± 1.4 mmol/l and the rural group of 6.0 ± 1.3 mmol/l. This calculates to p = 0.002 and p_{a+h} = 0.004, using a two-sided t-test. The minimum and maximum values for Group 1 were 4.9 mmol/l and 7.4 mmol/l, while Group 2 presented minimum and maximum values of 4.8 mmol/l and 6.1 mmol/l.

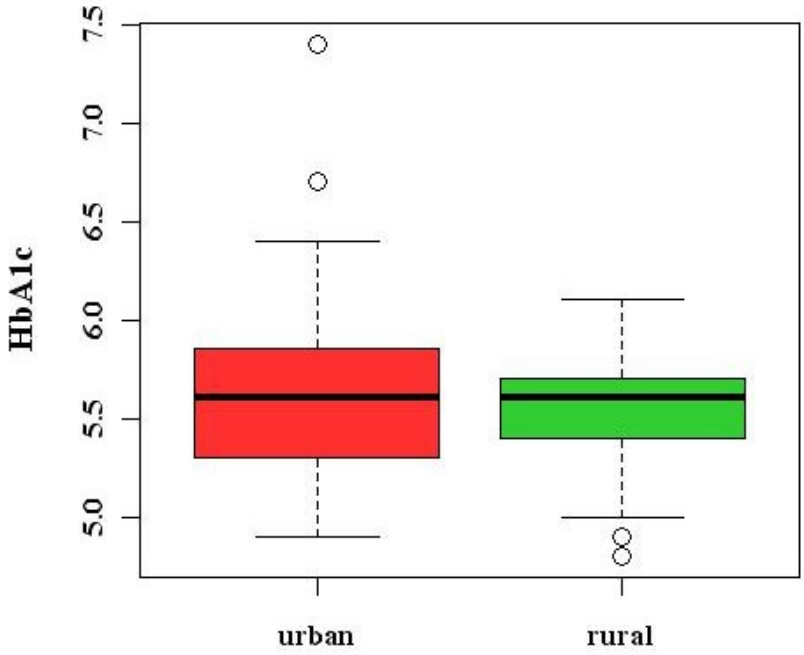
Figure 83 OGTT 2-h glucose, per group



The diagram outlines the results of the 2-h Glc concentration test. This measurement was done as part of the OGTT, two hours after the participants had taken 75 g glucose dissolved in water. The capillary blood glucose values were converted to venous plasma glucose values using the SEMDSA 2009 conversion formula (pg 187) to make the data compatible to the WHO and SEMDSA definitions.

However, as can be seen in Figure 84 no marked difference was found in the HbA1c values with Group 1 having a mean of 5.7 ± 0.5% and Group 2 having a mean of 5.5 ± 0.3% ($p = 0.080$, $p_{a+h} = 0.061$).

Figure 84 HbA1c measurements, per group



The HbA1c was measured as part of the analysis of the participants' glucose metabolism.The results are presented in the above diagram.

Using Fisher's exact test, the data were analysed for the presence of a disorder of glucose metabolism in each study group. Table 6 shows the details of the data found.

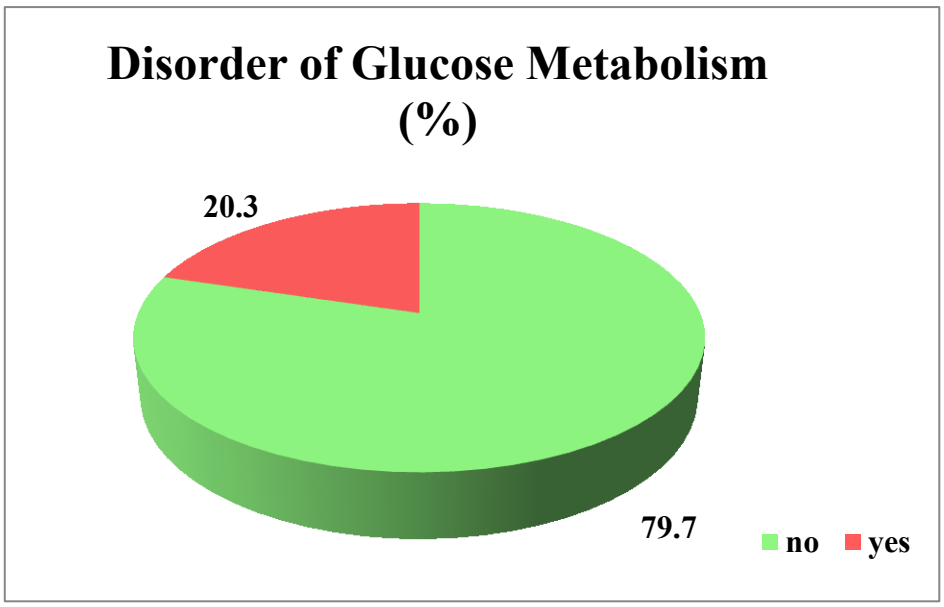
Table 6 Prevalence of disorder of glucose metabolism per group

		urban		rural		all	
Variable		***n***	**%**	***n***	**%**	***n***	**%**
Disorder of glucose metabolism							
	no	43	71.7	55	87.3	98	79.7
	yes	17	28.3	8	12.7	25	20.3
p = 0.04							
p_{a+h} = 0.023							
Individual components							
Diabetes type 2							
(DM type 2)							
	no	58	96.7	63	100	121	98.4
	yes	2	3.3	0	0.0	2	1.6
p = 0.24							
p_{a+h} = 0.996							
Impaired glucose tolerance							
(IGT)							
	no	49	81.7	58	92.1	107	87.0
	yes	11	18.3	5	7.9	16	13.0
p = 0.11							
p_{a+h} = 0.065							
Impaired fasting glucose							
(IFG)							
	no	56	93.3	60	95.2	116	94.3
	yes	4	6.7	3	4.8	7	5.7
p = 0.71							
p_{a+h} = 0.675							

The table presents the statistical analysis of the OGTT data done to assess the prevalence of a disorder of glucose metabolism. The guidelines of the WHO and SEMDSA were applied. Disorder of glucose metabolism: DM or IGT or IFG; DM: FG ≥ 7.0 mmol/l **or** 2-h Glc ≥ 11.1 mmol/l; IGT: FG < 7.0 mmol/l **and** 2-h Glc ≥ 7.8 and < 11.1 mmol/l; IFG: FG 6.1 to 6.9 mmol/l **and** 2-h Glc < 7.8 mmol/l. The capillary blood glucose values were converted to venous plasma glucose values using the SEMDSA 2009 conversion formula (pg 187) to make the data compatible to the WHO and SEMDSA definitions. Data presented as numbers (*n*) and percentages (%). p-values are for comparison between Group 1 and Group 2; p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

The analysis of the data yielded a 20.3% prevalence of a disorder of glucose metabolism in both groups, meaning that 25 participants suffered from any of the three disorders making up a dysfunctional glucose metabolism. More than double the number were part of Group 1 (28.3%) compared to Group 2 (12.7%), showing a significance with $p = 0.04$ and $p_{a+h} = 0.023$.

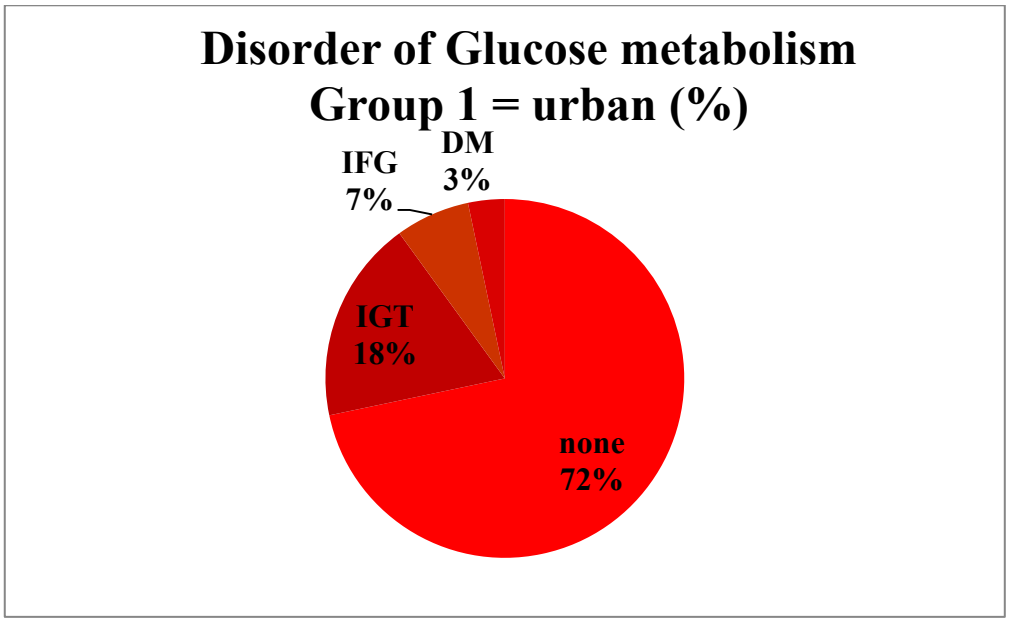
Figure 85 Prevalence of a disorder glucose metabolism in the total study population



The diagram shows the prevalence of the primary research question in the total study population: disorder of glucose metabolism no/yes. Data presented as percentage (%).

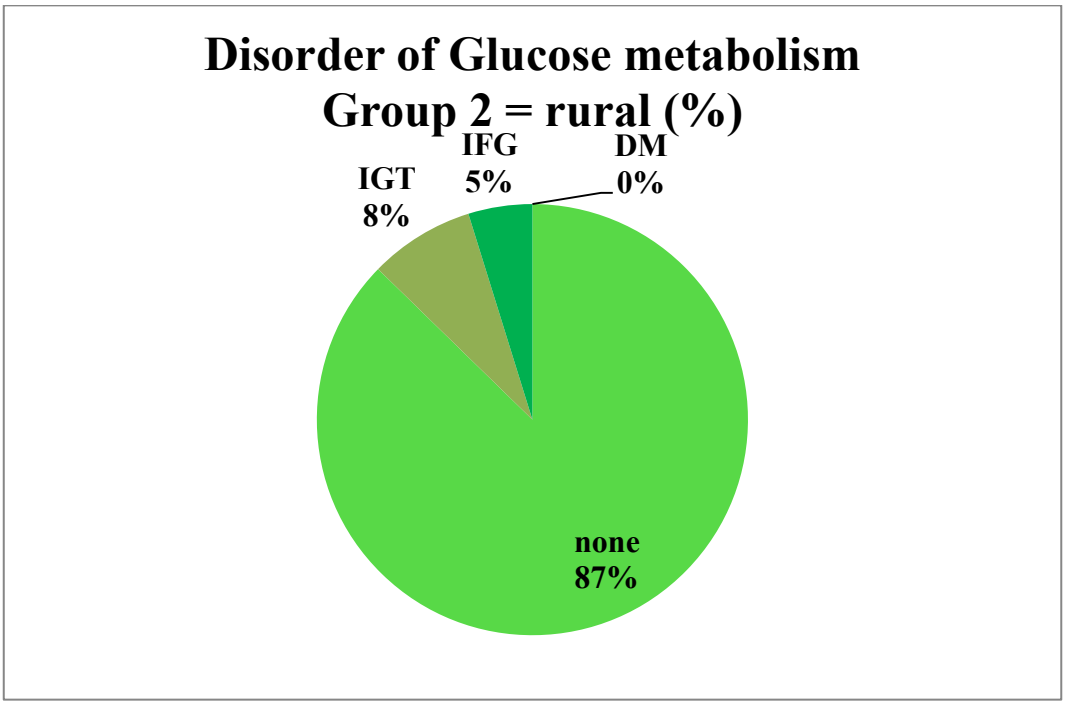
Nevertheless, no significance could be found when analysing the individual components of the disorder of glucose metabolism (Figure 86 and Figure 87). Only two participants suffered from a newly diagnosed DM, both of which belonged to the urban group (3.3 vs. 0%; $p = 0.24$, $p_{a+h} = 0.996$). This resulted in a prevalence of 1.6% of DM in both groups. In the urban setting, there were four (6.7%) participants and in the rural three (4.8%) participants presenting an IFG ($p = 0.71$, $p_{a+h} = 0.675$). Thus, the prevalence of participants suffering from an IFG in both groups came to seven (5.7%). Looking at the IGT, this was the most prevalent disorder presented: 16 participants (13.0%) of both groups presented this disorder, 11 participants of Group 1 and five of Group 2 (18.3 vs. 7.9%; $p = 0.11$, $p_{a+h} = 0.065$).

Figure 86 Prevalence of the individual components of a disorder of glucose metabolism, Group 1 (urban)



The diagram shows the percentage (%) of the individual components of the disorder of glucose metabolism present in the urban group after the performance of the OGTT.

Figure 87 Prevalence of the individual components of a disorder of glucose metabolism, Group 2 (rural)



The diagram shows the percentage (%) of the individual components of the disorder of glucose metabolism present in the rural group after the performance of the OGTT.

3. Fat metabolism

In the scope of the research, the characteristics of the fat metabolism of the participants were investigated. Table 7 shows the found data.

Table 7 Characteristics of fat metabolism per group

Variable	urban	rural	p-value	p_{a+h}-value
n	60	63		
Triglycerides (mmol/l)	1.1 ± 0.8	0.8 ± 0.4	0.040	0.024
Total cholesterol (mmol/l)	4.3 ± 1.3	4.6 ± 1.0	0.215	0.396
HDL-cholesterol (mmol/l)	1.3 ± 0.4	1.5 ± 0.4	0.014	0.002
LDL-cholesterol (mmol/l)	2.5 ± 0.9	3.0 ± 1.0	0.012	0.091

The table shows values obtained when examining the fat metabolism of the participants. Data are mean ± SD; p-values are for comparison between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

The urban participants presented slightly higher values of triglyceride compared to rural participants (1.1 ± 0.8 vs. 0.8 ± 0.4 mmol/l; p = 0.040, p_{a+h} = 0.024). Looking at the total cholesterol, there was no significant difference between the two groups. Group 1 had a lower mean value (4.3 ± 1.3 mmol/l) than Group 2 (4.6 ± 1.0 mmol/l). This was also true for the HDL-Chol measurement, with the latter showing a significant difference (Group 1 1.3 ± 0.4 vs. Group 2 1.5 ± 0.4 mmol/l; p = 0.014, p_{a+h} = 0.002). The values for the LDL-Chol were calculated using the Friedewald formula. Group 1 presented a mean value of 2.5 ± 0.9 mmol/l, that is a significant difference to the mean value of Group 2 (3.0 ± 1.0 mmol/l; p = 0.012). The difference was not significant anymore after adjustment of data for 'age' and 'height', p_{a+h} = 0.091.

4. Urine and haemoglobin examination

The urine of the participants was examined for glucose and albumin. The data were classified as urine glucose positive: no/yes and urine albumin positive: no/yes. The examination for glucose in the urine showed no significant difference in the two groups, with two people in the urban setting and four people in the rural setting having a positive urine sample (3.3 vs. 6.3%; p = 0.68). The examination of albumin in the urine however, presented a marked difference with 10% of participants of Group 1 having a positive urine sample and none of Group 2 (p = 0.01).

The measurements of the haemoglobin levels produced almost no difference between the two groups. The urban group presented a mean of 13.2 ± 1.6 g/dl and rural group a mean measurement of 13.2 ± 1.4 g/dl resulting in a p-value of 0.963.

5. Body impedance analysis

The body composition of the participants was analysed using body impedance analysis (BIA). The fat mass in kilogram and percentage as well as the lean body mass in kilogram were measured. Table 8 shows the specific data.

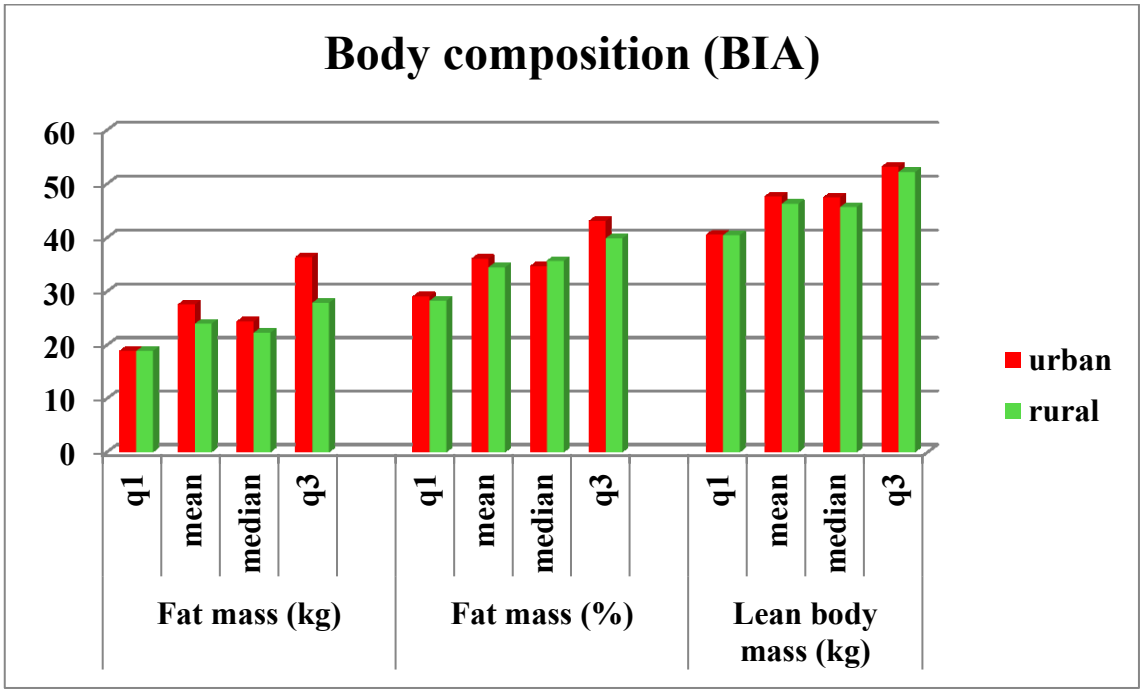
Table 8 Analysis of body composition using body impedance analysis, per group

Variable	urban	rural	p-value	p_{a+h}-value
n	60	63		
Fat mass (kg)	27.6 ± 12.8	24.0 ± 8.5	0.062	0.205
Fat mass (%)	36.1 ± 9.7	34.5 ± 8.7	0.335	0.907
Lean body mass (kg)	47.7 ± 8.5	46.3 ± 8.4	0.365	0.025

The method of BIA was applied to assess the fat mass in kg and % as well as the lean body mass in kg of the participants. This table shows the data obtained. Data are mean ± SD; p-values are for comparison between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

The investigation of the body composition using BIA presented no significant difference between the two study groups (Table 8). The fat mass in kg had the most pronounced, but still statistically insignificant difference with a p-value of 0.062 and $p_{a+h} = 0.205$. Group 1 had a mean value of 27.6 ± 12.8 kg and Group 2 a mean value of 24.0 ± 8.5 kg. The fat mass in percentage showed no difference with a p-value of 0.335 and $p_{a+h} = 0.907$ and mean values of 36.1 ± 9.7% for the urban group and 34.5 ± 8.7% for the rural group. Looking at the lean body mass urban participants had a mean of 47.7 ± 8.5 kg and rural participants a mean of 46.3 ± 8.4 kg. There was a significant difference of the lean body mass after adjustment for 'age' and 'height' between the urban and rural group ($p_{a+h} = 0.025$). Figure 88 shows the mean, 25th and 75th percentile and the median of the BIA measurements of the participants.

Figure 88 Body composition measurements, per group



The BIA method was applied to assess the fat mass in kg and % as well as the lean body mass in kg of the participants. The data show the mean, 25th percentile (q1), median and 75th percentile (q3) of the BIA measurements per group of participants.

6. Cortisol examination

The cortisol concentration in the saliva was measured at sunrise and sunset in order to assess a possible association of this variable and the primary question. The results are presented in Table 9.

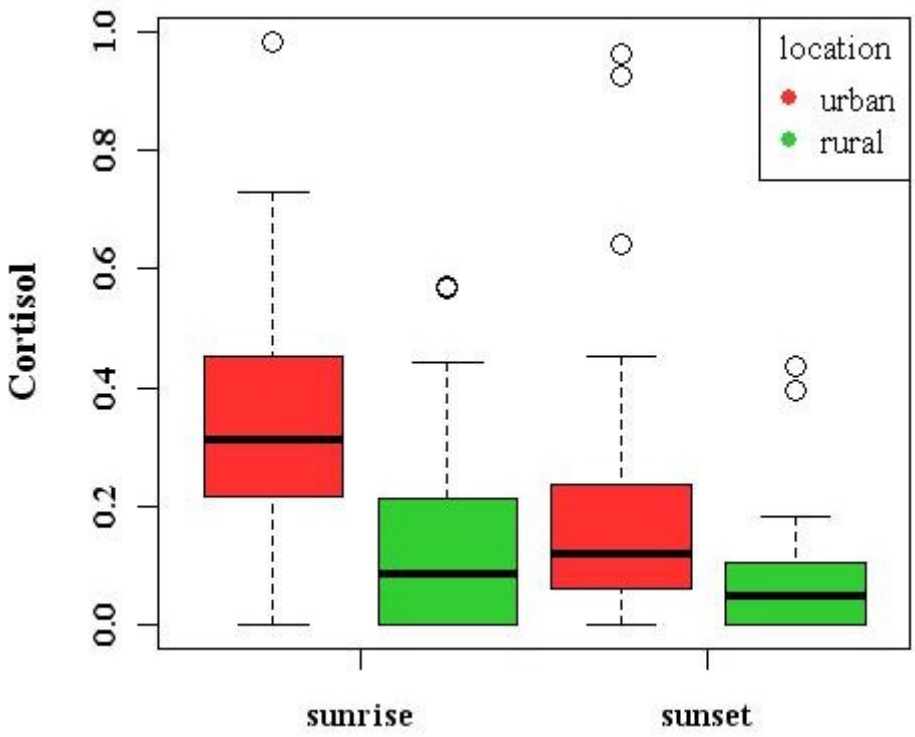
Table 9 Cortisol concentrations (µg/dl) at sunrise and sunset per group

Variable	Group	Mean ± SD	Min	Max	Median
Cortisol sunrise (µg/dl)	urban	0.34 ± 0.18	0.00	0.98	0.31
	rural	0.12 ± 0.15	0.00	0.57	0.08
$p < 0.001$	all	0.24 ± 0.20	0.00	0.98	0.22
$p_{a+h} < 0.001$					
Cortisol sunset (µg/dl)	urban	0.18 ± 0.20	0.00	0.96	0.12
	rural	0.07 ± 0.09	0.00	0.44	0.05
$p < 0.001$	all	0.13 ± 0.17	0.00	0.96	0.08
$p_{a+h} < 0.001$					

The cortisol concentrations in the saliva sample of urban and rural participants were examined at sunrise and sunset. This was done to establish a possible association between cortisol levels and the presence of a disorder of glucose metabolism and to detect a possible difference between the urban and the rural participants in general. Data are means ± SD, min = minimum, max = maximum and median; p-values are for comparison between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

As is evident from Table 9 and Figure 89, Group 1 presented a mean concentration of 0.34 ± 0.18 µg/dl at sunrise and Group 2 a mean concentration of 0.12 ± 0.15 µg/dl, showing a significant difference ($p < 0.001$, $p_{a+h} < 0.001$). A similar significance with p also < 0.001 and $p_{a+h} < 0.001$, was found when comparing the mean values of the sunset measurement (0.18 ± 0.20 vs. 0.07 ± 0.09 µg/dl).

Figure 89 Cortisol concentrations (µg/dl) sunrise and sunset, per group

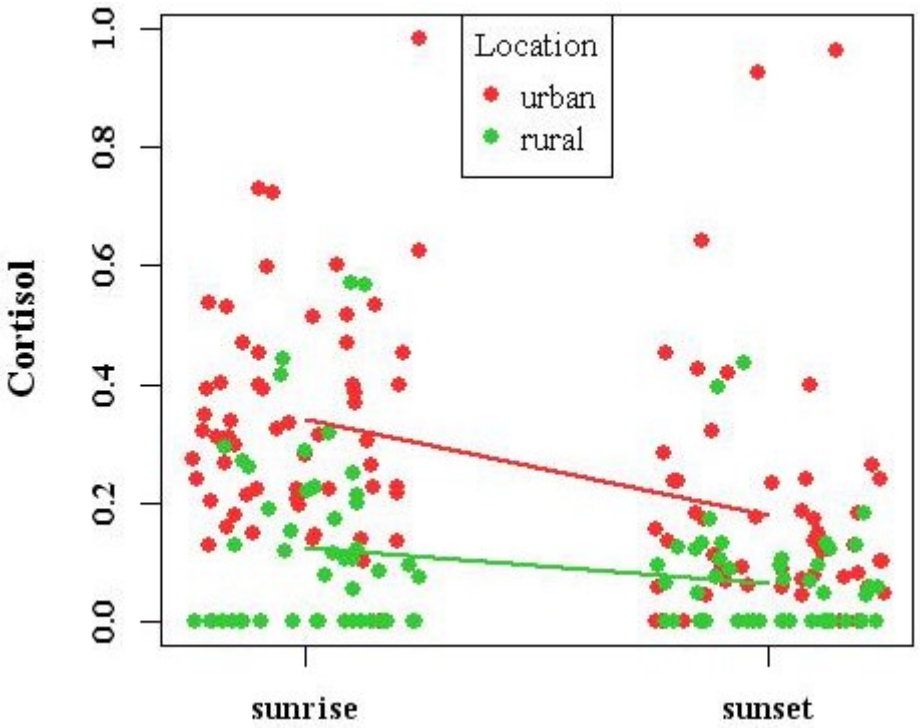


The cortisol concentration of urban and rural participants was examined at sunrise and sunset.

6.1. Decline of cortisol concentration: sunrise to sunset

Looking at the physiological decline of the concentration between sunrise and sunset a mean absolute decline of 0.21 ± 0.19 µg/dl was found in Group 1. Participants of Group 2 presented a less pronounced decline in their cortisol concentration between sunrise and sunset with a mean value of 0.14 ± 0.10 µg/dl, however, starting from a significantly lower baseline level. This calculated to a significant difference of decline between the urban and the rural group with $p = 0.016$ and $p_{a+h} = 0.021$. Figure 90 shows the individual measurements of the participants (per group) as well as the decline between the cortisol concentrations at sunrise and at sunset.

Figure 90 Absolute decline of cortisol concentration (µg/dl) between sunrise and sunset, per group



The above diagram shows individual measurements of cortisol concentration as well as the mean decline between sunrise and sunset absolute cortisol concentrations per group. As is indicated by the two continuous lines, the decline in the concentrations was more pronounced in the urban than the rural group. The urban group started from a much higher baseline value though.

The relative decline of cortisol concentration, as a marker of the diurnal cortisol variability was 37.2% in the urban group and 34.5% in the rural group with a non-significant p-value of 0.504 and $p_{a+h} = 0.879$. It must be noted though that in order to make this statistical calculation all measurements recorded as '0' had to be excluded. This makes the calculations statistically unstable and thus the results should be interpreted carefully.

6.2. Area under the line

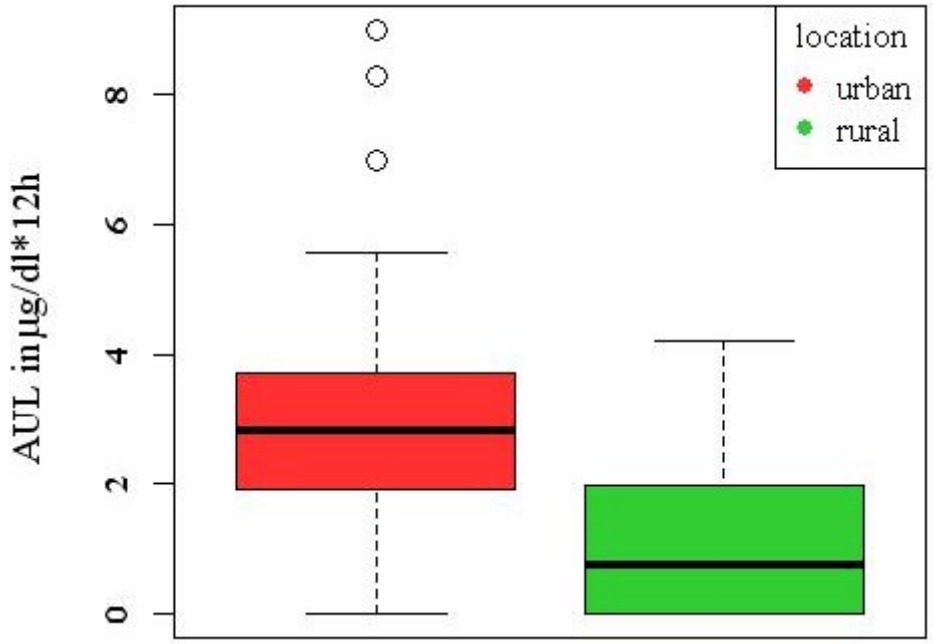
In order to assess the average overall exposure to cortisol, the area under the line (AUL) was calculated (Figure 91). A two-sided Wilcoxon rank-sum test was performed in order to assess the distribution of the data. The test showed a statistically significant difference in the exposure to cortisol in the baseline data and in the data adjusted for 'age' and 'height' between Group 1 and Group 2 with $p < 0.001$ and $p_{a+h} < 0.001$ (Table 10).

Table 10 Cortisol area under the line (AUL), per group

Variable	Group	Mean ± SD	Min	Max	Median
AUL	urban	3.08 ± 1.74	0.00	8.99	2.80
	rural	1.14 ± 1.28	0.00	4.19	0.74
$p < 0.001$	all	2.13 ± 1.82	0.00	8.99	1.96
$p_{a+h} < 0.001$					

The cortisol AUL was calculated to assess the overall exposure to cortisol in the course of the day. Data are means ± SD, min = minimum, max = maximum and median; p-values are for comparison between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

Figure 91 Area under the line (AUL) of cortisol concentration



In order to assess the overall exposure to cortisol the area under the line was calculated.

6.3. Association of cortisol concentration and the presence of a disorder of glucose metabolism

In order to assess the association of cortisol concentration and the presence of dysglycaemia, the absolute values of those participants with and those without the disorder were compared. This comparison was done for the whole study cohort as well as for the individual groups.

Table 11 Mean cortisol concentration (µg/dl) at sunrise/sunset and cortisol AUL of participants with and those without a disorder of glucose metabolism

	Disorder not present	Disorder present	p-value	p_{a+h}-value[46]
sunrise				
urban	0.33 ± 0.17	0.37 ± 0.21	0.600	0.083
rural	0.13 ± 0.14	0.09 ± 0.23	0.140	0.377
all	0.23 ± 0.18	0.30 ± 0.25	0.210	0.423
sunset				
urban	0.21 ± 0.23	0.10 ± 0.07	0.080	0.211
rural	0.07 ± 0.10	0.03 ± 0.05	0.290	0.076
all	0.14 ± 0.18	0.08 ± 0.07	0.470	0.249
AUL (all)	2.13 ± 1.81	2.27 ± 1.81	0.689	

In order to assess a possible association between the concentration of cortisol and the prevalence of a disorder of glucose metabolism, a statistical analysis of the cortisol concentrations at sunrise and sunset was done and the cortisol AUL calculated. The values of those participants in whom the disorder was not present and those in whom the disorder was present were compared. Mean data presented in µg/dl; p-values are for comparison between the two groups, p_{a+h}-values are for comparison between Group 1 and Group 2 and examine the association of 'age' and 'height' and the cortisol concentration in the saliva.

The mean values of cortisol concentration at sunrise and sunset in participants in whom dysglycaemia was not present and those in whom dysglycaemia was present showed no significant difference. There was also no significant difference in the cortisol AUL between the participants (Table 11).

Furthermore, the decline of the cortisol concentration between sunrise and sunset was compared between participants with and those without a disorder of glucose metabolism (Table 12).

[46] p_{a+h}: A linear regression model was applied to examine the influence of 'age' and 'height' on the mean cortisol concentrations in the participants in whom the disorder was present and those in whom it was not present. The p-values were calculated using a Mann-Whitney-U test

Table 12 Mean decline of cortisol concentration (µg/dl) of participants with and without a disorder of glucose metabolism, per group

	Disorder not present	Disorder present	p-value	p_{a+h}-value
urban	0.11 ± 0.24	0.27 ± 0.19	0.040	0.231
rural	0.06 ± 0.13	0.06 ± 0.18	0.943	0.949
all	0.08 ± 0.21	0.21 ± 0.19	0.011	0.004

In order to assess a possible association between the concentrations of cortisol and the prevalence of a disorder of glucose metabolism, a comparison of the decline in cortisol concentration between sunrise and sunset was performed. The values of those participants in whom the disorder was not present and those in whom the disorder was present were compared. Mean data presented in µg/dl; p-values are for comparison between the two groups, p_{a+h}-values are for comparison between Group 1 and Group 2 and examine the association of 'age' and 'height' and the cortisol concentration in the saliva.

Looking at Group 1, the mean decline of cortisol of participants without a disorder of glucose metabolism was 0.11 ± 0.24 µg/dl. For those with a disorder it was 0.27 ± 0.19 µg/dl, the latter, however, started at a significantly higher baseline value (mean: disorder not present 0.33 ± 0.17 µg/dl; disorder present 0.37 ± 0.21 µg/dl). The decline shows a significant difference with $p = 0.040$, but not after adjustment for 'age' and 'height' with $p_{a+h} = 0.231$. No significant difference was found in Group 2, where participants without and with the disorder presented a mean cortisol decline of 0.06 µg/dl (disorder not present mean 0.06 ± 0.13 µg/dl, disorder present 0.06 ± 0.18 µg/dl) ($p = 0.943$, $p_{a+h} = 0.949$). When analysing the study population as a whole, a significant difference was found: participants with no glucose disorder presented a mean decline of 0.08 µg/dl and those with a disorder a mean decline of 0.21 µg/dl. This calculates to a significance with $p = 0.011$ and $p_{a+h} = 0.004$. However, the participants in whom the disorder was present started at a higher baseline value (0.23 ± 0.18 vs. 0.30 ± 0.25, $p = 0.210$, $p_{a+h} = 0.423$).

7. Metabolic syndrome

The prevalence of the MetS in the Ovahimba people was a secondary question of the research. In order to answer this question, the definition of the Joint Interim Statement (see 'Diagnosis of the metabolic syndrome', pg 191) was used and the data obtained were then analysed using Fisher's exact test. Table 13 presents a summary of the data found. A logistical regression model was applied to the data to adjust for 'age' and 'height'.

Table 13 Prevalence of the MetS and its individual components, per group based on the JIS criteria

		urban		rural		all	
Variable		***n***	**%**	***n***	**%**	***n***	**%**
Metabolic syndrome	no	41	68.3	58	92.1	99	80.5
	yes	19	31.7	5	7.9	24	19.5
$p < 0.001$							
p_{a+h}[47] < 0.001							
Individual components							
High waist circumference	no	22	36.7	49	77.8	71	57.7
	yes	38	63.3	14	22.2	52	42.3
$p < 0.001$							
$p_{a+h} < 0.001$							
High triglycerides	no	53	88.3	62	98.4	115	93.5
	yes	7	11.7	1	1.6	8	6.5
$p = 0.029$							
$p_{a+h} = 0.045$							
Low HDL-cholesterol	no	31	51.7	47	74.6	78	63.4
	yes	29	48.3	16	25.4	45	36.6
$p = 0.010$							
$p_{a+h} = 0.009$							
High blood pressure	no	35	58.3	48	76.2	83	67.5
	yes	25	41.7	15	23.8	40	32.5
$p = 0.054$							
$p_{a+h} = 0.005$							
High fasting glucose							
	no	52	86.7	59	93.7	111	90.2
	yes	8	13.3	4	6.3	12	9.8
$p = 0.233$							
$p_{a+h} = 0.183$							

The table shows the prevalence of the MetS in the whole study population and in each individual group according to the definition of the Joint Interim Statement: high WC > 94/80 cm (for men/for women), high triglycerides > 1.7 mmol/l, low HDL-Chol < 1.0/1.3 mmol/l (for men/for women), high SBP > 130 mmHg and/or DBP > 85 mmHg, high FG > 5.6 mmol/l. Capillary blood glucose data were transformed to venous plasma glucose using the SEMDSA 2009 conversion formular (pg 187) to agree with the definition of the MetS. Data presented as numbers (n) and percentages (%); p–values are for comparison

[47] p_{a+h}-value: is the comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'. These parameters showed a statistically significant difference between Group 1 and Group 2.

between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'age' and 'height'.

The prevalence of the MetS in the total study population was 19.5% (n = 24) (Figure 92). A significant difference was found between the two study groups, as Group 1 presented almost four times the prevalence of Group 2 (31.7 vs. 7.9%; $p < 0.001$ and $p_{a+h} < 0.001$).

Figure 92 Prevalence of the MetS in the total study population

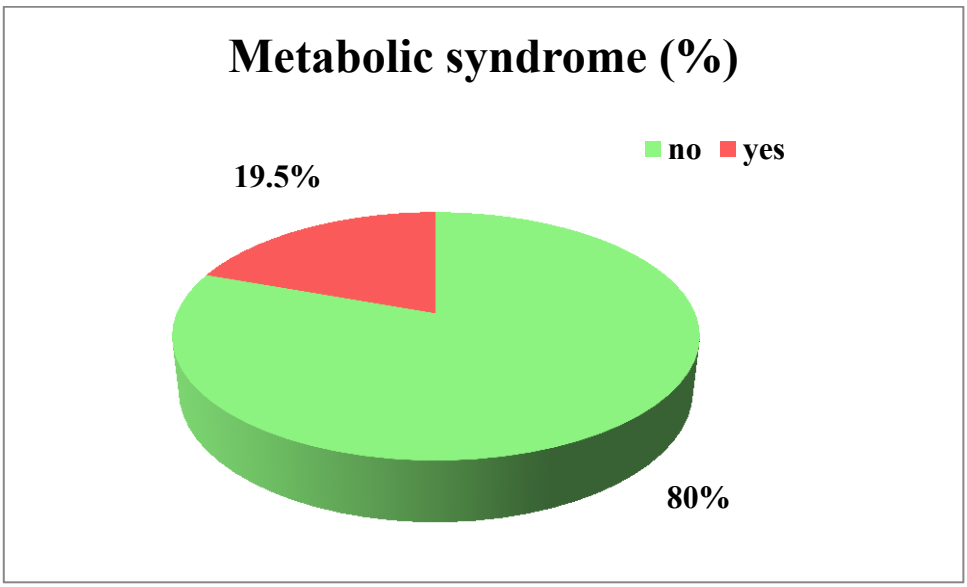


Figure 92 shows the prevalence of the MetS in the total study population. Data presented as percentage (%).

An investigation of the individual components of the MetS (Figure 93), indicates that a high WC presents the most significant difference between the two study groups (63.3 vs. 22.2%; $p < 0.001$, $p_{a+h} < 0.001$), with 42.3% of participants above the cut-off value. Seven participants (11.7%) in the urban setting were found to have high triglycerides, while there was only one participant (1.6%) in the rural area, showing a significant difference ($p = 0.029$, $p_{a+h} = 0.045$) in this category. In accordance with the above differences, the urban group contained more participants with low HDL-Chol than the rural group (48.3 vs. 25.4%; $p = 0.010$, $p_{a+h} = 0.009$). A total 36.6% of participants presented a low HDL-Chol level. The investigation of the BP only showed a significant difference between the two study groups after adjustment for 'age' and 'height' ($p = 0.054$, $p_{a+h} = 0.005$): Group 1 had 25 individuals (41.7%) and Group 2 had 15 individuals (23.8%) above the cut-off values. This totals to 40 participants (32.5%)

suffering from a BP which is considered as too high by the JIS. The second individual component which did not present a significant difference between the two groups was a high FG measurement with a p-value of 0.233 and $p_{a+h} = 0.183$ and a prevalence of 9.8% in the total study population. However, percentage-wise Group 1 still had more than double as many individuals with too high FG than Group 2 (13.3 vs. 6.3%).

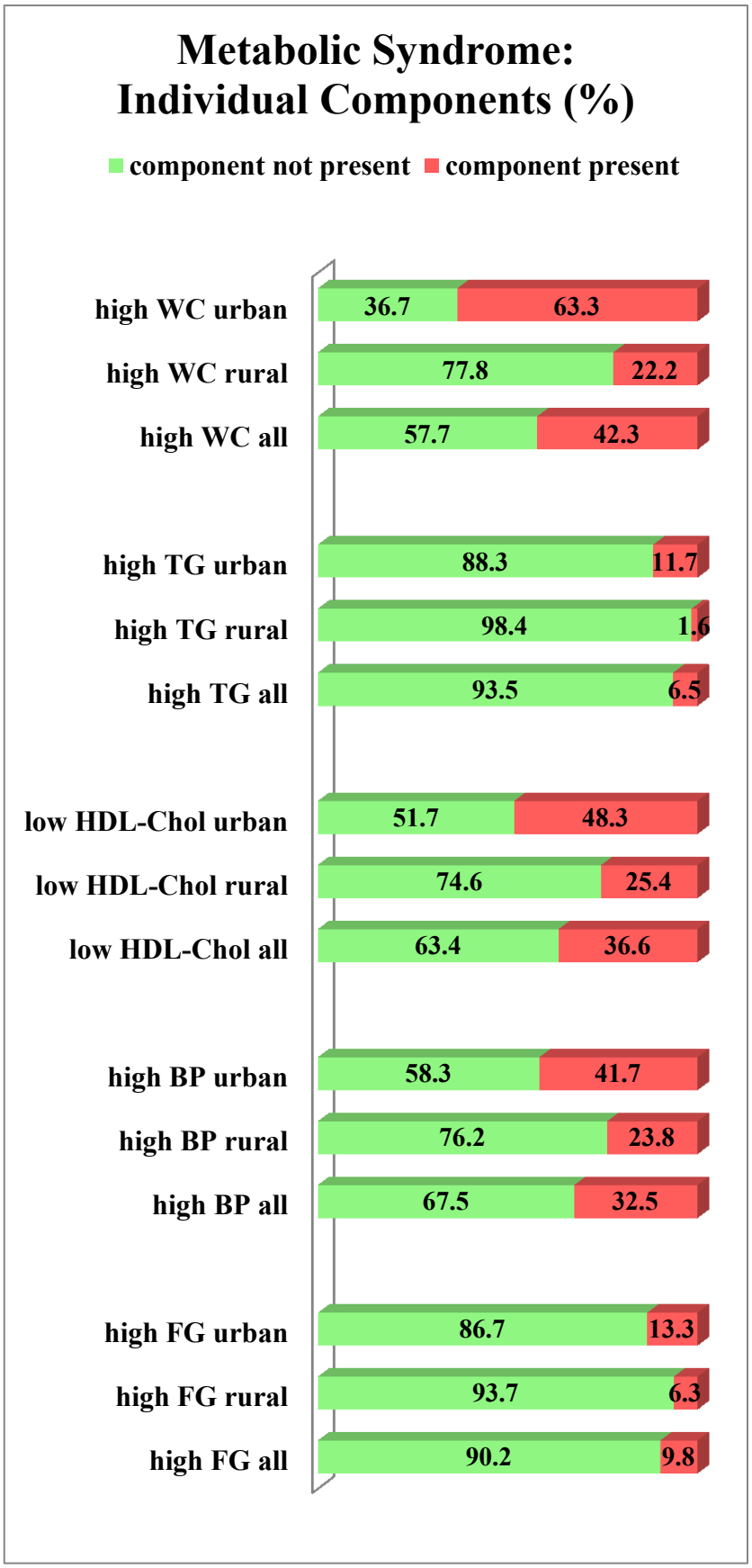


Figure 93

Prevalence of the individual components of the MetS.

The diagram shows the prevalence of the individual components of the MetS in the whole study population and each individual group. Data presented as percentage (%).

7.1. Association of cortisol concentration and the presence of the metabolic syndrome

In order to assess the association of cortisol concentration and the presence of the MetS, the absolute values of those participants with and those without the syndrome were compared. This comparison was done for the whole study cohort as well as for the individual groups.

Table 14 Mean cortisol concentration (µg/dl) at sunrise/sunset and cortisol AUL of participants with and those without the MetS, per group

	Disorder not present	Disorder present	p-value	p_{a+h}-value
sunrise				
urban	0.35 ± 0.19	0.33 ± 0.17	0.610	0.715
rural	0.14 ± 0.15	0.00 ± 0.00	0.050	0.116
all	0.23 ± 0.20	0.27 ± 0.20	0.400	0.267
sunset				
urban	0.19 ± 0.19	0.16 ± 0.22	0.320	0.738
rural	0.07 ± 0.10	0.01 ± 0.02	0.140	0.270
all	0.12 ± 0.16	0.13 ± 0.21	0.970	0.640
AUL (all)	2.13 ± 1.84	2.26 ± 1.80	0.805	

In order to assess a possible association between the cortisol concentration and the prevalence of the MetS, a statistical analysis of the cortisol concentrations at sunrise and sunset was done and the cortisol AUL calculated. The values of those participants in whom the syndrome was not present and those in whom the syndrome was present were compared. Mean data presented in µg/dl; p-values are for comparison between the two groups, , p_{a+h}-values are for comparison between Group 1 and Group 2 and to examine the influence of 'age' and 'height' on the cortisol concentration in the saliva.

There was no statistically significant difference in the cortisol concentration at sunrise and sunset of those participants in whom the MetS was not present and those in whom the syndrome was present (Table 14). The assessment of a possible association of 'age' and 'height' and mean cortisol values, calculated with a Mann-Whitney-U test also yielded no significant difference between the study groups. A Wilcoxon Rank-sum test was used to calculate the cortisol AUL of the participants, which showed no significant difference between the participants with and those without the MetS (Table 14).

Table 15 Mean decline of cortisol concentration (µg/dl) of participants with and without the MetS, per group

	Disorder not present	Disorder present	p-value	p_{a+h}-value
urban	0.16 ± 0.24	0.14 ± 0.25	0.843	0.689
rural	0.07 ± 0.14	+0.01 ± 0.02	0.154	0.358
all	0.11 ± 0.20	0.11 ± 0.23	0.740	0.883

In order to assess a possible association of cortisol and the prevalence of the MetS, a comparison of the decline in cortisol concentration between sunrise and sunset of those participants with and those without the MetS was undertaken. Mean data presented in µg/dl; p-values are for comparison between Group 1 and Group 2, p_{a+h}-values are for comparison between Group 1 and Group 2 and examine the association of 'age' and 'height' and the cortisol concentration in the saliva.

Participants of the urban group not suffering from the MetS presented a mean decline in cortisol concentration of 0.16 ± 0.24 µg/dl, while those suffering from the MetS had a mean value of 0.14 ± 0.25 µg/dl, showing no significant difference ($p = 0.843$, $p_{a+h} = 0.689$) (Table 15). The participants of the rural group in whom the disorder was present showed an increase in cortisol concentration of 0.01 ± 0.02 µg/dl, the participants in whom the disorder was not present showed a decline of 0.07 ± 0.14 µg/dl. The difference was not significant with $p = 0.154$ and $p_{a+h} = 0.883$.

7.2. Correlation between the area under the line and the metabolic syndrome

Using the Pearson's correlation coefficient the correlation between the cortisol AUL and the individual components of the MetS was calculated. There was no strong correlation between cortisol exposure, measured by AUL and any of the MetS components (Table 16).

Table 16 Pearson's correlation between cortisol AUL and the MetS individual components

Variable	r-coefficient
Waist circumference	0.058
Blood pressure-systolic	-0.076
Blood pressure-diastolic	- 0.026
HDL-Chol	-0.146
Triglycerides	0.006
Fasting glucose	-0.001

The Pearson's correlation was calculated to assess the correlation between the cortisol AUL and the individual components of the MetS. Data presented are r-coefficients.

8. Framingham risk score (FRS)

In order to assess the 10-year cardiovascular risk of the participants, the FRS was calculated. The results are presented in Table 17 and Figure 94.

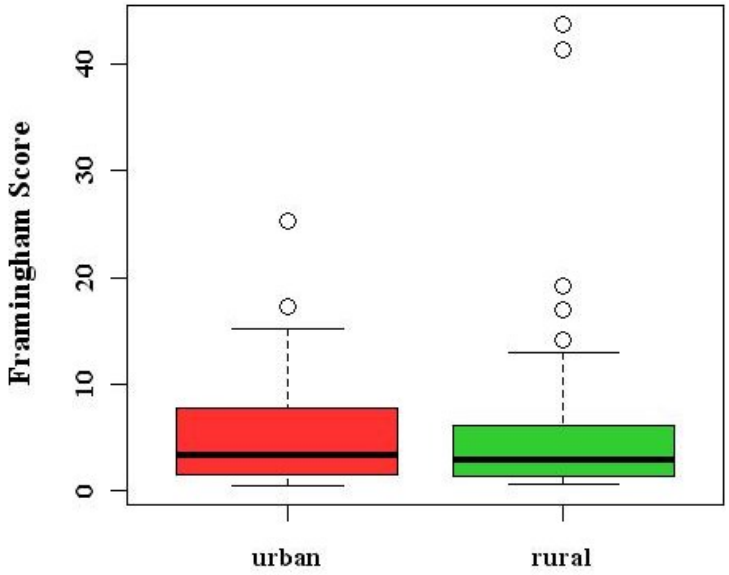
Table 17 10-year cardiovascular risk of participants according to the FRS (%), per group

Variable	Group	*n*	Min	Max	Mean	Median	q_1	q_3
Framingham risk score	urban	60	0.5	25.3	5.3 ± 5.3	3.3	1.6	7.6
	rural	62	0.7	43.7	5.5 ± 7.9	3.0	1.4	6.0
p = 0.876	all	122	0.5	43.7	5.4 ± 6.7	3.2	1.5	7.0

The table shows the statistical analysis of the 10-year cardiovascular risk of the participants, calculated using the FRS. Data presented as percentage, unless otherwise indicated. *n* = number, min = minimum value, max = maximum value, SD = standard deviation, $q_1 = 25^{th}$ quartile, $q_3 = 75^{th}$ quartile.

Unlike results for the bulk of the data, there was no significant difference in the FRS between the urban and the rural group (p = 0.876).

Figure 94 Framingham risk score (%), per group



The diagram outlines the result of the FRS applied to the participants of the research study. This was done to assess the 10-year cardiovascular risk within the study population.

9. Questionnaire

The participants furthermore had to complete a questionnaire containing questions on education, employment, health status and diabetes in the family history, physical activity, nutrition and change of diet and/or weight. Table 18 provides a summary of the questions and answers.

Table 18 Summary of questions & answers of questionnaire

Variable		urban (%)	rural (%)	all (%)	Variable	Grp	Mean
Education							
	No education	49.1	98.4	74.2			
	Elementary school	11.9	1.6	6.7			
	Secondary school	27.1	0.0	13.3			
	High school	10.2	0.0	5.0			
	Tertiary education	1.7	0.0	0.8			
Employment							
	mainly sitting down						
	Farming	28.8	50.8	40.0			
	House work	39.0	47.5	43.3			
	Office work	22.0	0.0	10.8			
	Studying	1.7	0.0	0.8			

Variable		urban (%)	rural (%)	all (%)	Variable	Grp	Mean
	Pensioner	1.7	1.6	1.7			
	Unemployed	6.8	0.0	3.3			
Diabetes							
Suffering from DM 2	no	100	100	100			
	yes	0.0	0.0	0.0			
Father	no	98.2	100	99.2			
	yes	1.8	0.0	0.8			
Mother	no	98.3	100	99.2			
	yes	1.7	0.0	0.8			
Siblings	no	93.2	98.3	95.8			
	yes	6.8	1.7	3.4			
Smoking							
Smoked before	no	90.0	67.2	78.5			
	yes	10.0	32.8	21.5			
Smoking now	not at all	93.3	80.3	86.8			
	sometimes	0.0	4.9	2.5			
	every day	6.7	14.8	10.7			
Snuff	not at all	88.3	61.7	75.0			
	sometimes	3.3	11.7	7.5			
	every day	8.3	26.7	17.5			
Physical activity							
Work	mainly sitting down	40.7	9.8	25.0			
	walk a lot, but no lifting/carrying	22.0	85.2	54.2			
	walk a lot, heavy lifting/carrying	6.8	4.9	5.8			
	heavy labour	30.5	0.0	15.0			
Walking to work	nothing	13.6	1.6	7.5			
	< 15 min	25.4	18	21.7			
	15 - 29 min	25.4	34.4	30.0			
	30 - 44 min	16.9	16.4	16.7			
	45 - 59 min	5.1	13.1	9.2			
	> 1h per day	13.6	16.4	15.0			
Sports	none	73.7	18.9	47.3			
	walk, cycle, other exercise	21.1	79.2	49.1			
	lots of sports	3.5	1.9	2.7			
Nutrition							
Meals/day	1 - 2/day	82.1	100	91.5			
	3 - 4/day	17.9	0.0	8.6			

Variable		urban (%)	rural (%)	all (%)	Variable	Grp	Mean
	5-6/day	0.0	0.0	0.0			
	> 7/day	0.0	0.0	0.0			
					Servings sausage/week	urban	0.8
						rural	0.2
					Servings chicken/week	urban	1.5
						rural	0.6
					Servings beef, goat, sheep, pork/week	urban	3.2
						rural	1.2
					Servings fish/week	urban	1.2
						rural	0.3
					Servings vegetables/week	urban	1.9
						rural	0.6
Fast food eaten	1 or >/day	19.0	1.6	10.1			
	4 - 6/week	3.4	0.0	1.7			
	1 - 3/week	12.1	0.0	5.9			
	1 - 3/month	3.4	3.3	3.4			
	< 1/month	62.1	95.1	79.0			
Oil used in household	vegetable oil	91.7	82.0	86.8			
	margarine spread	5.0	1.6	3.3			
	vegetable margarine	3.3	1.6	2.5			
	butter	0.0	13.1	6.6			
	no fat at all	0.0	1.6	0.8			
Cream used	none	63.6	1.6	31.0			
	cream for cooking	34.5	93.4	65.5			
	whipped cream	1.8	1.6	1.7			
Portions of vegetables eaten	2 or >/day	6.8	0.0	3.3			
	1/day	13.6	0.0	6.7			
	4 - 6/week	10.2	0.0	5.0			
	1 - 3/week	25.4	0.0	12.5			
	< 1/week or none	44.1	100	72.5			
Portions of fruit eaten	2 or >/day	11.9	0.0	5.9			
	1/day	13.6	1.7	7.6			
	4 - 6/week	6.8	0.0	3.4			
	1 - 3/week	28.8	0.0	14.3			
	< 1/week or none	39.0	98.3	68.9			

Variable		urban (%)	rural (%)	all (%)	Variable	Grp	Mean
Milk products eaten/drunk	none	16.9	0.0	8.3			
	yes	83.1	100	91.7			
					Cups low fat milk products/day	urban	0.7
						rural	0.7
					Cups normal milk products/day	urban	1.1
						rural	5.1
Carbohydrates eaten							
					Slices white bread, rolls/day	urban	2.1
						rural	12.3
					Slices brown bread/day	urban	2.2
						rural	11.9
					Slices sweet bread/day	urban	0.8
						rural	12.4
					Bowls porridge/day	urban	1.6
						rural	2.1
					Bowls cereals/day	urban	0.3
						rural	0.1
Bread spread used	margarine spread	24.5	0.0	13.8			
	vegetable margarine	7.0	7.0	7.4			
	butter	47.1	85.0	70.2			
	nothing	21.0	29.1	44.7			
Portions sweet food, cakes, biscuits	2 or >/day	8.0	0.0	4.2			
	1/day	13.6	0.0	6.8			
	4 - 6/day	3.4	1.7	2.5			
	1 - 3/week	15.3	1.7	8.5			
	< 1/week or none	59.3	96.7	78.0			
Portions sugar, honey, sweets	2 or >/day	68.0	19.3	26.1			
	1/day	14.0	1.7	7.8			
	4 - 6/week	9.0	42.2	25.2			
	1 - 3/week	15.5	5.3	10.4			
	< 1/week or none	29.3	33.3	31.3			
Drinks							
					Cups of tea/day	urban	2.8
						rural	6.6

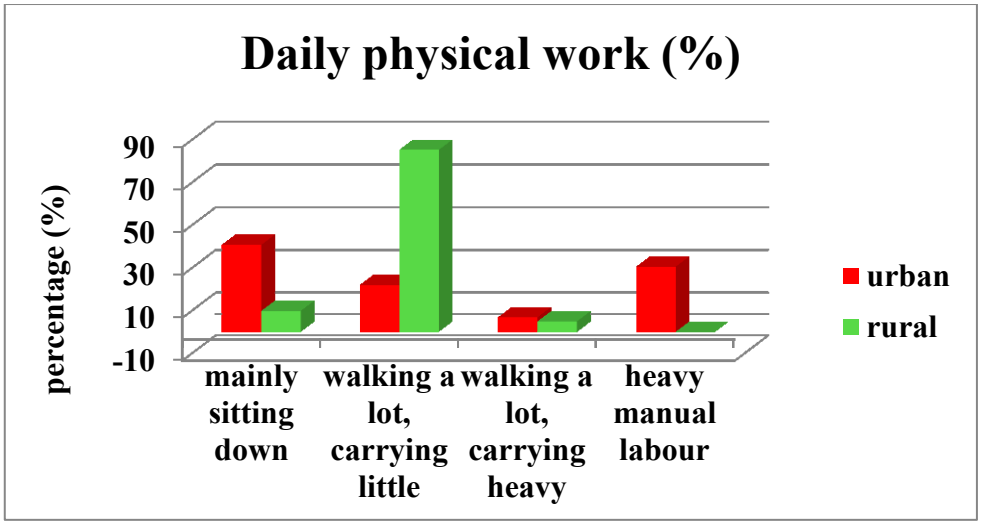
Variable		urban (%)	rural (%)	all (%)	Variable	Grp	Mean
					Cups of coffee/day	urban	1.5
						rural	4.9
					Bottles soft drink/day	urban	2.6
						rural	0.8
					Bottles of sugar free soft drink/day	urban	0.4
						rural	0.2
					Glasses of juice/day	urban	1.0
						rural	0.6
					Bottles of beer/day	urban	0.7
						rural	1.2
					Glasses of wine/day	urban	0.1
						rural	0.5
					Portions of spirit/day	urban	0.1
						rural	0.5
Weight							
Change in diet	none	84.2	100	92.3			
	eat more vegetables & fruit	1.8	0.0	0.8			
	less fast food & sweets	10.5	0.0	5.1			
	drink less alcohol	3.5	0.0	1.7			
Loss of weight	no	39.7	33.3	36.4			
	yes, a little	41.4	51.7	46.6			
	yes a lot	19.0	15.0	16.9			

The table shows the results of the questionnaire completed by the participants. The questions covered the areas of education, presence of DM in the family, illness of the participants, physical activities, work, dietary habits and weight changes. Data presented as numbers (n) and percentages (%) and mean; p–values are for comparison between Group 1 and Group 2.

The quality of the data is disputable as the answers given in the questionnaire often do not correspond with observations made by us and the interpreters. Due to this, an extensive statistical analysis was forgone. However, looking at the data on physical activity, it can be seen that it correlates with the gross of the research data.

Figure 95 shows that participants in urban areas are more involved in daily work sitting down or heavy labour rather than walking long distances. Participants in rural areas though, seem to be more involved in daily activities requiring walking long distances, but not lifting or carrying heavy objects.

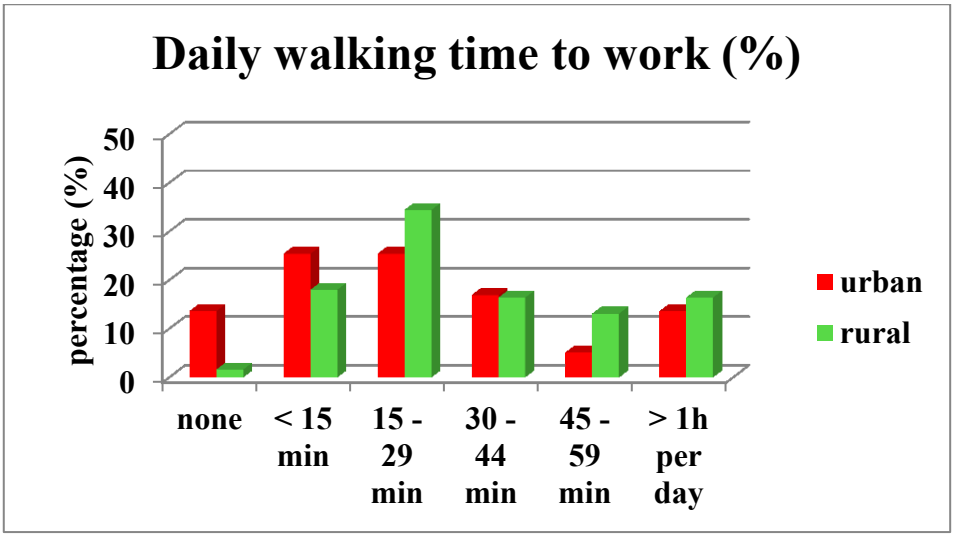
Figure 95 Daily physical activity (%), per group



The diagram outlines the physical activities done by the participants as part of their daily work. Data presented as percentage (%).

The daily walking time to work correlates with the above findings: participants of Group 1 have shorter walking times to work compared to participants of Group 2 (Figure 96). However, as mentioned above, these findings should be treated carefully, especially as most participants do not own a watch and measure time according to the movement of the sun.

Figure 96 Walking time to work (%), per group



The diagrams outlines the average time the participants spend on walking to work each day. Data presented as a percentage (%).

10. Bone ultrasound measurements

With the aim of assessing the participants' acoustical properties of bone, the broadband ultrasound attenuation (BUA) and speed of sound (SOS) were used to measure the stiffness index (SI) and Z-score. The data were compared to a reference group of Afro-Americans living in the US (pre-set on equipment). Table 19 shows a summary of the obtained data. Furthermore, a linear regression model was applied to adjust the data for 'sex', 'age' and 'height' and 'sex', 'age', 'height' and 'weight' (BUA, SOS, SI). The same model was applied to the Z-score to adjust for 'height' and 'height' and 'weight'.

Table 19 Characteristics of bone ultrasound measurement per group

Variable	Grp	Min	Max	Mean ± SD	Median
BUA (dB/MHz)	urban	91	155	127.6 ± 14.8	129.0
	rural	53	187	125.6 ± 23.2	131.0
p = 0.626	all	53	187	125.5 ± 20	130.0
p_{s+a+h}[48] = 0.911					
$p_{s+a+h+w}$[49] = 0.805					
SOS (m/s)	urban	1497	1696	1570.8 ± 39.7	1564.0
	rural	1486	1709	1585.1 ± 51.6	1582.5
p = 0.138	all	1486	1709	1579.0 ± 47.2	1573.5
p_{s+a+h} = 0.004					
$p_{s+a+h+w}$ < 0.001					
SI	urban	69	139	104.7 ± 17.3	101.5
	rural	45	183	107.4 ± 25.7	109.0
p = 0.559	all	45	183	106.2 ± 22.4	104.0
p_{s+a+h} = 0.109					
$p_{s+a+h+w}$ = 0.025					
Z-score (SD)	urban	-1.1	3.5	+1.3 ± 1.3	1.1
	rural	-2.8	7	+1.7 ± 1.8	1.8
p = 0.248	all	-2.8	7	+1.6 ± 1.6	1.5
p_h[50] = 0.361					
p_{h+w}[51] = 0.128					

The data given in this table present the participants' acoustical properties of the bone. *n* = number, min = minimum value, max = maximum value, SD = standard deviation, q_1 = 25th quartile, q_3 = 75th quartile, BUA = broadband ultrasound attenuation, SOS = speed of sound, SI = stiffness index; p-values are for comparison between Group 1 and Group 2; p_{s+a+h}-values are for comparison between Group 1 and Group 2 after adjustment for 'sex', 'age' and 'height', $p_{s+a+h+w}$-values are for comparison between Group 1 and Group 2 after adjustment for 'sex', 'age, 'height' and 'weight'; p_h-values are for comparison between Group 1 and Group 2 after adjustment for 'height' only, p_{h+w}-values are for comparison between Group 1 and Group 2 after adjustment for 'height' and 'weight'.

Measured in decibel per megahertz, the BUA measurements were found to be very similar in both study groups (127.6 ± 14.8 vs. 125.6 ± 23.2 dB/MHz; p = 0.626, p_{s+a+h} =

[48] p_{s+a+h}: comparison between Group 1 and Group 2 after adjustment for 'sex', 'age' and 'height'.

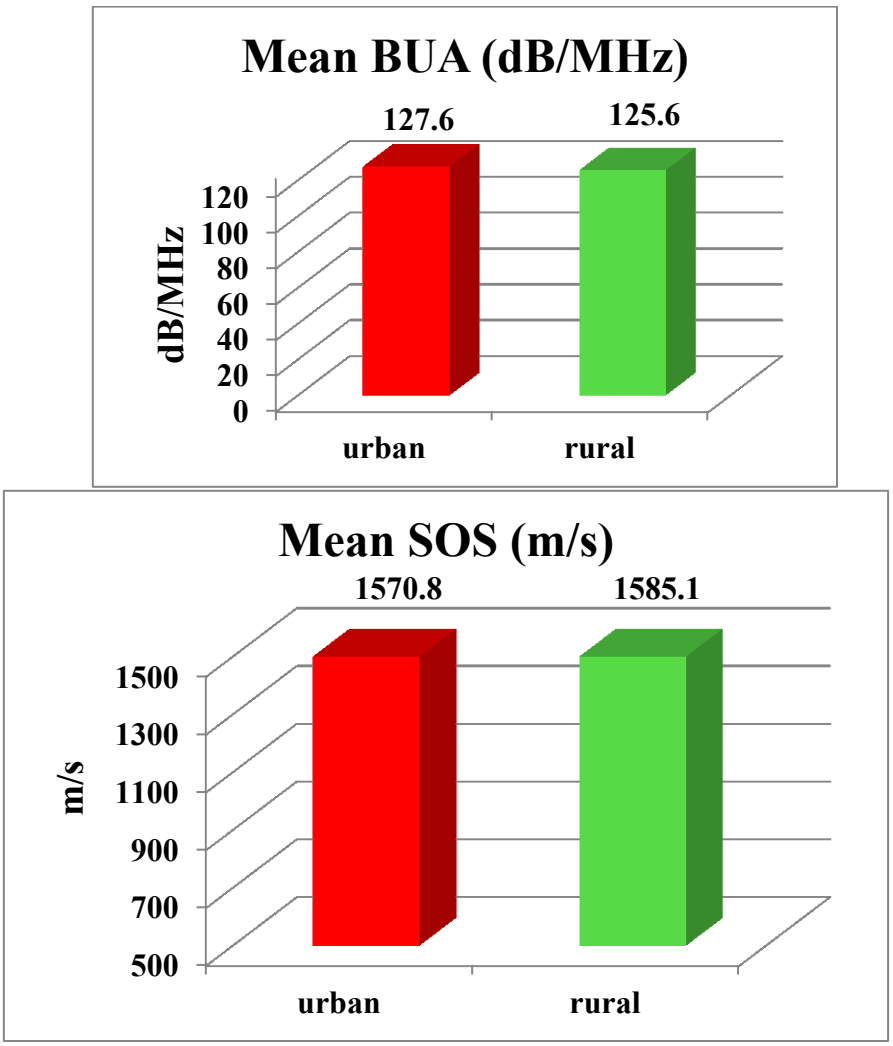
[49] $p_{s+a+h+w}$: comparison between Group 1 and Group 2 after adjustment for 'sex', 'age', 'height' and 'weight'. The adjustment for 'weight' was done, even though this parameter just missed statistical significant difference in the baseline evaluation.

[50] p_h: comparison between Group 1 and Group 2 after adjustment for 'height'. It was not necessary to adjust the data for 'age', as this parameter is already included in the calculation of the baseline Z-score.

[51] p_{h+w}: comparison between Group 1 and Group 2 after adjustment for 'height' and 'weight'. It was not necessary to adjust the data for 'age', as this parameter is already included in the calculation of the baseline Z-score.

0.911, $p_{s+a+h+w} = 0.805$), with a median of 129 vs. 131 dB/MHz in Group 1 and Group 2 respectively (Table 19 and Figure 97, Figure 98 and Figure 99).

Figure 97 Mean BUA (dB/MHz) and SOS (m/s), per group

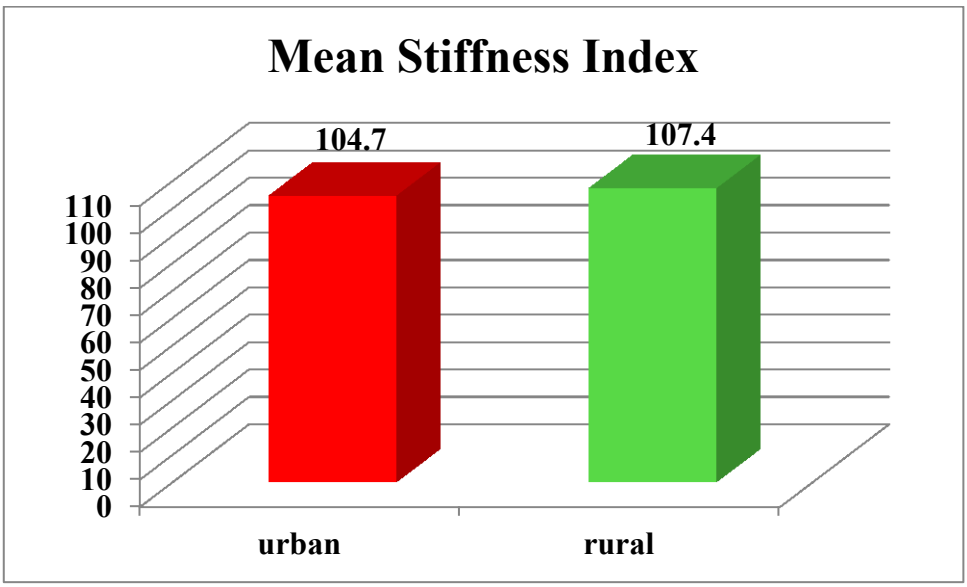


The diagrams outline the mean BUA and SOS measurement obtained when examining the participants acoustical properties of bone.

The first step of statistical analysis showed that the mean SOS of the urban group at 1570.8 ± 39.7 m/s was not significantly different to the mean SOS of the rural group at 1585.1 ± 51.6 m/s ($p = 0.138$). However, once the data was adjusted for 'sex', 'age' and 'height' and 'sex', 'age', 'height' and 'weight' a statistically significant difference between both cohorts presented ($p_{s+a+h} = 0.004$, $p_{s+a+h+w} < 0.001$) . The BUA and SOS values are used to obtain the stiffness index (SI), which presented a median of 101.5 in Group 1 and 109.0 in Group 2. The mean values were calculated to be 104.7 ± 17.3 and 107.4 ± 25.7 of Group 1 and 2 respectively ($p = 0.559$, $p_{s+a+h} = 0.109$). The adjustment

of the data for ‘sex’, ‘age’, ‘height’ and ‘weight’ showed a significant difference between the cohorts with $p_{s+a+h+w} = 0.025$.

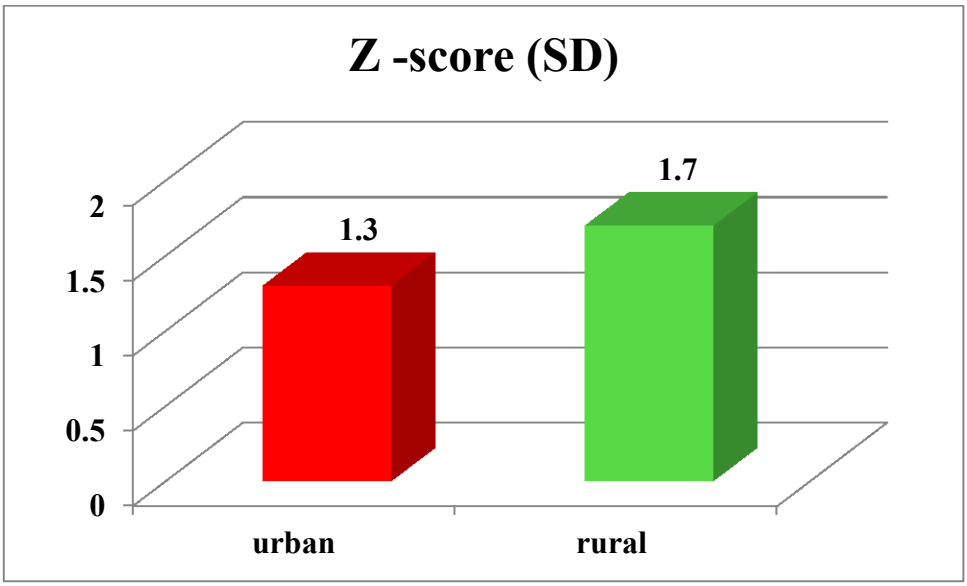
Figure 98 Stiffness Index, per group



The SI is calculated using the values of the BUA and SOS measurements and is an expression of the bone quality with the aspects of strength and structure. The diagram shows the mean SI of both study groups.

The Z-score is a comparison of the participant's acoustical properties of bone to that of a same aged healthy person of the same sex given in standard deviation (SD). As can be concluded from Table 19, there was also no statistically significant difference in this parameter (Group 1 +1.3 ± 1.3 vs. +1.7 ± 1.8), with p = 0.248, p_h = 0.361 and p_{h+w} = 0.128. The maximum value for the urban group lay at +3.5 and that for the rural group at +7.0. The minimum values were not that far apart, with Group 1 presenting a minimum of -1.1 and Group 2 of -2.8.

Figure 99 Mean Z-score (SD), per group



The diagram shows the mean Z-score of both groups as a SD. The SD is in comparison to the Z-score of a same aged healthy person (also Table 19, pg 234).

10.1. Association between bone ultrasound, milk consumption, walking time and cortisol AUL

The Pearson's correlation coefficients were calculated to examine a correlation between 'milk consumption' and acoustical properties of bone as well as 'walking time' and acoustical properties of bone (Table 20). For the calculation of the latter parameter, the 'walking to work' data of the questionnaire was changed to metric values. Leaving the data as non-metric data would have resulted in a rather confusing picture. Changing the data to metric values allows for the assessment whether a relationship between 'walking time' and bone ultrasound measurement exists. Furthermore, the same

statistical method was used to correlate the cortisol AUL and the bone ultrasound measurements (Table 20).

Table 20 Association between bone ultrasound, cortisol AUL, milk consumption and walking time

Variable	r_{AUL}[52]	r_{mc}[53]	r_{wt}[54]
BUA	0.021	0.084	0.104
SOS	-0.200	0.131	0.233
SI	-0.107	0.130	0.195
Z-score	-0.179	0.166	0.193

In order to assess the association between bone ultrasound, cortisol AUL, 'milk consumption' and 'walking time', the Pearson's correlation was applied to the relevant data. r_{AUL}-values are the correlation between cortisol AUL and bone ultrasound; r_{mc}-values are the correlation between the 'milk consumption' and bone ultrasound measurements; r_{wt}-values are the correlation between the 'walking time' and the bone ultrasound measurements.

Using the Pearson's correlation, we found that there was no strong correlation between the cortisol AUL and bone ultrasound measurements. In addition, no strong correlation between 'milk consumption' and bone ultrasound and 'walking time' and bone ultrasound could be detected (Table 20).

[52] r_{AUL}: the Pearons's correlation was used to assess a correlation between cortisol AUL and bone ultrasound measurements.

[53] r_{mc}: the Pearson's correlation was used to assess a correlation between 'milk consumption' and bone ultrasound measurements.

[54] r_{wt}: the Pearson's correlation was used to assess a correlation between 'walking time' and bone ultrasound measurements

Chapter 6 Discussion

The number of people suffering from diabetes mellitus type 2 (DM) increased dramatically over the last few decades (Sicree et al. 2009). Even though the increase is universal, the developing world is showing even more dramatic increases compared to the developed world, as urbanisation, nutritional transition and westernisation are taking a firm hold (Hossain et al. 2007). The primary purpose of our research was to assess the influence of lifestyle changes and modification of the social environment in the face of urbanisation on the risk for a disorder of glucose metabolism in the Ovahimba people of Namibia. Secondary to this, the cortisol homeostasis of the participants was examined and the prevalence of the metabolic syndrome (MetS) ascertained. Furthermore, the participants' 10-year cardiovascular risk was calculated according to the Framingham risk score (FRS) and the acoustical properties of bone examined.

In order to answer the above questions, two groups of participants were formed: 'Group 1', also called 'urban group' consisted of participants having been living in the town of Opuwo for at least three years, thus being subjected to urbanisation and 'westernisation'. 'Group 2', also called 'rural group' consisted of participants living a traditional lifestyle in the rural area of the Kaokoveld in north-western Namibia. Each participant underwent the oral glucose tolerance test (OGTT), the gold standard to assess glucose metabolism and detect dysglycaemia (Phillips 2012, WHO 2006). Anthropometric measurements were taken, the body fat and lean mass measured and the fat metabolism examined to identify cardiovascular risk factors, assess the prevalence of the MetS and calculate the 10-year cardiovascular risk. In addition, two saliva samples were collected, one at sunrise and one at sunset to examine the cortisol homeostasis and a possible association with dysglycaemia. Lastly, bone ultrasound was used to determine the acoustical properties of bone of the participants.

The results will be discussed below. Firstly, urbanisation and its risk factors for dysglycaemia will be outlined briefly. This will be followed by a discussion of the risk factors presenting in the study population. The prevalence of the primary endpoint of the study, the presence or not of a disorder of glucose metabolism will then be outlined. In addition, the prevalence of the individual components of dysglycaemia will be

presented. This will be followed by a discussion of the results, taking the risk factors found in the participants into account and comparing it to current literature.

Once the primary question has been discussed, the discussion of the secondary questions studied in this research will follow. To start with, the cortisol homeostasis and its possible influence on the primary question will be discussed, followed by the prevalence of the MetS. Afterwards the 10-year cardiovascular risk of the participants calculated according to the FRS will be outlined. To finish off, the bone ultrasound measurements of the Ovahimba people will be discussed. In continuation with the primary question, the secondary questions will be discussed in comparison to the current literature on the particular topic.

1. Urbanisation, a change of lifestyle and the consequences

Urbanisation is occurring rapidly in sub-Saharan Africa (SSA) and Namibia is not excluded from this trend. Misra & Khurana (2008) reported that 38% of Africans lived in urban areas in 2008, a number which is projected to reach 50% by 2020 (Misra & Khurana 2008). The African Development Bank (ADB) describes a similar rate of urbanisation for Namibia, with the highest rate in the north. Here, 7.5% of rural dwellers moved into towns in 2006. The projection for the years 2010 to 2015 is an annual urbanisation rate of 3.3% for the Namibian population as a whole (CIA 2011).

It has been widely established by now that urbanisation and the adoption of a modern lifestyle with economic and social development is associated, among others, with an increase in non-communicable diseases (NCD) such as DM, hypertension and other cardiovascular diseases (Vorster et al. 2011, Popkin 2006). The change of lifestyle is mainly in the form of a nutritional transition with a change in dietary pattern from a healthy traditional diet to an increased intake of refined carbohydrates, energy–dense snack foods, saturated fatty acids and sweetened beverages. The nutrition transition is often further aggravated by a sedentary lifestyle with decreased physical activity resulting in ever rising cardiovascular risk factors such as obesity, high blood pressure (BP) and dysglycaemia (Vorster et al. 2011, Misra & Khurana 2008). According to Popkin (2006), these changes are happening very rapidly in developing countries, shifting the burden of NCDs towards the poor.

1.1. Risk factors associated with diabetes

The Ovahimba people of north-western Namibia have not been spared the adverse effects of urbanisation: changes in diet and physical activity are resulting in overweight/obesity, abnormal glucose and fat metabolism and high BP all of which pose an increased risk for pre-diabetes, diabetes and cardiovascular diseases (CVD) (Vorster et al. 2011).

1.1.1. Changes in dietary pattern and physical activity

It was mentioned in 'Results' (pg 227) that the questionnaire we used should be interpreted carefully, considering the discrepancy between answers given and the observations we made. However, certain trends in changes of dietary patterns and physical activity observed correspond to current literature suggestive of a nutritional transition found with urbanisation. 19% of participants in the urban group reported to eat fast food one or more times a day, compared to 1.6% in the rural group (Table 18, pg 227). While 95.1% of rural participants ate fast food less than once a month, only 62.1% of the urban group did so. Similarly, none of the rural people ate two or more portions of cakes/biscuits per day, compared to 8% in the urban group. 68% of the latter group also reported to eat sugar and sweets at least twice a day, while this was the case in only 19.3% of rural people. On average, an urban participant drank 2.6 bottles of soft drinks (not sugar-free) a day, while a rural participant only drank 0.8 bottles per day. The physical activity connected to work is similar: while 40.7% of urban participants did work mainly sitting down, 85.2% of rural participants did work mainly walking, but not heavy lifting (Figure 95, pg 232). The latter also had a much longer daily walk to work compared to the urban group. On the other hand, the urban participants had a higher intake of fruits and vegetables than the rural group, which according to Vorster et al. (2011), could be mainly due to the increased availability and affordability of these products in towns and cities.

1.1.2. Overweight and obesity

The adverse effects of this nutritional transition can be clearly seen in the study population (Figure 78, pg 200). Even though the urban participants' average weight of 73.4 kg only tended to be higher than the rural participants' average weight of 68.5 kg with no statistically significant difference, a significantly higher waist circumference

(WC) presented in the first group (94.1 vs. 78 cm). It is the latter parameter rather than the overall weight that poses an increased risk for CVD, DM and other NCDs (Lee et al. 2008, Alberti et al. 2006). Another risk factor for NCDs is an increased body mass index (BMI) as a measurement combining the weight and height of an individual. The mean BMI in the rural group was 24.2 kg/m^2, being just below the WHO cut-off to overweight (24.9 kg/m^2), while the mean BMI in the urban group of 26.6 kg/m^2 already lies within the WHO range of 'overweight', presenting a significant difference between the two study groups (WHO 2011) (Figure 79, pg 201; Figure 80, pg 202). Looking at the individual WHO weight groups applied to the study, 30.1% of Group 1 were overweight and 15.0% obese. By comparison, 12.7% of Group 2 was overweight and 6.3% were obese. Therefore, 45.1% of urban participants, 19.0% of rural participants and 32.1% of the whole study population were overweight/obese.

In their article on the global nutritional transition and obesity in the developing world, Popkin et al. (2012) outline that a change of lifestyle, as part of the urbanisation process brings about a dramatic increase in obesity in the developing world. In addition, the authors report that urban women seem to have higher baseline prevalence and a higher increase in overweight/obesity than their rural counterparts. There was no data given for men. The data on obesity we obtained strongly support these statements, as has been made evident in the above paragraph. The data also correlate well to research done in other SSA countries, where overweight/obesity was found to be high in the general population and higher in urban than in rural population groups. Lissock et al. (2011) report a mean BMI of 28.01 kg/m^2 and 24.12 kg/m^2 in an urban and rural Cameroonian population respectively. The same Cameroonian population had a mean WC of 94.01 cm in the urban and 85.78 cm in the rural setting. Rural dwellers in the Democratic Republic of Congo had a lower mean BMI of 21.9 kg/m^2 compared to our study's rural participants, but urban dwellers in both countries had similar BMIs (Hightower et al. 2011).

Group 1, the urban participants of our cohort, presented significantly more overweight/obese people with a larger WC than Group 2, the rural dwellers. However, looking at the body composition, the lean body mass after adjustment for 'age' and 'height' ($p_{a+h} = 0.025$) was the only significantly different parameter between the urban and the rural dwellers (Figure 88, pg 213). Urban participants had a total fat mass in

kilograms of 27.6 (36.1%) compared to 24.0 (34.5%) in rural participants. The lean body mass was even less different, with p = 0.365 (mean: 47.7 kg urban and 46.3 kg rural). These values are comparable to the percentage body fat found in Germany, which Scheuing et al. (2013) reported to be 37.8% in a multi-centre study undertaken in Germany and Austria. These findings are inconsistent with the current literature on this topic, which reports significant differences in the body composition between urban and rural dwellers in SSA (Lissock et al. 2011). In their analysis of urban and rural differences in metabolic profiles in a Cameroonian population, Lissock et al. (2011) established that urban participants had a body fat mass of 28.27% compared to 22.15% in rural participants. The semi-nomadic Fulani people of northern Nigeria (equivalent to the rural participants of our study) showed even better body composition: fat mass in percentage was 20.2 and fat free mass in kilogram came to 45.4 (Glew et al. 2010). Even though the comparison of body composition in our study is very broad, the whole cohort having been used instead of specific age groups within the study population, it is obvious that the Ovahimba seem to have a much higher fat content and lower lean body mass than other SSA communities which have been studied. This combination of high fat content and low lean body mass is associated with a higher risk of diabetes and other cardiovascular risk factors (Lissock et al. 2011, Rush et al. 2007).

1.1.3. Glucose metabolism

The presentation of an abnormal glucose metabolism is often another undesirable consequence of urbanisation, as is reported in the literature. The high prevalence of dysglycaemia in the study population has been outlined in Table 6 (pg 208) and Figure 85 (pg 209). Often, high mean levels of fasting glucose (FG) and 2-h glucose (2-h Glc) levels[55] precipitate dysglycaemia and are first warning signs. In the total study population the mean FG (5.1 mmol/l) and mean 2-h Glc levels (6.3 mmol/l) showed no abnormalities. In line with most other risk factors of urbanisation though, significant differences between the urban and rural group were present (Table 5, pg 204). The mean FG concentration was 5.3 mmol/l in the urban and 4.9 mmol/l in the rural group ($p < 0.001$, $p_{a+h} < 0.001$) and the 2-h Glc was 6.7 mmol/l and 6.0 mmol/l ($p = 0.002$, p_{a+h} 0.004) in the urban and rural group respectively. According to the cut-off of the

[55] 2-h glucose level: plasma glucose level measured two hours after the intake of 75 g of glucose as part of the OGTT

International Diabetes Federation (IDF) for normal glucose levels, 20.6% of urban participants had an above normal FG and 17.5% an above normal 2-h Glc. In Group 2, 6.7% and 8.3% had an above normal FG and 2-h Glc respectively.

The data on glucose metabolism are therefore comparable to the data in current literature on the SSA region, where Sabir et al. (2011) report a FG of 5.37 mmol/l and a 2-h Glc of 6.5 mmol/l in an urban Fulani population of Nigeria. A rural community in South Africa presented a mean FG of 4.9 mmol/l and a 2-h Glc of 6.2 mmol/l (Motala et al. 2008).

1.1.4. Fat metabolism

Another adverse effect of urbanisation reported in literature is a deterioration of the fat metabolism in urban people. This is mainly due to an increased intake of partially hydrogenated fats and vegetable oils, foods originating from animals mostly rich in total fats and saturated fatty acids, and a decreased intake of polyunsaturated fatty acids (Popkin et al. 2012, Vorster et al. 2011, Popkin 2006).

The analysis of the questionnaire showed that participants of Group 1 have a higher intake of meat products, and therefore inevitably also of saturated fatty acids (Table 18, pg 227). Urban participants on average have 0.8 servings of sausage, 1.5 servings of chicken and 3.2 servings of beef/goat/sheep/pork per week, compared to 0.2, 0.6 and 1.2 servings per week respectively by the rural participants. On the other hand, most of the rural participants reported butter to be the main fat used in the household on a daily basis. Furthermore, they also reported a high daily intake of milk and other dairy products: 5.1 dairy products/day compared to 1.1 dairy products/day taken in by urban participants. The reason for this is that diet, culture and economy of the rural participants are mainly centred on their cattle. Both groups reported a high intake of vegetable oil for cooking, 91.7% in the urban and 82% in the rural group. Alcohol consumption was low in both groups. It was mentioned above already that the urban group had a much higher intake of fast foods than the rural group (urban: 19% have 1 or > fast foods/day vs. rural: 1.6% have 1 or > fast foods/day) and with that Group1 had a much higher intake of saturated fatty acids as Group 2.

Although the urban group, is presenting an obvious change of lifestyle with high prevalence of overweight/obesity coupled with dysglycaemia, and although the rural

group has such a high intake of dairy products known to raise plasma cholesterol, LDL-Chol and triglycerides, the mean values of fat metabolism of both groups can be classified as 'ideal' according to the American Heart Association's (AHA) categories (AHA, Glew et al. 2010). Total triglycerides were 1.1 mmol/l and 0.8 mmol/l and total cholesterol 4.3 mmol/l and 4.6 mmol/l in the urban and rural group respectively (Table 7, pg 211). LDL-Chol, using the Friedewald formula (Friedewald et al. 1972), calculated to 2.5 mmol/l and 3.0 mmol/l in Group 1 and 2 respectively. Lastly, the mean HDL-Chol as the 'good cholesterol' in urban participants was 1.3 mmol/l and in rural participants 1.5 mmol/l. Even though all mean values can be classified as 'ideal', total triglycerides were significantly higher in the urban group compared to the rural group and HDL-Chol was significantly lower. This is in line with other cardiometabolic risk factors associated with urbanisation outlined above. The mean LDL-Chol before adjustment for 'age' and 'height' though, was significantly higher in the rural than the urban group. This is contrary to what was expected.

Comparing the fat metabolism of the Ovahimba to other SSA people, a similar picture can be seen. Lissock et al. (2011) also established 'ideal' mean values of fat metabolism in an urban and rural Cameroonian population, with significantly higher values in the urban compared to the rural participants. Urban-dwelling black South-Africans presented a similar fat metabolism than urban Ovahimba participants in our study: total triglycerides were 1.1 mmol/l, total cholesterol 4.4 mmol/l, LDL-Chol was 3.3 mmol/l and HDL-Chol 1.17 mmol/l (Peer et al. 2012).

Mbalilaki et al. (2010) conducted a study in Tanzania involving Masai people and rural and urban Bantu people. The Masai are a semi-nomadic tribe and can be compared to the Ovahimba people of our research study, especially concerning the high intake of animal fats and dairy products. Interestingly, a similar pattern in the fat metabolism could be observed: all mean values were in the 'ideal' category for all groups. However, the Masai, who are comparable to our rural group[56], had higher total cholesterol and LDL-Chol than their 'rural' group, comparable to our urban group (Mbalilaki et al. 2010). Glew et al. (2010) observed a similar phenomenon in the semi-nomadic Fulani

[56] In their study, Mbalilaki et al. 2010 had three groups: 'the Masai', who are semi-nomadic Fulani people, and therefore comparable to our Group 2, secondly 'the rural' group formed by people living in small towns and therefore comparable to our Group 1 and thirdly 'the urban' group formed by people living in big cities. There is no comparable group to the latter in our study.

people of northern Nigeria: an ideal fat metabolism even though there is a high intake of dairy products (30% of calories are derived from dairy products in the Fulani people).

The exact cause for the favourable lipid profile of the Ovahimba people in the presence of obvious risk factors for the opposite is unknown. Assumptions can be made based on the research done in other semi-nomadic people of SSA and black African communities worldwide. Even though there is a high intake of dairy products in rural participants, their overall caloric intake is often still half that of people in the developed world, resulting in a favourable lipid profile (Glew et al. 2010). Furthermore, the rural lifestyle often includes many hours of walking each day, for men it is finding water and pasture for the cattle, for women it is fetching water and fire wood, often carrying heavy loads. These high levels of activity will have a protective effect on the lipid profile (Glew et al. 2010, Mbalilaki et al. 2010, Mbalilaki et al. 2007). In their editorial, Willett & Mozaffarian (2010) argue that blood lipid concentrations are affected more by industrialised *trans* fatty acids than *trans* fatty acids derived from natural sources i.e. ruminant fats.

Lastly, it has been well established that black people of diverse origin often exhibit an anti-atherogenic lipid profile that is contrarious to the high rate of obesity, abnormalities in glucose tolerance, hypertension and unhealthy lifestyle factors frequently present (Gaillard 2010, Gaillard et al. 2009). This is also in contrast to Caucasians, who are more prone to the development of dyslipidaemia in the presence of such risk factors (de Kock et al. 2012). However, the favourable lipid profile does not seem to have a cardio protective effect on people of SSA compared to their white counterparts, as the rate of CVD in SSA is rapidly increasing (Gaillard et al. 2009). In addition, Willey et al. (2011) conducted a study on race-ethnic differences in lipid profiles and myocardial infarction risk and found, among other things, that Non-Hispanic black Americans exhibited a less atherogenic lipid profile than Non-Hispanic white Americans, however the former group presented an equal risk for myocardial infarction than the latter group. Various studies have been conducted on the genetic differences of lipid traits between Europeans and Africans (mostly Afro-Americans) and these strongly support the fact that the favourable lipid profile of black people has a genetic component to it (Chang et al. 2011, Deo et al. 2009).

1.1.5. Blood pressure

A pathological blood pressure (BP) is not a direct risk factor for the development of diabetes. However, both conditions share the same risk factors and therefore commonly co-exist. In addition, a high BP accelerates the development of diabetes associated complications and deaths. Studies have shown that a tight BP control is therefore especially necessary in patients with diabetes and that once the BP control is relaxed the incidence of complications increases again (Colosia et al. 2013, Holman et al. 2008). Colosia et al. (2013) further state that hypertension in people of the developing world is often far more aggravating than among people in developed countries as the former frequently lack the resources for the treatment of high BP. Furthermore, a high BP and dysglycaemia form part of the MetS, a cluster of metabolic risk factors for premature morbidity and mortality (Assah et al. 2011).

The mean value of the systolic BP (SBP) for both groups was 123.0 ± 20.2 (urban) and 109.4 ± 16.4 mmHg (rural) and for the diastolic pressure (DBP) 81.7 ± 13.7 (urban) and 74.8 ± 10.3 (rural) (Figure 81, pg 203). Both measurements presented a significant difference between the urban and the rural group. These mean values are slightly lower than values measured in the Bantu population in Tanzania examined by Mbalilaki et al. in 2010. The Masai group, comparable to Group 2 of our cohort (see footnote 56, pg 245), had mean values of 118 mmHg systolic and 71 mmHg diastolic, while their rural group, comparable to Group 1 of our cohort, presented mean values of 134 mmHg systolic and 80 mmHg diastolic. A study done in urban and rural Cameroon showed higher mean BP measurements as well as no significant difference between the urban and the rural group (Lissock et al. 2011). A similar picture can be seen when comparing the mean BP measurements of the Ovahimba with those of urban and rural communities in the Congo. The latter again presented higher blood pressure values: SBP 127 and 124 mmHg and DBP 82 and 78 mmHg in the transitional and traditional groups respectively (comparable to the urban and rural group of our study).

The prevalence of high BP (not hypertension) was then looked at when analysing the data for the prevalence of the MetS and was defined as a SBP ≥ 130 mmHg and DPB ≥ 85 mmHg as stated by the Joint Interim Statement (JIS). The same trend as above could be seen: even though a high BP was the third most prevalent metabolic abnormality (32.5% in the total study population) it was still less prevalent than in other

communities in SSA (Ulasi et al. 2010, Mbalilaki et al. 2007). Comparing the results to communities in Europe and the US showed that study populations in the latter areas presented values at least 10 – 15 mmHg higher on average than the Ovahimba people (Ervin 2009, Agyemang & Bhopal 2003).

1.1.6. Family history and age

A family history of diabetes is a strong and independent risk factor for the development of diabetes. This has long been established in many studies done in the developed and developing world (Wikner et al. 2013, Motala et al. 2008). However, there does not seem to be a strong correlation between a family history of DM and present occurrence of dysglycaemia in the Ovahimba. Only six participants reported DM in a family member, of which only two had a disorder of glucose metabolism themselves, in both cases impaired glucose tolerance (IGT). None of the participants with DM had a family history of the disease and only 1.2% of participants with dysglycaemia had a family history (Table 18, pg 227).

Another long established independent risk factor for dysglycaemia is increasing age. This risk factor becomes especially important in developed countries, where life expectancies can be higher than 70 or 80 years. The mean ages of the study groups were 46.3 years and 51.1 years in Group 1 and Group 2 respectively. This matter is discussed in more detail further down.

2. Primary endpoint

2.1. Primary endpoint: Disorder of glucose metabolism

The primary endpoint of the study was the prevalence of dysglycaemia in the Ovahimba people and whether there existed a significant difference between the urban and the rural group. This would then allude to the fact that lifestyle changes and the modification of social behaviour influence the risk for a disorder of glucose metabolism. This will be discussed in the following section in the light of the anthropometrical measurements, the glucose and fat metabolism, the cortisol homeostasis and other risk factors for dysglycaemia outlined above.

There was a 20.3% prevalence of dysglycaemia in the whole study population, of which 28.3% occurred in urban participants and 12.7% in rural participants (Table 6, pg

208). Once the data was adjusted for 'age' and 'height', the difference was still statistically significant with $p_{a+h} = 0.023$. The data presented a statistical significance comparable to current literature on this topic and demonstrate that a change of lifestyle is associated with an increased risk of dysglycaemia in the Ovahimba people. Looking at the individual components of dysglycaemia two very different cases presented in our study population: an above-average high rate of pre-diabetes, but a far below-average prevalence of DM.

The total study population showed an IGT of 13%. The difference between the urban, 18.3%, and rural, 7.9%, was not significant. The prevalence of an impaired fasting glucose (IFG) of 5.7%, although also not presenting a significant difference, was lower: 6.7% in the urban and 4.8% in the rural group (Figure 86, pg 210; Figure 87, pg 210).

The IGT prevalence of 13% in the study population lies far above the national estimate of 6.6% given by the IDF for the Namibian population (IDF 2013). This makes the prevalence of 18.3% in Group 1 of our study three times the national average, while the prevalence in the rural group of 7.9% lies just above it. The urban rate and the total rate of IGT in our study population are also above the 2013 IDF estimate of 8.3% for the African continent, and the 2013 IDF global estimate of 6.9% (IDF 2013). It must be noted though that the age profile for the IDF estimate is 20 - 79 years, while the age profile for the study population is 30 – 80 years. However, no alternative current data on Namibia for the latter age profile could be found. Studies done in other SSA countries mostly reported a slightly lower rate of IGT prevalence. The IDF (2013) estimated the prevalence of people suffering from IGT in 2013 in South Africa to be 9.03% in the whole population, while Peer et al. (2012) observed a prevalence of 10.7% in urban-dwelling black South Africans (IDF 2013). Evaristo-Nato et al. (2010) reported a prevalence of 8.1% in the rural Angolan community in 2010 (Evaristo-Nato et al. 2010). Only villagers in Cameroon presented a similar IGT prevalence of 12.1%, as reported by Napoli et al. in 2010. Compared to European countries, the IGT prevalence of Ovahimba people would appear to be higher.

However, in comparison with the data from Europe, the Ovahimba people show a much higher prevalence of IGT. According to the IDF's 6th edition of the Diabetes Atlas, Europe has a comparative prevalence of IGT of 8.1% and a comparative

prevalence of DM of 6.8% (IDF 2013). There is a wide variation of prevalence of dysglycaemia across European countries. In 2010, the national prevalence of IGT and DM in Germany were 6.6% and 12% respectively, lying in the top half of European countries (Shaw et al. 2010).

Research studies that included impaired fasting glucose (IFG), report very different prevalence levels in SSA communities. In rural Angola, Evaristo-Neto et al. (2010) report the IFG prevalence to be 12.1%, which is higher than the prevalence of IGT in the community. Peer et al. (2012), on the other hand, report a 1.2% prevalence of IFG in urban-dwelling South Africans. A low IFG rate was also observed in Mozambique, where 2.5% of participants presented with IFG. No significant difference was found between urban and rural dwellers in this study (Silva-Matos et al. 2011). These values place the prevalence of IFG in Ovahimba midway between the extremes.

The analysis of the prevalence of DM in the study population presented a very different picture. Only two participants suffered from DM (1.6%) both of whom were part of the urban group (3.3%), showing no significant difference between the urban and rural group (Table 6, pg 208). Unexpectedly, the prevalence lies far below the 2012 IDF estimate of 6.1% for the national prevalence of DM in Namibia, and also below the estimated 4.5% for Africa (IDF 2012, IDF 2011). The prevalence of 1.6% on the other hand, is already higher than the national 1.4% estimate for DM given by King et al. in 1998 for the year 2025. This shows how the diabetic epidemic has progressed in Namibia, even in an indigenous population group.

The fact that the prevalence of DM in the Ovahimba people is lower than the national estimate given by the IDF is to some extent surprising as studies done in other SSA countries have mostly presented a higher than estimated prevalence. Evaristo-Neto et al. (2010) and Napoli et al. (2010), for example, found a much higher than estimated prevalence in rural Angola and rural Cameroon respectively in 2010. Similar findings were reported by Katchunga et al. (2012) on a study done among urban Congolese adults.

Furthermore, when comparing the prevalence of diabetes in Ovahimba people to other SSA countries, the prevalence is much lower among the Ovahimba. In rural Angola the prevalence was 2.8%; in rural Cameroon 7.1%; in Congo 4.7% in urban and

2.9% in rural adults; in Nigeria, 4.6% in the urban Fulani population, and in South Africa 6.5% in the general population (IDF 2012, Katchunga et al. 2012, Sabir et al. 2011, Evaristo-Neto et al. 2010, Napoli et al. 2010). Once again, these data must be compared cautiously, as the age groups in the respective studies varied slightly.

It can be concluded that the present investigation's main findings were that there is a significant difference in the presence of a disorder of glucose metabolism between the urban and rural group. This supports our hypothesis that urbanisation concurrent with a change of lifestyle does influence the risk of dysglycaemia. We further expected that a high prevalence of pre-diabetes compared to a low prevalence of DM in the total study population will be present, showing that the Ovahimba are well on their way into a diabetic epidemic. The lack of statistical significance in the prevalence of individual components of dysglycaemia between the urban and rural group may be attributed to the limited sample size of our study.

2.1.1. Interpretation of findings

So, what could be the possible reason for above results? It is obvious that urbanisation has caused the risk factors for diabetes and CVD to increase in the urban participants. The nutritional transition combined with a more sedentary lifestyle of people living in towns has given rise to a very high prevalence of dysglycaemia. The risk factors seem to be the same as in developed countries: urbanisation, obesity, sedentary lifestyle and hypertension. This was already established by several other authors who did research in SSA countries (Duboz et al. 2012, Evaristo-Neto et al. 2010, Motala et al. 2008). Many authors have reported demographic transition[57] to be another risk factor for the increasing diabetes epidemic in developing countries (Duboz et al. 2012). However, this does not seem to be the case in Namibia. According to the CIA Factbook, the life expectancy of a Namibian in 2011 was 51.6 years (50.9 for men and 52.2 for women), almost ten years less than the 1991 WHO's life expectancy for Namibia of 61 years (CIA 2011, WHO 2009). Even though the life expectancy for the Ovahimba people is estimated to be slightly higher at 53.3 (50 for men and 57 years for

[57] Demographic transition: transition from high birth and death rates to low birth and death rates, i.e. an increasingly elderly population. This takes place as part of a country's development from a pre-industrialised to industrialised country (Dahan 1998).

women), it is still far below what would be considered a demographic transition (NPC 2007).

On the other hand, as Namibia becomes more industrialised, the socioeconomic status of its people reincreases, which is also the case in the town of Opuwo (personal observation and informal interviews with translators). An increase in socioeconomic status is frequently associated with an increase in obesity and its risk for NCD, especially in developing countries (Misra & Khurana 2008). This change in disease pattern from predominantly infectious, communicable diseases to NCD with an increasing prevalence of aetiological risk factors for the MetS, DM and other CVD is defined as the epidemiological transition. The epidemiological transition has been described by researchers examining NCD in North Africa and Kenya as an emerging hostile consequence of urbanisation and increase in socio-economic standard in SSA (Belfki et al. 2012, Kaduka et al. 2012).

Moreover, the rise of more affluent urban people has only taken place in the last few years in the Kaokoveld region, before which malnutrition and growth-retardation were common (informal interview with translator). Therefore, its people are subjected to the 'thrifty phenotype[58] and thrifty genotype[59]' theories, which could contribute largely to the apparent epidemic in the region.

We did not examine insulin resistance as such. Nevertheless, on account of various data published on the high insulin resistance of black people, it can be assumed that the Ovahimba people, similar to other Bantu people and people of black origin, exhibit an increased insulin resistance. It is well established that insulin resistance and decreased β-cell function are the underlying pathogenesis for the development of pre-diabetes and DM (Gaillard 2010, Amoah et al. 2002). Studies done in the African diaspora, in Afro-American communities, as well as comparative studies done between ethnicities, have

[58] Thrifty phenotype: This theory suggests that reduced foetal growth and foetal mal-nutrition is associated with an increased risk for hypertension, stroke, diabetes and coronary heart disease when faced with over-nutrition in later life (Prentice & Moore 2005, Fall 2001). For more details on the thrifty phenotype hypothesis the reader is referred to the section 'The thrifty phenotype and the thrifty genotype theory' as part of the section on 'Obesity' (pg 21) in this work.

[59] Thrifty genotype: This theory, first described by Neel in 1962, suggests that genes, which were advantageous in times of famine by promoting fat storage, are detrimental in times of abundance by resulting in metabolically disadvantageous phenotypes such as obesity, diabetes and CVD. For more details on the thrifty genotype hypothesis the reader is referred to the section 'The thrifty phenotype and the thrifty genotype theory' as part of the section on 'Obesity' in this work.

shown that black people tend to exhibit greater insulin resistance, consistently higher mean FG and higher post-glucose challenge insulin levels than their white counterparts. Therefore they are more prone to the development of dysglycaemia (Gaillard 2010, Gaillard et al. 2009). Haffner et al. (1996) conducted 'The Insulin Resistance Atherosclerosis Study' in the US, which showed that nondiabetic African-Americans were more insulin resistant and hyperinsulinaemic, even after adjustment of the data for obesity, than their nondiabetic white counterparts, making this phenomenon partly responsible for the higher rates of pre-diabetes and diabetes in black American communities. A study done in a native Ghanaian community presented a similar picture: increased insulin concentrations (measured by fasting insulin and c-peptide concentrations) in the study group with worsening glucose tolerance, while other risk factors such as high BMI, obesity and high WC showed no significant difference between the study groups (Amoah et al. 2002). Osei et al. (1997) stipulate that these phenomena, also observed in their study with native Ghanaians, Ghanaian immigrants to the US, Afro-Americans and white Americans, are genetically determined and result in the higher prevalence of pre-diabetes and diabetes in black communities compared to white communities with a similar anthropometrical profile.

The high rate of dysglycaemia in the urban people was expected beforehand, as it is in line with research done in other urban parts of SSA and the world. However, the high prevalence of pre-diabetes in the rural group was rather unexpected. A similar phenomenon presented in a rural community in South Africa where the inhabitants had a moderate prevalence of diabetes and a high prevalence of total disorder of glycaemia (Motala et al. 2008). The authors argue that this shows that the respective community, unlike what was expected, is already well into an epidemic of glucose intolerance and it is suggestive of an early stage of the diabetic epidemic. This could be the case in our rural Ovahimba as well. Although we did not observe much western influence, not all dietary habits could be witnessed as the communities often spread out over vast areas and not all households were visited personally.

Furthermore, it could also be that once the rural Ovahimba are subjected to non-traditional edible products, their body reacts differently than that of other African people. As Glew et al. (2010) and Mbalilaki et al. (2010) argued on the genetic factors involved in the favourable lipid profiles of semi-nomadic people, the same could apply

to the glucose metabolism of the Ovahimba. Could genetics be responsible for an unfavourable glucose metabolism once subjected to the slightest change towards a non-traditional diet? This hypothesis has been raised by Hightower et al. (2011) who found a similar picture when studying the glucose metabolism of Congolese people living in three different locations (traditional, transitional and modern communities). The authors argue that rather than urbanisation causing CVD risk factors, the latter pre-exists and is then augmented by a change in lifestyle. This argument can be further supported when looking at the studies done in the Pima Indian populations of Mexico (rural) and the US (urban). These showed that once the Pima Indian people are exposed to a modern lifestyle, they exhibit an exorbitant prevalence of diabetes, resulting in the hypothesis that this population has a genetic risk for the development of dysglycaemia that is exposed once a modern/western lifestyle is adopted (Schulz et al. 2006).

Our study is the first to examine the glucose metabolism of the Ovahimba; no comparison to earlier prevalence of glucose metabolism disorders can be made. Therefore, it could be that the Ovahimba society has always had a genetic propensity towards an unfavourable glucose metabolism once subjected to environmental changes, which could then result in unexpectedly high prevalence of pre-diabetes and later diabetes in rural and urban areas. However, these are just assumptions and further research would be needed to confirm these statements.

With such a high prevalence of pre-diabetes in the total study population a high rate of diabetes would have been expected. However, this was not the case. Only two participants were identified has having DM, both of them living in Opuwo. It does show nevertheless, that the Ovahimba are well on their way into a diabetic epidemic and a much higher prevalence of DM can be expected in the future.

The risk of diabetes increases with age. The mean age of the participants was 46.2 in Group 1 and 51.1 in Group 2. Therefore, it could be that the study population was in general too young to show the development of diabetes. Yet, while the one diabetic was 80 years old with age being the only risk factor, the other diabetic was only 35 years old with a high WC, a high BMI, a high FG value and unfavourable lipid profile. However, the life expectancy of the Ovahimba being 53.3 years, the study's mean age was a close representation of the age of the whole population. The low life expectancy could also be

a reason for the scenario of high pre-diabetes and low diabetes (Evaristo-Neto et al. 2010).

It was outlined above that the Ovahimba are in the midst of the urbanisation process. Yet, this is a very recent development that has only taken off in the past few decades. As was explained in the section on the history of the Ovahimba people (pg 124), the Kaokoveld area was excluded from trade and other interaction from the rest of Namibia and Angola almost until Namibian Independence in 1990 (Rizzo 2000). This exclusion meant that major development, as we see it today, did not take place until the 1990s. There were not many shops selling western foods and the socioeconomic status of the people did not allow them to purchase 'western foods' until recently (informal interview with translator). The people were therefore possibly not subjected to the environmental risk factors for diabetes long enough for it to be highly prevalent. This fact was emphasised by a statement given by the medical superintendent for the Kaoko region during an informal interview: he previously worked in health-care in the Damaraland province, an area which was not excluded from the pre-Independence modernisation and development. Here, the rate of diabetes was extremely high. He also mentioned that there were hardly any diabetic patients at the Opuwo District Hospital despite the many risk factors obviously present. It could be that the people of Kaokoveld, compared to other communities in developing countries, are at an earlier point of the diabetic epidemic where a high prevalence of pre-diabetes has not yet swept into a high rate of diabetes. It is at this point that action should ideally be taken to prevent the epidemic of pre-diabetes to become a diabetic epidemic in the Kaoko region.

3. Secondary endpoints

3.1. Cortisol homeostasis

Cortisol is the most important glucocorticoid hormone of the body and as part of the adrenocorticotropic system it is intricately involved in the stress response of the body, the pathophysiology of which was explained in the section on 'The role of cortisol' (pg 31) (Dalmazi et al. 2012, Kann 2009). Other functions and effects of cortisol have also been outlined in the same section. For the purpose of interpretation of the cortisol examination the focus will be on the involvement of cortisol in the stress response of the body.

Cortisol is an antagonist to insulin in the body and thus increases blood glucose concentration and, if high concentrations of cortisol persist, results in visceral obesity, dyslipidaemia, pancreatic β-cell dysfunction, hypertension and IGT (Dalmazi et al. 2012, Praveen et al. 2011). It therefore becomes obvious that high concentrations of cortisol make the person susceptible to the development of dysglycaemia and the MetS (Dalmazi et al. 2012, Anagnostis et al. 2009, Björntrop 2001).

The fact that cortisol plays a pivotal role in the stress response of the body through hyperactivity of the hypothalamic-pituitary-adrenal (HPA)-axis has been well-established in numerous studies (Dalmazi et al. 2012, Huisman et al. 2002, Gerra et al. 2001). The stress response to psychosocial stress caused by urbanisation, modernisation and modification of the social environment is no exception to this. The question that arises is how these processes induce a stress response in the human body.

In his article on culture and disease Dressler (2004) explains that urbanisation and migration are accompanied by cultural change and a modification of the social environment. A person's knowledge of how to function in society is often ineffective in a new setting, easily resulting in social conflicts. This requires the person to adapt to a new set of social rules and norms and mostly a new language, which is often perceived as taxing and stressful. If the person adapts quickly, long-term effects on health can be minimised. However, if the process of social adaption is extended or fails altogether, and societal acceptance and support are incomplete, long-term health risks can result (Mashele et al. 2010, Dressler 2004, Cassel et al. 1960). Dressler (2004) and Cassel et al. (1960) further state that a person's ability to resist the stresses of social and cultural adaption as well as stresses experienced in everyday life, depends hugely on that person's social support: the better the social support, the less likely health risks will arise and vice versa. However, urbanisation is often accompanied by loss of social support and culture (Mashele et al. 2010). This is further enhanced by the replacement of collectivism, deeply anchored in most traditional African cultures with individualism following once modernisation takes place. This disruption of social relationships and stability can increase a person's perception of stress which in turn activates the stress response of the body leading to poorer health (Malan et al. 2006).

Furthermore, the perception of social status often changes with a change of the living environment (Dressler 2004). A study done on social transformation in the West Indies

showed that traditionally the highest status in a community was given to the mostly elderly, often prosperous, thoughtful and articulate persons (Dressler 1982). However, once urbanisation, and with that the inevitable social transformation took place, the perception of prestige and success changed: it is now shaped by the lifestyle of the 'Euroamerican consumer markets' (Dressler 2004). This means that a consumer lifestyle has to be adopted and the more a person can live and afford this lifestyle the higher the social prestige will be. In their study in the West Indies Dressler (1982) measured the outcome of this social transformation by a person's BP: the highest BP were presented by people whose aspirations for a higher status failed and whose social support was weak.

Newly urbanised persons and communities, especially in developing countries, often do not have the economical means to live a consumer-determined lifestyle and therefore risk of failure to adapt and blend into the new society is high (Dressler 2004). Anagnostis et al. (2009) and Tull et al. (2003) further point out that low socioeconomic status and unemployment are widespread in these communities, resulting in high levels of anxiety and chronic stress. Many studies have shown that the poorer the coping style of a person to deal with these chronically stressful events, the higher the risk of adverse health effects (Malan et al. 2012). However, due to the fact that we did not examine individual coping styles within the framework of active and passive coping styles, no detailed discussion follows here. For more information the reader is referred to Malan et al. (2012), Malan et al. (2006) and Huisman et al. (2002).

Psychosocial stress leads to altered stress-hormone profiles, increased α-adrenergic vascular response, IFG and hypertension (Malan et al. 2012). When the input of stress is prolonged the reactivity of the HPA-axis changes: from peaks of cortisol secretion at the moment of stress, but regression after removal of the stressor, to a phase of sensitisation with prolonged cortisol secretion even after the removal of the stressor. If the stressor persists chronically, the physiological decline of the concentration in the course of the day is delayed, and concentration and secretion stay high. This disrupts the diurnal circadian rhythm of the cortisol homeostasis, with a disruption of the HPA-axis activity in the morning, resulting in lower morning values and little reactivity during the day (Stawski et al. 2013, Anagnostis et al. 2009, Björntrop 2001). Anagnostis et al. (2009) call this 'a state of functional hypercortisolism'. The cortisol homeostasis is reflected in

the concentration of cortisol in saliva samples, making the examination of its concentration a useful biomarker for the analysis of the function/dysfunction of the HPA-axis and thus a predictor of health (Stawski et al. 2013).

Consideration of the above issues, when projected onto our study, yielded two hypotheses that were tested. Firstly, we hypothesised that urban participants would present higher mean cortisol concentrations and a greater cortisol exposure due to more perceived psychosocial stress as a result of urbanisation and a modification of the social environment. Furthermore, these high cortisol concentrations would be associated with a higher prevalence of dysglycaemia and the MetS in the participants. Secondly, we hypothesised that the urban group would show less variability of cortisol concentration in the course of the day as a result of prolonged stress experienced and thus will show a less steep decline in cortisol concentration.

Group 1 presented significantly higher cortisol concentrations in the saliva at sunrise and sunset, with $p < 0.001$ and $p_{a+h} < 0.001$ compared to Group 2 (Table 9, pg 214 and Figure 89, pg 215). Additionally, when looking at the cortisol area under the line (AUL) the urban participants showed a significantly greater overall exposure to cortisol with $p < 0.001$ and $p_{a+h} < 0.001$ in the Wilcoxon rank-sum test (Figure 91, pg 217). This is an indication that urban participants suffer more from psychosocial stress than rural participants. This correlation has been proven in various studies (Stawski et al. 2013, Malan et al. 2012, Anagnostis et al. 2009, Dressler 2004).

A large cross-sectional study was done in South Africa, where participants from different levels of urbanisation were represented. As part of this THUSA (Transition and Health during Urbanisation in South Africa) study, Malan et al. (2012) analysed coping mechanisms and neuroendocrine function in black African men. The study showed that urban men had a poorer physiological profile, altered stress hormone profiles[60], increased vascular responses, IGT and hypertension. Even though there was no significant difference in the cortisol concentration of urban and rural men, a trend could be observed. The results suggested that urban men encounter more psychosocial stress (Malan et al. 2012).

[60] Stress hormone profile: the stress hormone profile includes measurements of prolactin, testosterone and cortisol concentrations and the cortisol:testosterone ratio (Malan et al. 2012).

A study conducted with black women residing on the Caribbean island of Dominica examined the association between perceived stress due to internalised racism[61], coping behaviour and cortisol secretion. In order to assess the diurnal cortisol rhythm, saliva samples were collected in the morning and in the evening. Questionnaires were completed to assess stress, internalised racism and coping behaviour. The results showed that women with high levels of internalised racism perceived higher levels of stress and also presented a more pronounced dysregulation of the HPA-axis (Tull et al. 2005). In their study examining daily stressors and salivary cortisol, Stawski et al. (2013) found that on stressor days, overall cortisol exposure measured by area under the curve (AUC) were higher in the participants compared to non-stressor days. From this the authors conclude an increased neuroendocrine activity due to stress experiences. The authors further explain that the presence of the stressor more than its severity was associated with a high AUC.

The second part of the hypothesis looked at a possible association between cortisol levels and dysglycaemia and the MetS. As mentioned above, these conditions often result from prolonged increased activity of the HPA-axis. In our small study cohort there was no significant difference in the mean values of those participants with and those without a disorder of glucose metabolism (Table 11, pg 218) and the MetS (Table 14, pg 224). The comparison of the cortisol AUL between those participants in whom the disorder was present (dysglycaemia and/or MetS) and those in whom it was not present, also showed no significant difference. An interesting finding was that the rural participants with the MetS showed an increase of cortisol concentration in the course of day with a mean increase of 0.01 ± 0.02 µg/dl. Even though the difference was not significant with $p = 0.154$ and $p_{a+h} = 0.358$, a tendency is obvious. This finding supports the hypothesis that a missing decline of cortisol concentration in the course of the day promotes the development of the MetS. Apart from this, our study size was too small to show possible associations within each individual study group. The assessment of the correlation between cortisol exposure, measured by the AUL and the individual components of the MetS also yielded no pronounced results (Table 16, pg 226). The conclusion we can draw from the interpretation of our data is that the urban group has a

[61] Internalised racism: the 'extent to which blacks agree with racist stereotypes about blacks' (Tull et al. 2005).

higher cortisol exposure compared to the rural group. Furthermore, we can say that the urban group has a higher prevalence of metabolic disorders.

Our second hypothesis was that the urban group would show less variability of the cortisol concentration in the course of the day by presenting a less steep decline than Group 2. However, this was not the case in our study. Figure 90 (pg 216) shows individual sunrise and sunset values as well as the absolute mean decline of both groups. Group 1 starts at a higher baseline value, but then presents a significantly steeper decline of 0.20 ± 0.21 µg/dl compared to 0.14 ± 0.10 µg/dl in Group 2 ($p = 0.016$, $p_{a+h} = 0.021$) (Figure 90, pg 216). When comparing the relative decline of both groups, no statistically significant difference could be seen (Group 1 37.2% vs. Group 2 34.5%, $p = 0.504$, $p_{a+h} = 0.879$).

Huisman et al. (2002) point out that a paradoxical model of the activity of the HPA-axis under stressful conditions exists: this model stipulates that there is evidence of a decreased HPA-axis activity, as a sign of malfunction, and hypocortisolism in times of prolonged stress due to 'increased feedback inhibition of the pituitary-adrenal level of the HPA-axis' (Huisman et al. 2002). The view of the authors is that there is no clear-cut model for HPA-axis response to stress. Similar to our study, their study on the comparison of cardiovascular and endocrine parameters in urban and rural South Africans, showed very mixed patterns of cortisol homeostasis. Women in informal settlements showed lower cortisol concentrations compared to their rural counterparts, which the authors ascribe to chronic and unavoidable stressful conditions. The male participants living in informal settlements, however, showed significantly higher cortisol levels than their counter-parts in high-class urban areas. According to the authors this can be a sign of a 'defeat or submissive reactivity pattern'. The analysis of cortisol levels as part of the THUSA study (see above) also showed a mixed pattern of results: a trend could be seen in that urban men showed higher cortisol levels than rural men. However this difference was statistically not significant. Furthermore, no difference could be detected in the cortisol levels of active and passive coping urban men (Malan et al. 2012).

A study was conducted in Ireland to ascertain salivary cortisol levels, stress and mood in healthy older individuals. In line with the current literature the authors hypothesised that subjectively perceived stress leads to negative mood associated with

higher cortisol concentrations and decreased HPA-axis variability. However, conflicting results were found: even though perceived stress was correlated to negative mood, there was no correlation between negative and positive mood and cortisol levels (Simpson et al. 2008). According to Heim et al. (2000) there are several underlying mechanisms leading to hypocortisolism as a result of chronic stress: a reduced synthesis of hormones or an exhaustion of these can occur at different levels of the HPA-axis, there can be an adaptive down-regulation of corticotropin-releasing-factor receptors in the pituitary gland resulting in a hypersecretion of the releasing hormone, furthermore an increased feedback sensitivity of the HPA-axis develops and lastly morphological changes can result in hypocortisolism (Heim et al. 2000). When looking at the decline of cortisol concentration during the day, Stawski et al. (2013) found similar results to our study. In line with the current literature, the authors expected the cortisol decline to be flatter on stressor days compared to non-stressor days. However, this could not be verified as participants showed a steeper decline on stressor days. The authors argue that this could have been due to the time interval the HPA-axis needs to react to stress.

It is obvious that there is no clear-cut direction in the research on HPA-axis activity in times of prolonged stress. 'Stress' is a very subjective condition. As Dressler (2004) puts it, 'anything can be stressful (or supportive) if the individual perceives it as so' (Dressler 2004). Heim et al. (2000) further state that the perception of stress and resulting neuroendocrine abnormality are influenced by genetic vulnerability, previous experiences and personality traits. A situation one individual perceives as stressful might not be perceived as such by another individual. Regarding the latter aspect ethnic differences in the perception of stress and coping mechanism also have to be taken into consideration (Malan et al. 2012). It must be remembered that this analysis is a statistical picture of a group of participants sharing the same environment. As Dressler (2004) points out, an interpretation of a group of people leaves little space for the insight into what is occurring at an individual level. Furthermore, there seems to be a great variability in the response of the HPA-axis to stress in males and females that was not considered in our study (Simpson et al. 2008, Huisman et al. 2002).

Considering all the above-mentioned aspects, it is not surprising that our study, in some aspects, yielded contrarious results to our initial hypothesis. In order to get a clearer picture of the association between urbanisation, psychosocial stress, HPA-axis

activity and health risks in the Ovahimba community further and larger studies need to be conducted, which include the assessment of perceived stress, coping styles and gender differences. The data of our study would then be helpful as baseline values from which conclusions could be drawn.

3.2. The metabolic syndrome

The MetS is a cluster of interrelated risk factors that are metabolic in nature and pose a 2-fold increased risk for CVD and a 5-fold greater risk for the development of diabetes (Grundy 2008). It is a combination of abdominal obesity, dyslipidaemia, insulin resistance, high BP and high plasma glucose (Belfki et al. 2012, Tamashiro 2011). There is not complete agreement about the definition, and how much emphasis should be placed on each individual component of the MetS. The WHO was first to release a definition, placing great emphasis on dysglycaemia, making either insulin resistance, IGT or IFG a pre-requisite. The IDF on the other hand, attributes a pivotal role to central obesity, making this component a pre-requisite (Cornier et al. 2008, Fezeu et al. 2007). For the purpose of our study, the definition of the Joint Interim Statement (JIS) was used ('Diagnosis of the metabolic syndrome', pg 191). This is an attempt by some major health organisations to harmonise the definition of the MetS (Alberti et al. 2009). Equal weight is put on all components and ethnic-specific cut-offs for waist circumference (WC) should be applied. Therefore, the diagnosis was made if any three of the following were present: high WC ≥ 94/80 cm (for men/for women), high triglycerides ≥1.7 mmol/l, low HDL-Chol ≤1.0/1.3 mmol/l (for men/for women), high BP systolic (SBP) ≥130 mmHg and/or diastolic (DBP) ≥85 mmHg, high FG ≥5.6 mmol/l[62] (Alberti et al. 2009).

Applying the definition of the JIS, 19.5% of the total study population was diagnosed with the MetS (Figure 92, pg 221). There was a significant difference between the urban and rural group, with 31.7% being metabolically unhealthy individuals in Group 1 and only 7.9% in Group 2, with $p < 0.001$ and $p_{a+h} < 0.001$ (Table 13, pg 220). With these values, the Ovahimba are comparable to the world population, of which it has been established that 20-30% are suffering from the MetS (Kaduka et al. 2012). Comparing our study to other studies done in SSA is difficult, as different definitions have often

[62] Capillary blood glucose data were transformed to venous plasma glucose using the SEMDSA 2009 conversion formular (pg 186) to agree with the definition of the MetS.

been used. Due to the lack of data, comparisons will also be made with studies that used different definitions.

An urban population of Kenya presented an overall prevalence of 34.6% using the 2009 IDF consensus statement criteria, which are the same as the JIS criteria we used in our study (Kaduka et al. 2012). The authors furthermore report the MetS prevalence to be 30.5% in West Africa, 31.2% in greater Tunis and between 25-30% on the Seychelles (Kaduka et al. 2012). Assah et al. (2011) report a much lower prevalence of MetS in Cameroon with 17.7% in urban people and 3.5% in rural people. In this study however, the criteria of the NCEP-ATP III were used which have a WC cut-off of ≥102 cm in men and ≥88 cm in women. Similar to our study though, a significant difference was found between the urban and rural presence of the MetS. With a high waist-circumference (≥ 94 cm for men and ≥ 80 cm for women) as pre-requisite, Ulasi et al. (2010) report an 18.0% prevalence of the MetS in a semi-urban community and a 10.0% prevalence in a rural Nigerian community.

Looking at the individual components of the MetS, a high WC was most common (42.3%), followed by low HDL-Chol (36.6%) and high BP (32.5%). By far the least common was the presence of high triglycerides (6.5%) and high fasting glucose (9.8%) (Table 13, pg 220). This is continuous with the discussion on FG, IFG and lipid profiles of the Ovahimba as outlined above. The constellation of most common (high WC, low HDL-Chol, high BP) and least common (high triglycerides, high FG) components is also reflective of research done in other areas of SSA (Belfki et al. 2012, Kaduka et al. 2012, Ulasi et al. 2010, Motala et al. 2009).

In western countries in contrast, insulin resistance and high FG also often go hand in hand with obesity, hypertension and high triglycerides (Lin et al. 2011, Gaillard et al. 2009). According to Gaillard et al. (2009) it is apparent that the impact of the five components of the MetS for future development of DM and CVD varies between racial/ethnic groups. Even with a high metabolic risk, hypertriglyceridaemia is rarely present in black people of African descent (Lin et al. 2011, Ukegbu et al. 2011). Ukegbu et al. (2011) argue that the application of the current MetS criteria, be it with or without one component being more weighted, under-predict the rate of MetS in black populations. In their study comparing Afro-Americans and Non-Hispanic whites, Lin et al. (2011) found that Afro-Americans had a higher prevalence of hypertension, insulin

resistance and FG but a lower prevalence of high triglycerides than their white counterparts. Despite the fact that the Afro-Americans presented a high prevalence of all risk factors besides one, they presented with a lower MetS than the Non-Hispanic whites. Furthermore, it has been established that total cholesterol and LDL-Chol are more strongly associated with CVD risk in Caucasians than in Afro-Americans (Frazier-Wood et al. 2013). These phenomena repeatedly call into question the validity of the various MetS criteria and whether there should be different criteria for different ethnicities. Ethnic specific criteria would allow health professionals to filter out patients at high risk of CVD and DM more accurately (Gaillard et al. 2009).

The MetS is a cluster of risk factors causing NCD. And as it has been with all NCDs over the past few decades, the prevalence of the MetS is increasing rapidly, especially in the developing world (Assah et al. 2011, Gaillard 2010, Ulasi et al. 2010). Unfortunately, once again no previous data are available on the prevalence of the MetS in Ovahimba people. However, one can safely assume there has been a rise over the past few years. Literature points out that the risk for development of DM in the presence of the MetS is five times higher than without the syndrome (Kaduka et al. 2012, Grundy 2008). Nevertheless, with a MetS prevalence of 31.7% in the urban and 7.9% in the rural population, only 3.3% and 0.0% presented with DM in our cohort respectively. This emphasises the statement made above, that the Ovahimba people are at the beginning of an epidemiological transition with the emergence of chronic risk factors such as obesity, hypertension and dysglycaemia resulting in greater risk of premature morbidity and mortality. At the base of this lies the rapid urbanisation occuring in developing countries explained above. Besides being responsible for the increase in the obvious risk factors, urbanisation also goes hand in hand with increased psychological stress. The latter has been established as a risk factor for the development of the MetS (Belfki et al. 2012, De Kock et al. 2012, Tamashiro 2011).

3.3. Framingham risk score (FRS)

In order to assess the 10-year general CVD risk of the Ovahimba people, the FRS was applied to the obtained data, as recommended by the South African Heart Association and the Lipid and Atherosclerosis Society of Southern Africa (LASSA) (SA Heart Association 2012). This is a multivariable assessment tool validated in black and white populations designed to identify people at high risk for the development of any

cardiovascular event. It encompasses the intensity of each of the individual risk factors for CVD (age, treated or untreated high systolic BP (SBP), diabetes, smoking, total cholesterol and HDL-Chol or BMI replacing lipids) and gives a percentage of the risk, while placing the person in a risk group. Risk groups are as follows: low risk: < 3%, moderate risk: 3 – 15%, high risk: 15 – 30% and very high risk: > 30% (SA Heart Association 2012, Framingham Heart Study (FHS) website).

The mean percentage of 10-year CVD risk in our study population was 5.4%, meaning that the general study population has a moderate risk of incurring a CVD event in the next ten years (Table 17, pg 226). Unlike most of the cardiovascular risk factors outlined above, there was no significant difference in the mean risk percentages between the urban and the rural group. Dividing the participants into risk groups, the following picture presents: 48.0% of participants were at low risk (46.7% Group 1 vs. 49.2% Group 2), 43.9% at moderate risk (45.0% Group 1 vs. 45.0% Group 2), 5.67% at high risk (0.8% Group 1 vs. 3.2% Group 2) and 1.6% at very high risk (Group 1: 0.0% vs. Group 2: 3.2%). The WHO recommends that all patients with a 10-year CVD risk of > 30%, or > 20% if resources permit, be treated pharmacologically (Mendis et al. 2011). This means that almost half of the study population is at moderate risk of incurring a cardiovascular event in the next 10-years, while three patients should ideally receive pharmacological intervention according to the WHO guidelines (SA Heart Association 2012).

Data on the 10-year general CVD risk of communities in sub-Saharan Africa are scarce and no study using the FRS could be found. Most authors report on the prevalence of CVD in the respective populations. Due to this, the figures observed in our cohort will be compared to studies which used other risk assessment tools to calculate the CVD risk in black populations, were conducted in the developed world and including black participants or studies done in other developing countries.

Mendis et al. (2011) conducted a study across eight lower to middle–income countries to determine the percentage of the population in each risk group and to assess the cost of giving drug treatment if a cut-off for cardiovascular risk of 30% is used.

Most people had a low 10-year CVD risk[63], with numbers ranging from 79.2% in Pakistan to 96.1% in China. 90 – 98.9% had an intermediate risk (< 20%), while there were less than 10% of people in the high risk group in all countries. Nigeria, which is the similar to Namibia, presented the following percentages: low risk 86.0%, intermediate risk 9.0% and high risk 5.0% (Mendis et al. 2011). A study conducted in Senegal showed that 24.9% of the population are at high risk of a CVD event within the next 10 years, while 20.5% of participants of a study conducted on black people residing in the U.K. were classified as high risk (Pessinaba et al. 2013, Schofield et al. 2012).

Critics of the FRS point out that the assessment tool was developed on data gathered from mainly Caucasian participants, who had a high prevalence of important CVD factors such as hypercholesterolaemia, smoking and obesity and only represented a specific socioeconomic group (Schofield et al. 2012, Bitton & Gaziano 2010). This makes the application of the FRS to other populations imprecise. Some European studies have shown an overestimation of CVD in the study population of up to 30% (Bitton & Gaziano 2010). The same is true for studies done in other ethnic sub-groups such as Africans in the U.K. (Schofield et al. 2012). Schofield et al. (2012) did a study to assess the CVD risk in a U.K. black population and found that except for the QRISK2 assessment tool, all other (Framingham, ASSIGN and ETHRISK) algorithms only found a moderate agreement between the CVD risk and national figures in the black population. Hurley et al. (2010), on the other hand found that the FRS was well calibrated across three different ethnic groups (Non-Hispanic whites, Non-Hispanic blacks and Mexican Americans), once separate models for each group were developed. This was done as part of their study to assess the relationship between risk factors and cardiovascular mortality. In addition, the FRS is the only CVD assessment tool that has been evaluated in a developing country (China) (Bitton & Gaziano 2010).

Even though the FRS is the gold standard one could argue that it appears to be imprecise in the prediction of CVD risk in people of African descent. The application of the FRS to our study population has not been compared to other risk assessment tools

[63] Calculated using the WHO/ISH risk score. The risk prediction charts were designed using standardised collection and assessment of data on the risk factor prevalence and relative risk. This was done in the WHO epidemiological sub-regions. The absolute risk of a CVD event was calculated by determining individual relative risk to population incidence rates of major CVD events in low and middle–income countries (Mendis et al. 2011).

and therefore no comment can be made whether or not a more appropriate tool for the Ovahimba exists. The FRS has been used to supply a first indication of the 10-year CVD risk in this society. It is therefore recommended that another study investigating the most appropriate tool to calculate 10-year CVD risk be conducted in future. It should then be considered using an algorithm that takes ethnicity and/or social inequality into consideration. The WHO together with the International Society of Hypertension (ISH) has developed a WHO/ISH risk prediction chart to assess 10-year CVD risk in developing countries. This tool was designed to encompass the risk factors for CVD as well as the population distribution of these risk factors and the population-estimate of absolute risk (Mendis et al. 2007, WHO website). For more information on this assessment tool the reader is referred to the article of Mendis et al. (2007), and the WHO website (http://ish-world.com/downloads/activities/colour_charts_24_Aug_07.pdf) where the charts are available. It becomes obvious that even though various tools exist to assess general cardiovascular risk in black people, no standardised tool predominates and it is recommended that more research be done in SSA using the various assessment tools.

4. Bone ultrasound in the Ovahimba people

Acoustical properties of bone, bone architecture and bone elasticity are a measurement of bone strength (VanderJagt et al. 2004). It is an interaction between bone formation by osteoblasts, bone resorption by osteoclasts and bone remodelling by osteocycte, which normally is a well-balanced process (Rachner et al. 2011). A disturbance of this balance will result in low quality of bone making it a risk factor for osteoporosis and therefore for non-traumatic fractures. The probability of fracture based on bone strength is traditionally expressed by the 'gradient of risk' (WHO 2007). This is 'the increase in relative risk per standard deviation (SD) unit decrease in bone mineral measurements' (WHO 2007). The SD is expressed by means of the Z-score[64]. According to the WHO, qualitative ultrasound measurements at the calcaneus (as done in our study) are associated with a 1.5- to 2-fold increase in general fracture risk for each SD decrease in measurement. The more sight-specific the measurement is, the higher the gradient of risk will be for the respective site (WHO 2007).

[64] Z-score: Is a comparison of the participant's acoustical properties of bone to that of a healthy person of the same age, sex and ethnicity. The score is expressed in standard deviations.

Consequently, great bone strength is protective of osteoporotic fractures (National Osteoporosis Foundation of South Africa [NOFSA] 2010). Non-modifiable risk factors for low bone quality include age, gender, family history of osteoporosis, genetics and ethnicity, menopause/hysterectomy and other medical conditions (hyperthyroidism, endogenic hypercortisolism etc.) (Kanis et al. 2012, Kann et al. 2002). In addition to non-modifiable risk factors, various conditions pre-dispose someone to low bone mass and thus osteoporosis. These include alcohol, smoking, low body mass index and eating disorders, poor nutrition and vitamin D and calcium deficiency, sustained therapy with steroids, heparin or thyroxine and insufficient physical activity (Kanis et al. 2012, Rachner et al. 2011). The clinical manifestations, epidemiology, burden of disease, risk factors, diagnosis and ethnical differences of osteoporosis and the immediate and long-term consequences of osteoporotic fractures have been discussed in detail in the section on bone ultrasound and osteoporosis (pg 68).

The quality of bone can be measured using different techniques. The most common are dual-energy X-ray absorptiometry (DXA) and quantitative ultrasound (QUS). The former uses the absorption of X-ray by the calcium content of the bone, thus giving a value of the density of the bone. QUS, on the other hand, uses ultrasound waves whose speed, shape and intensity are altered as they pass through the bone by the bone's physical and mechanical properties. This means that the QUS measurements are influenced by the bone's mineralisation, elasticity and architecture. The acoustical properties of bone are measured in terms of the speed of sound (SOS)[65] and the broadband ultrasound attenuation (BUA)[66] (Moayyeri et al. 2012, Kann 2001). The BUA and SOS are then used to calculate the stiffness index (SI)[67], from which the Z-score is derived. The group chosen as a reference group in our study (pre-set on the ultrasound machine) was a group of Afro Americans living in the US.

[65] SOS: speed of the sound wave travelling through the calcaneus, measured in m/s (Laabes et al. 2008)

[66] BUA: 'the slope of regression line derived from the ratio of the signal amplitude of the calcaneus to that of water (reference) at each frequency of ultrasound', measured in dB/MHZ (VanderJagt et al. 2004). In other words, BUA is the expression of how much sound is absorbed/attenuated by the bone, depending on the sound frequency.

[67] SI: an expression of the measured bone strength in comparison to that of young adults of same sex and at PBM (Trimpou et al. 2010). The Z-score is derived from the SI.

Even though DXA is the gold standard, QUS was chosen as the method of assessing bone quality in our cohort. This was done because QUS does not use ionising radiation but ultrasound waves to measure the acoustical properties of the bone, making these scanners harmless. QUS scanners are furthermore relatively inexpensive and easy to transport (Moayyeri et al. 2012). QUS is not recommended for diagnosing osteoporosis in terms of the WHO definition as it does not allow for cross-calibration and international standardisation (due to variability of QUS devices) and there is a lack of studies assessing the connection between acoustical properties of bone, pharmacological therapy and treatment success. However, numerous studies exist confirming the accuracy of QUS compared to DXA results. QUS is also advantageous in the rural setting and, furthermore, it has been shown that QUS results correlate well with fracture probability (Moayyeri et al. 2012, Laabes et al. 2008, Hadji 2003, Kann 2001). Therefore, QUS was chosen to assess the acoustical properties of bone in our cohort.

It is believed that the prevalence of osteoporosis in sub-Saharan Africa is low. However, as urbanisation and westernisation take root on the continent, it is predicted that bone quality will decrease in the population with an increase in osteoporotic fracture as a consequence (Zebaze & Seeman 2003). The purpose of assessing the bone quality in our study was to establish a baseline indication and compare this baseline to research done in other black communities, to examine whether a difference between urban and rural measurements exists and to assess the risk for osteoporosis. Lastly, the aim was to compare the participants' acoustical properties of bone to that of other ethnicities and establish whether the results are comparable to the current literature. In order to answer these questions, the BUA and SOS were measured and the SI and its Z-score were calculated. Studies using qualitative ultrasound to assess bone quality in SSA communities are very scarce. Where available, these studies were used to draw comparisons, otherwise studies from other parts of the world were used. Furthermore, it must be noted that due to the scarcity of literature available comparisons were also made with studies using different machines.

4.1. Bone ultrasound measurements of the Ovahimba - the general picture

The acoustical properties of bone in the general study population showed very good baseline values indicative of good bone health with adequate strength, mineralisation and architecture. None of the baseline data (BUA, SOS, SI and Z-score prior to

adjustment) showed a significant difference between the urban and the rural group. There were only two measurements of bone ultrasound that showed a statistically significant difference between the urban and the rural group. Firstly, the SOS measurement after adjustment for 'sex', 'age' and 'height' and 'sex', 'age', 'height' and 'weight' ($p_{s+a+h} = 0.004$, $p_{s+a+h+w} < 0.001$); and secondly the SI measurement after adjustment for 'sex', 'age', 'height' and 'weight' ($p_{s+a+h+w} = 0.025$) (Table 19, pg 234). This significant difference in the SOS and SI measurement after adjustment could be the first indication that a change of lifestyle influences bone ultrasound measurements in the Ovahimba. However, our study cohort was too small to fully verify this statement.

The Z-score was obtained to ascertain the gradient of risk for the participants. The mean Z-score of the whole cohort was 1.6 standard deviations above that for a healthy person of the same age, sex and ethnicity. This shows that the Ovahimba have greater bone strength compared to the Afro-Americans. The latter were used as a reference group for the calculation of the Z-score. However, no statistical analysis was done as the raw data of the reference group was not obtained.

A study done assessing the bone quality of nomadic Fulani herdsmen in northern Nigeria (study population similar to Group 2) also used QUS as an assessment tool. The mean age of the study population was 26 years, compared to the mean age of 51.1 years of the rural group in our study. The results between the two semi-nomadic tribes were comparable; the Fulani presented a mean BUA of 124 dB/MHZ and mean SOS of 1572 m/s which calculated to an SI of 102 (Laabes et al. 2008). However, considering that the Fulani population was on average almost 25 years younger and thus at time of peak bone mass (PBM), it can be said that the rural Ovahimba people of our study showed superior bone strength. VanderJagt et al. (2004) assessed the acoustical properties of bone of urban Nigerians in 2004. The age group at PBM (20-29 and 30-39 years old) showed a BUA of 131 and 137 dB/MHZ and SOS of 1565 and 1584 m/s in women and men respectively. This calculated to an SI of 102 and 108 in the mentioned groups (VanderJagt et al. 2004). The decline of bone strength started around the age of 40 years in the Nigerian participants and therefore it can safely be said that the PBM of Nigerian participants tended to be only marginally higher than the mean QUS measurements of the whole Ovahimba study population. Here again, the Ovahimba show a more favourable bone health.

Literature on the measurement of acoustical properties of bone by quantitative ultrasound in SSA is extremely scarce. Only the above mentioned studies were found and no study investigating the SI - Z-score of any community in SSA was found. Presenting excellent QUS measurements the Ovahimba people do not seem to be at risk for developing osteopenia or osteoporosis. This is also reflected in the relatively high Z-score of both groups: 1.3 and 1.7 in the urban and rural group respectively.

Our participants demonstrate greater bone ultrasound measurements when compared to other black Africans. There could be various explanations for this, though none has been proven in our study and only assumptions can be made. It is therefore recommended that more studies examining the acoustical properties of bone in different SSA communities be conducted in order to validate these statements.

A high PBM at the age of 20-30 years will reduce the risk of osteoporosis and non-traumatic fractures in later life. Several factors play a vital role in the formation of PBM: heredity, bonetropic nutrients such as Vitamin D, calcium and protein, endocrine factors such as sex steroids (IGF-I and $1.25(OH)_2D$), and cortical and mechanical forces such as physical activity and body weight (Bonjour et al. 2009). According to Bonjour et al. (2009), hereditary factors are the most prominent determinants. We did not examine genetics (or hormones effective on the bone metabolism other than cortisol) in our study, and there was only a weak correlation between cortisol AUL and bone ultrasound and therefore this subject will only be theoretically addressed further down.

The life of the Ovahimba centres on their herds, from which they obtain ample calcium and protein-rich animal products. This is more prevalent in the rural communities, though urban people often still have strong ties with their rural families and obtain animal products from the villages. Therefore, the intake of calcium-rich dairy products such as o*maere*[68], buttermilk and cream is high from an early age on, allowing for optimal calcium intake at adolescence and early adulthood when PBM is formed (Bonjour et al. 2009, Laabes et al. 2008). In their research on the bone quality of nomadic Fulani herdsman, Laabes et al. (2008) queries whether most of the calcium-rich dairy products are being sold for income. That would account for a high availability of calcium-rich products, but a low intake and thus relatively low bone strength in their

[68] *Omaere*: milk that is fermented and soured in a calabash

study population. Even though this phenomenon was not observed in our study population, we could not show a strong correlation between 'milk consumption' and acoustical properties of bone (Table 20, pg 238).

Another well-studied protector of bone strength is physical activity. The effect of physical activity on bone strength is especially important when PBM is laid down and then to slow down bone mass loss in later life (Callréus et al. 2012, NOFSA 2010, Bonjour et al. 2009, Micklesfield et al. 2003). Trekking with the animals, fetching water from the wells and collecting food starts from early childhood and continues throughout adulthood in the rural Ovahimba. These activities all involve a fair amount of daily physical activity, which will have contributed to the high bone ultrasound measurements observed in our cohort. Many of the urban participants grew up in rural villages and therefore it might well be that their bone strength is still based on high levels of physical activity during early adulthood. Furthermore, it is common for urban participants to use walking as means of transport. However, no strong correlation could be established in our study between 'walking time' and acoustical properties of bone (Table 20, pg 238). The reason for this could have been the relatively small study cohort though.

Several studies have shown that physical activity, especially voluntary vigorous, recreational activity is lower among black compared to white South African women (Chantler et al. 2012, Lloyd et al. 2010, Micklesfield et al. 2003). Nevertheless, black women present a higher bone mineral density (BMD), measured by DXA. In their study investigating lifetime physical activity and BMD in black South African women, Micklesfield et al. (2003) found a correlation between household and occupational activity and walking for transport with a higher BMD. The authors furthermore found that the positive effect of this type of physical activity on BMD, equivalent to vigorous leisure time activity, is most prominent in adolescence and early adulthood.

In line with physical activity it was proven that weight-bearing is positively correlated with PBM as well as preservation of bone mass in later life (Callréus et al. 2012, Lloyd et al. 2010). The total study population presented a body mass index (BMI) of 25.4 kg/m^2 which lies in the WHO category of 'overweight' and a mean weight of 71 kg. A large body size seems to be protective of low bone quality due to the positive effects of mechanical loading of the bone (Kruger et al. 2011, Lloyd et al. 2010,

VanderJagt et al. 2004). Consequently, this relatively larger body size of the participants could be another contributing factor to the high bone quality in the community. Compared to our study population, the semi-nomadic Fulani herdsmen studied by Laabes et al. (2008) presented a mean BMI of 20 kg/m^2 (WHO category 'normal'), which was positively correlated with a low SI. Conversely though, Chantler et al. (2012) argue that it is fat-free soft tissue mass rather than just general high body mass that is positively correlated to bone strength. Black Africans tend to have a higher fat-mass than other ethnicities, which, according to Chantler et al. (2012), is negatively correlated to BMD due to the inflammatory nature of adipose tissue. However, the interaction of fat-mass, lean body mass and bone quality seems to be site-specific and therefore it is recommended that further studies be conducted with the Ovahimba people to establish the interaction between these parameters.

Furthermore, load-carrying on the head is a traditional activity done from a young age on (< 11 years) of both urban and rural Ovahimba women. It can either be water from the wells (often in 25-30 l canisters, smaller for younger girls), wood collected for fire or in town carrying shopping bags, maize meal bags or sugar bags. This load-carrying, especially during growth presents additional weight-bearing and Lloyd et al. (2010) found that South African women who did or still do a lot of load-carrying on the head have a higher BMD at the lumbar spine measured by DXA. In addition, there was a positive correlation between the weight of the load and the lumbar spine BMD (Lloyd et al. 2010, VanderJagt et al. 2004). It can be assumed that this load-carrying combined with often long hours of walking allow for a great bone strength in Ovahimba women, the group at highest risk of developing osteoporosis throughout life.

In their article on the skeletal health of Nigerian men and women, VanderJagt et al. (2004) point out that women in sub-Saharan Africa often show high parity and extended periods of breastfeeding (up to two years) both of which are calcium-depleting conditions. The participants in our study had on average six siblings, showing a high parity in the society. The length of breastfeeding was not established. No formal investigation of the effect of parity and breastfeeding on bone quality in the study population was done, but it appears that these aspects did not have a detrimental effect on the bone health of women in the study. In addition, another risk factor for healthy bone strength widespread in southern Africa is the use of progesterone-only

contraception (Kruger et al. 2011, Lloyd et al. 2010). However, we did not examine the use of contraception. Therefore, no comment on the above statements can be made regarding our study population.

4.2. Effects of urbanisation on bone health

Low bone ultrasound measurements are sometimes considered a consequence of urbanisation and modernisation as the fracture incidence in urban areas is often higher than in rural areas, while rural people often exhibit a higher bone strength compared to urban people (Rosengren et al. 2010, Pongchaiyakul et al. 2005). However, not all studies have confirmed these findings; some studies found no significant difference between urban and rural bone strength and fracture incidence or the complete opposite. Gu et al. (2007) conducted a study using DXA to examine the BMD in urban and rural Chinese men and women. They found a significantly higher BMD and bone mineral content in their urban compared to their rural participants. A study conducted in Poland, also using DXA showed that there was no significant difference of the BMD between rural and urban participants (Filip & Zagórski 2001). However, these findings are in contrast to most other studies conducted across the world.

Several studies done in South Africa examining the effect of urbanisation on bone health showed a significant decline in BMD and bone formation and an increase in bone loss associated with an urban lifestyle (Kruger et al. 2011, Kruger et al. 2003). Kruger et al. (2003) and (2011) argue that these findings are due to an increase in protein intake aggravating an existing calcium deficiency in urban women, lower physical activity, smoking, higher alcohol consumption and the use of injectable progestin contraception. The authors furthermore examined bone markers (osteocalcin[69] and N-telopeptides of type 1 collagen[70]) and found that bone turnover decreased and bone resorption increased with bone formation staying the same in urban women. This was especially prevalent in the group of actively growing girls (15-25 years) suggesting a lower PBM and subsequent low bone mass later in life.

These findings are comparable to studies in Thailand and Europe. A study done in Thailand using DXA showed that the urban - rural difference in BMD was significant across all age groups, but more pronounced in younger participants. This would suggest

[69] Osteocalcin: marker of bone turnover or remodelling (Kruger et al. 2003)
[70] N-telopeptides of type 1 collagen: marker for bone resorption (Kruger et al. 2003)

that the effects of urbanisation are more detrimental at the time when PBM is formed than in later life (Pongchaiyakul et al. 2005). Meyer et al. (2004) found that BMD measured using single energy X-ray absorptiometry was higher in rural areas of Norway with a lower fracture risk in the countryside compared to cities. Similar results were found in a study conducted in Sweden to assess BMD and hip fracture incidence in an urban and rural setting (Rosengren et al. 2010).

Even though the effects of urbanisation on metabolic aspects have been evident in our study population, only two parameters of the bone ultrasound presented a statistically significant difference between Group 1 and Group 2 (SOS $p_{s+a+h} = 0.004$, $p_{s+a+h+w} < 0.001$ and SI $p_{s+a+h+w} = 0.025$) (Table 19, pg 234). Both groups presented good bone health, with the rural group slightly better. The reasons for this can only be assumed. Firstly, as outlined above, urbanisation and modernisation have only really taken root in Kaokoveld in the past decade or two (informal interview with translator). Therefore, the urban participants examined by us might not have been subjected to the effects of urbanisation at the time when PBM was established and consequently they present high bone quality measurements even at an older age. Even though they might have been living in the city for at least three years (inclusion criteria for Group 1), they might have grown up in the rural areas and thus benefited from the bone strength-promoting aspects of rural life. It would be interesting to conduct another examination of the acoustical properties of bone in Ovahimba and including adolescent and young adults, currently exposed to urbanisation to fully validate this statement.

Furthermore, it must be taken into consideration that osteoporotic fractures and bone strength variations are site-specific, also when examining urban - rural differences (Gu et al. 2007, Pongchaiyakul et al. 2005). Therefore, it could be that even though there was no difference in the bone strength of the calcaneus in our study population, there might be a difference when measuring this parameter at other sites.

4.3. Bone ultrasound measurements of Ovahimba compared to other ethnicities

Ethnicity and race are important factors influencing acoustical properties of bone and osteoporosis. The difference between African-American and Caucasian women lies at one standard deviation of bone quality. This is sufficient to account for the 50% lower fracture risk which African-American women have compared to Caucasian women

(Cauley et al. 2005). It has also been established that bone loss is greater in white compared to black Americans, however, the difference lessens with age (Hochberg 2007, Cauley et al. 2005). Furthermore, there seem to be differences in the fracture outcome and treatment between various ethnicities (Cauley 2011, Curtis et al. 2009). The latter has been discussed in detail in the section 'Ethnic differences in bone quality and osteoporosis' (pg 81). Since we only examined the acoustical properties of bone in our study, greater emphasis will be placed on this topic as well as ethnic differences in fracture occurrence as a result of low bone strength.

The Ovahimba people presented much better values of bone ultrasound compared to white Europeans and Asians. Paggiosi et al. (2012) published results from the OPUS (European multicentre Osteoporosis and Ultrasound) multicentre study of white European women, investigating the bone quality measured by quantitative ultrasound. Using an Achilles+ machine, the authors report a mean BUA for Berlin participants in the age group 20-24 years of 117.3 dB/MHZ and in later age groups as follows: 35-39 years old mean BUA 117.0 dB/MHZ and 55-59 years old mean BUA 110.6 dB/MHZ. Corresponding SOS values were as follows: at PBM mean SOS of 1582 m/s (25-29 years old), 35-39 years old mean SOS 1567 m/s and 55-59 years old mean SOS 1548 m/s. These values were used to calculate the SI: age group 20-24 mean SI 100.8, age group 35-39 mean SI 96.5 and age group 55-59 mean SI 87.2 (Paggiosi et al. 2012). A white Polish population examined in 1999 also showed much lower measurements than our study population: the mean SOS was 1514.3 m/s and the mean BUA 111.4 dB/MHZ. The mean age of the latter participants was 56.4 years, which is comparable to the mean age in our study (Pluskiewicz & Drozdzowska 1999).

A large longitudinal study, called the Fels Longitudinal study done in Yellow Springs, Ohio was started in 1929, initially to assess children's physical growth, maturation and psychological development. Since then the study has expanded to include, among others, skeletal maturation and biology. Lee et al. (2006) conducted a study to investigate the heritability of acoustical properties of bone in Caucasian men and women as part of the Fels study. The mean age of the study population was 45.8 years and it presented the following bone quality measurements: mean BUA of 79.3 dB/MHZ, mean SOS 1664.4 m/s and mean SI 102.9. The study also found a moderate correlation between QUS at the heel and bone strength showing a significant genetic

effect on bone strength (Lee et al. 2006). Using an Achilles ultrasonometer to measure the QUS in healthy Chinese men, Zhu et al. (2008) found that the results of the study are comparable to current literature: mean BUA 111.7 dB/MHZ, mean SOS 1562.4 dB/MHZ and mean SI 92.9.

Comparing the above studies to the results of our study should serve the purpose to show the latter's comparability to current literature. Ample research exists examining the bone quality, osteoporosis and/or fracture risk in various ethnicities. Afro-Americans have better bone quality at all skeletal sites compared to white Americans, who in turn show a better bone quality than Hispanics (Cauley 2011, Looker et al. 2009, Nelson et al. 2004). The same is reflected in the prevalence of non-traumatic fractures in women of the US: white women appear to have the highest fracture rates, followed by Native Americans, Hispanics, Asians and lastly Afro-Americans (Cauley et al. 2007, Nelson et al. 2004). In his article on racial difference in bone strength, Hochberg (2007) discusses several published studies about, among other factors, the bone quality in various ethnicities. The author confirms the above statements and further ads that black compared to white men also present a greater bone strength, the difference being less pronounced than in women, though.

VanderJagt et al. (2004) found a similar scenario when comparing the bone ultrasound of healthy Nigerian men and women to European and Asian men and women; Nigerian women clearly showed better acoustical properties of bone than Italian women and the difference was even greater when the Nigerian women were compared to women of Japanese origin (VanderJagt et al. 2004). Several studies have been conducted in South Africa comparing the bone health of black and white women and men within the country or with participants of other countries. Nelson et al. (2004) conducted a study investigating the bone geometry of black and white women in Johannesburg and Detroit using whole-body DXA. The research showed that black women in both countries had greater bone strength allowing for greater mechanical strength which is consistent with lower fracture rates reported by the black women of both countries (Nelson et al. 2004).

Interestingly, the researchers also found that, even though the black American women had a higher BMD at all skeletal sites compared to their counterparts, this was not the case in South African women. Black South African women had higher BMD at

all skeletal sites except the lumbar spine (Nelson et al. 2004). This is consistent with a study done by Chantler et al. (2012) in black and white premenopausal South African women. The authors found that this phenomenon could be due to the often lower social economic status of black women, commonly associated with sub-optimal nutrition and growth delays. The lumbar spine is made predominantly of trabecular bone, whose turnover is mainly influenced by hormonal and metabolic factors (Chantler et al. 2012). However, studies on the BMD of South African children has shown the same results as above: black children present greater bone strength at all sites except the lumbar spine compared to white children, suggesting that this phenomenon is, at least in part, also genetically determined (Vidulich et al. 2006). It can only be assumed that the participants of our study present the same picture as they would genetically be closer to black South Africans than black Americans, however, whole-body BMD must be measured to confirm this hypothesis.

Several reasons for ethnical differences in bone ultrasound are discussed in the literature. Genetics and heritability are strong determinants of bone strength, as was proven by various human twin pair and family studies (Lee et al. 2006). Lee et al. (2004) conducted a study in 2004 taking advantage of the family structure of the Fels Longitudinal Study (see above) and found that variables measured by QUS (BUA and SOS) determining acoustical properties of bone are also heritable (Lee et al. 2004). These findings were confirmed by the same authors in a 2006 study comparing the genetic influence on areal BMD (measured by DXA) and BUA/SOS (measured by QUS). It appears that 16-40% of genetic variances are shared by both measures, while unique unshared genetic effects were also found for both measures.

Studies done among South African children have shown that even before PBM, children of black ancestry presented a higher bone strength and lower fracture rate compared to white children. This is even though black children in South Africa are on average more exposed to environmental factors negatively affecting bone mass, such as poor nutrition with low calcium, low physical activity and compromised growth and development reflected by lower birth weights. The differences can therefore be attributable to genetic influence on bone mass (Thandrayen et al. 2009, Vidulich et al. 2006). A further study done on South African children during puberty showed that black children had a favourable bone geometry compared to white children with lower

cortical thickness and greater endosteal diameter allowing for greater resistance to torsional and bending forces (Micklesfield et al. 2011). A similar study done in American children found comparable results and in addition showed that Hispanic children have greater bone strength than Caucasian, which is comparable to adult studies (Wetzsteon et al. 2009, Cauley et al. 2007). For more detailed information on the geometrical differences of bone in black and white children, the reader is referred to the above cited articles. The differences in bone geometry in blacks and whites have also been confirmed in adults. Nelson et al. (2004) found that while white women in America and South Africa had greater bone width, black participants in both countries have more bone in cross-section and therefore greater bone strength.

Other factors that are influenced by genetics would be the higher PBM in black compared to white young adults, the slower bone loss in the former ethnic group and greater bone strength in correspondence to mechanical loading in blacks. Bryant et al. did a study in 2003 to investigate the racial differences in bone turnover and calcium metabolism in black and white young adult females (mean age: blacks = 12.8 and whites = 13.7 years old). The participants stayed in a housed environment for three weeks, consumed a controlled diet and all excreta was collected. The research showed that the higher PBM of the black girls is due to greater calcium retention of up to 57% in black compared to white girls allowing for greater bone strength. In addition, even though, the black girls had a higher bone resorption, they also presented a higher bone formation[71] resulting in a higher bone turnover and therefore in better bone quality (Bryant et al. 2003). A high PBM will allow for a greater bone strength in later life and therefore for a reduced risk for osteoporosis and non-traumatic fractures.

Several studies investigating the ethnical differences in loss of bone strength resulted in the finding that the latter is greater in older Caucasian than in older African-American men and women (Sheu et al. 2011, Looker et al. 2009, Cauley et al. 2005). Cauley et al. (2005) went on to investigate whether there were ethnical differences in volumetric and/or areal BMD using DXA. Results showed that loss of volumetric BMD was slower in African-American women and that the magnitude of the ethnical difference was greater for volumetric than areal BMD loss. However, the extent of the difference of quality loss seems to be decreasing with age (Looker et al. 2009).

[71] As determined by bone turnover markers

In their research on ethnical differences in bone geometry in childhood, Wetzsteon et al. (2009) found that, among others, greater mechanosensitivity in black children is a reason for the greater bone strength. The reason for this increased mechanosensitivity appears to be a greater osteocycte density (prime mechanosensory cells) in black compared to white skeletons. This increased cell density results in greater bone strength in black children relative to the mechanical loading at the specific sites (Qiu et al. 2009 in Wetzsteon et al. 2009).

Apart from the genetic influences on ethnical differences that were discussed, there are other influences with a less pronounced impact. These include the effect of hormones, lifestyle factors such as physical activity and diet, weight and BMI, parity and prolonged breastfeeding and socioeconomic status. Physical inactivity, high parity, prolonged breastfeeding and low socioeconomic status are more commonly present in black people compared to white people in SSA and US. These factors are negatively correlated to bone strength and therefore would result in lowering bone quality. However, the influence of these factors seems to be less pronounced than the genetic impact, since black people still show more favourable bone quality than whites in most parts of the world. Moreover, when comparing the bone ultrasound of the Ovahimba people to communities in other countries, one should remember there is a difference in bone strength at specific sites of the skeleton and that we only measured the calcaneal properties in our study. Furthermore, due to a lack of research studies done/published on bone ultrasound in SSA communities, the authors were forced to use: studies which used other assessment tools, studies where the age groups were not fully comparable and studies in other parts of the world, not only SSA. Studies using women or men only were also included in the literature review, even though no differentiation was done on the gender in our study.

That means that only some of the aspects of bone quality in SSA, the impact of urbanisation on the latter parameter and ethnical differences have been addressed in this section to present a broad picture. To examine this topic in the Ovahimba fully, more in-depth research is needed. This would also help to reduce the discrepancy which exists between the small number of studies done in the developing compared to the developed world.

Summary

The number of patients suffering from diabetes mellitus type 2 (DM) worldwide has increased rapidly over the past few years and it is expected that the numbers will increase further: from 171 million people suffering from diabetes in 2000, to 382 million in 2013 and to 592 million people by 2035 (IDF 2013, Hossain et al. 2007). Until some time ago diabetes, especially type 2 DM, was seen as a disease of the more affluent and therefore of the western industrialised world (King & Rewers 1991). However, this picture is changing as more and more data from the developing world become available showing an alarming rise of the prevalence of DM in these countries.

Therefore, the aim of our study was to assess the association of lifestyle changes and modification of the social environment in the face of urbanisation on the risk for a disorder of glucose metabolism in the Ovahimba people of Namibia. Secondary to this, the cortisol homeostasis of the participants was investigated with the question whether urban compared to rural participants have a higher cortisol exposure due to increased psychosocial stress. In order to assess the cardio-metabolic risk profile of the Ovahimba, the prevalence of the metabolic syndrome (MetS) was ascertained and the participants' 10-year cardiovascular risk was calculated according to the Framingham risk score (FRS). Lastly, the acoustical properties of bone of the study cohort were examined with the question whether lifestyle changes affect bone quality. No study with the above-mentioned questions has been conducted in the Ovahimba yet; therefore another aim of our study was to establish baseline data for further research.

In order to answer the above questions, two groups of participants were formed from the Ovahimba community in Namibia: 'Group 1', also called 'urban group' consisted of participants having been living in the town of Opuwo for at least three years, thus being subjected to urbanisation and 'westernisation'. 'Group 2', also called 'rural group' consisted of participants living a traditional lifestyle in the rural area of the Kaokoveld in north-western Namibia. Each participant underwent the oral glucose tolerance test. In addition, anthropometric measurements were taken, the body fat and lean mass measured by body impedance analysis (BIA) and the fat metabolism examined to identify cardiovascular risk factors, assess the prevalence of the MetS and calculate the 10-year cardiovascular risk. In addition, two saliva samples were collected, one at

sunrise and one at sunset to examine the cortisol homeostasis and a possible association with dysglycaemia, the MetS and low quality of bone. Lastly, bone ultrasound was used to determine the acoustical properties of bone of the participants.

In the first step of statistical analysis a descriptive analysis of the data was performed as a group comparison. Nominal variables were evaluated using Fisher's exact test. A two-sided t-test was applied to the continuous variables with the null-hypothesis of equal mean values in both groups. A prevalence of 5% was taken as the basis for the statistical power. In a second step of statistical analysis, the data were adjusted for various confounders. In addition, a Mann-Whitney-U test was applied to the data of disorder of glucose metabolism, MetS and cortisol concentration to assess a possible association of cortisol concentration and the presence or not of dysglycaemia and MetS. In a third step of statistical analysis, the Pearson's correlation was calculated for the cortisol area under the line (AUL) and metabolic parameters as well as bone ultrasound measurements.

The analysis showed significant differences in all anthropometrical data (age, height, weight, hip and waist circumference (WC), body mass index (BMI), systolic and diastolic blood pressure (SBP, DBP) before and after exercise and heart rate after exercise) except for 'sex', 'diastolic BP after exercise' and 'heart rate at rest'. The characteristics of glucose metabolism showed significant differences of the fasting glucose (FG) and 2-hours glucose, but not of the HbA1c. The analysis of the primary question 'disorder of glucose metabolism: yes/no' presented a significant difference between the urban and the rural group (Group 1 28.3% vs. Group 2 12.7%), but this significance was not present in the individual components (diabetes mellitus type 2 (DM) 3.3% vs. 0.0%, impaired glucose tolerance (IGT) 18.3% vs. 7.9%, impaired fasting glucose (IFG) 6.7% vs. 4.8%). The investigation of the fat metabolism and BIA measurements showed significant differences for triglycerides, HDL-Chol, LDL-Chol before adjustment and lean body mass after adjustment. A significant difference was seen in the mean saliva cortisol concentrations at sunrise and sunset, the mean absolute decline of cortisol concentration and the cortisol AUL. The relative decline was not significantly different. The prevalence of the MetS was significantly higher in the urban group (Group 1 31.7% vs. Group 2 7.9%). Looking at the Framingham risk score, Group 1 showed a 10-year cardiovascular risk of 5.3 ± 5.3% and Group 2 of 5.5 ± 7.9%,

with no significant difference. The analysis of the bone ultrasound measurements only showed two significant differences between the urban and the rural group: the SOS data after adjustment for 'sex', 'age' and 'height' and the SOS and SI data after adjustment for 'sex', 'age', 'height' and 'weight'. The mean Z-score of the study cohort was +1.6 ± 1.6 standard deviations. There was only a weak correlation between milk consumption and walking time and bone ultrasound measurements.

The interpretation of the results of our study showed that the Ovahimba of Namibia are not spared the adverse effects of urbanisation and westernisation. The significant difference in the presence of a disorder of glucose metabolism between the urban and rural group supports the hypothesis that urbanisation concurrent with a change of lifestyle was associated with an increased risk of dysglycaemia in our study cohort.

Research has shown that psychosocial stress, a condition often associated with urbanisation leads to an alteration of the cortisol homeostasis with increased cortisol exposure. The urban participants had significantly higher mean concentrations at sunrise and sunset and a higher cortisol AUL, supporting our hypothesis that urban participants will present higher cortisol exposure due to increased psychosocial stress.

Another adverse effect of urbanisation is the high prevalence of metabolic and cardiovascular disorders. Our study population presented a prevalence of the MetS of 31.7% in the urban and 7.9% in the rural group, showing a significant difference. The calculation of the FRS showed that of the total study cohort, 48.0% were at low risk, 43.9% at moderate risk, 5.7% at high risk and 1.6% at very high risk of incurring a cardiovascular event in the next 10 years. This assessment tool showed no significant difference between the two study groups.

The acoustical properties of bone were measured to establish baseline data for future studies and to assess the impact of urbanisation on bone quality. Our hypothesis that urban participants will have a lesser bone quality could partially be verified. There were two measurements of bone ultrasound that showed a statistically significant difference between the urban and the rural group. Firstly, the SOS measurement after adjustment for 'sex', 'age' and 'height' and 'sex', 'age', 'height' and 'weight' ($p_{s+a+h} = 0.004$, $p_{s+a+h+w} < 0.001$); and secondly the SI measurement after adjustment for 'sex', 'age', 'height' and 'weight' ($p_{s+a+h+w} = 0.025$). This significant difference in the SOS and SI

measurement after adjustment could be the first indication that a change of lifestyle affects bone ultrasound measurements in the Ovahimba. The mean SI - Z-score of the whole cohort was 1.6 standard deviations above that for a person of the same age, gender and ethnicity. This indicates that the Ovahimba have greater bone strength compared to the Afro-Americans.

In conclusion, our study has shown that urbanisation is associated with an increased risk for a disorder of glucose metabolism in Ovahimba people. We could furthermore show that urbanisation is associated with an increased cortisol exposure, alterations of metabolic parameters including the metabolic syndrome and parameters of bone quality.

Zusammenfassung

Die Anzahl der an Diabetes mellitus Erkrankten hat in den letzten Jahren weltweit rapide zugenommen, und es wird erwartet, dass die Zahlen weiterhin ansteigen: von 171 Millionen im Jahr 2000, 382 Millionen im Jahr 2013 und auf 592 Millionen Diabetes-Kranker im Jahr 2030 (Hossain et al. 2007). Früher wurde der Diabetes mellitus, besonders Diabetes mellitus Typ 2 (DM) als eine Krankheit der reichen und damit der westlichen industrialisierten Länder gesehen (King et al. 1991). Dieses Bild hat sich gewandelt, da mehr und mehr Daten aus Entwicklungsländern vorliegen, die einen beängstigenden Anstieg der Prävalenz des Diabetes mellitus zeigen.

Aus diesen Gründen widmete sich unsere Studie primär der Frage, inwiefern sich für eine spezifische indigene namibische Bevölkerungsgruppe (Ovahimba) darstellen lässt, dass die Veränderung der Lebensweise im Rahmen der Urbanisierung mit einer erhöhten Prävalenz von Glukosestoffwechselstörungen einhergeht. Sekundär wurde der Cortisolhaushalt der Probanden mit der Fragestellung untersucht, ob ein erhöhter psychosozialer Stress, welcher häufig mit dem Prozess der Urbanisierung assoziiert ist, mit erhöhten Cortisolwerten in unserer Studienkohorte einhergeht. Weiterhin wurden die Facetten des Metabolischen Syndroms (MetS) untersucht und der Framingham risk score (FRS) berechnet um das kardiometabolische Risikoprofil der Studienkohorte zu beurteilen. Ferner wurde die Knochengesundheit osteosonometrisch mit der Fragestellung untersucht, ob die Änderung des Lebensstils im Rahmen der Urbanisierung einen Einfluss auf die Knochendichte hat. Da unsere Studie die erste Studie in dieser Form bei den Ovahimba war, galt es auch, Grunddaten für mögliche weiterführende Studien zu erlangen.

In diesem Kontext untersuchten wir zwei Studiengruppen: Gruppe 1, auch als ‚städtische Gruppe' bezeichnet, bestand aus sechzig Probanden, die seit mindestens drei Jahren in der Stadt Opuwo leben und so dem Prozess der Urbanisierung ausgesetzt sind. Gruppe 2, auch als ‚ländliche' Gruppe bezeichnet, setzte sich aus 63 Probanden zusammen, die in den ländlichen Gebieten des Kaokovelds im Nord-Westen Namibias, einer traditionellen Lebensweise nachgehen. Die anthropometrischen Daten der Probanden wurden erhoben und mit den Probanden der orale Glukose Toleranz Test (OGTT) durchgeführt. Weiterhin wurde mittels Body Impedance Analysis (BIA) die

Körperzusammensetzung analysiert und ferner die Fettstoffwechselparameter untersucht um kardiometabolische Risikofaktoren zu identifizieren und die Prävalenz des Metabolischen Syndroms als auch den FRS berechnen zu können. Außerdem wurde zu Sonnenaufgang und Sonnenuntergang jeweils eine Speichelprobe für die Analyse des Cortisolhaushalts entnommen. Die Knochendichte wurde mittels quantitativen Ultraschalls ermittelt.

In dem ersten Schritt der statistischen Analyse wurde eine deskriptive Analyse der Daten mittels des Exakten Fishers Tests und eines zweiseitigen t-Tests durchgeführt. Das Signifikanz Niveau wurde bei 5% festgelegt. In einem zweiten Schritt der statistischen Analyse wurden die Daten für verschiedene Störfaktoren adjustiert. Weiterhin wurde ein möglicher Zusammenhang zwischen Glukosestoffwechselstörung, MetS und Cortisolhaushalt mittels des Mann-Whitney-U Tests untersucht. In einem dritten Schritt der statistischen Analyse wurde der Pearson's Korrelationskoeffizient zwischen Area under the Line (AUL) des Cortisols und den metabolischen Parametern als auch den Knochendichtemessungen errechnet.

Die Analyse zeigte statistisch signifikante Unterschiede in allen anthropometrischen Daten (Alter, Größe, Gewicht, Taillen- und Hüftumfang, BMI, systolisch und diastolischer Blutdruck vor körperlicher Betätigung und systolischer Blutdruck und Puls nach körperlicher Betätigung) außer Geschlecht, diastolischer Blutdruck nach körperlicher Betätigung und Puls in Ruhe. Die Daten des Glukosestoffwechsels zeigten signifikante Unterschiede in der Nüchternglukose und dem 2-Stunden Glukosewert, aber nicht im HbA1c Wert. Die Analyse der primären Fragestellung ‚Glukosestoffwechselstörung: ja/nein' zeigte signifikante Unterschiede zwischen der ländlichen und der städtischen Gruppe (Gruppe 1 28.3% vs. Gruppe 2 12.7%). Allerdings zeigten sich keine signifikanten Unterschiede in den einzelnen Komponenten der Glukosestoffwechselstörung (Diabetes mellitus Typ 2 3.35 vs. 0.0%, gestörte Glukosetoleranz 18.3% vs. 7.9%, gestörte Nüchternglukose 6.7% vs. 4.8%). Die Untersuchung des Fettstoffwechsels und der Körperzusammensetzung zeigte signifikante Unterschiede der Triglyzerid, HDL-Chol, LDL-Chol (vor Adjustierung) Konzentration und die Körpermasse nach Adjustierung. Ein signifikanter Unterschied zeigte sich im Mittelwert der Cortisol Konzentration bei Sonnenaufgang und –untergang, der absoluten Cortisol Abnahme und der AUL. Die Prävalenz des

Metabolischen Syndroms war signifikant höher in Gruppe 1 im Vergleich zu Gruppe 2 (Gruppe 1 31.7% vs. Gruppe 2 7.9%). Die Berechnung des Framingham risk scores ergab folgende Werte: Gruppe 1 hat ein 10-Jahre kardiovaskuläres Risiko von 5.3 ± 5.3% und Gruppe 2 von 5.5 ± 7.9%, der Unterschied war nicht signifikant. Die Analyse der Knochendichte ergab nur zwei signifikante Unterschiede zwischen den Studiengruppen: die SOS Daten nach Adjustierung für ‚Geschlecht', ‚Alter' und ‚Größe' und die SOS und SI Daten nach Adjustierung für ‚Geschlecht', ‚Alter', ‚Größe' und ‚Gewicht'. Der Mittelwert des Z-Wertes lag bei +1.6 ± 1.6.

Die Ergebnisse unserer Studien zeigen, dass die Veränderung der Lebensweise der Ovahimba im Rahmen der Urbanisierung bereits unerwünschte gesundheitliche Folgen mit sich bringt. Der signifikante Unterschied in der Prävalenz der Glukosestoffwechselstörung zwischen der städtischen und der ländlichen Kohorte unterstützt unsere Hypothese, dass eine Veränderung der Lebensweise mit einem erhöhten Risiko für Glukosestoffwechselstörungen assoziiert ist.

Durchgeführte Studien haben gezeigt, dass es im Rahmen der Urbanisierung häufig zu erhöhtem psychosozialem Stress kommt und damit zu erhöhten Cortisolkonzentrationen. Die Hypothese, dass die städtischen Probanden höhere Cortisolwerte und eine höhere Cortisol AUL auf Grund der Urbanisierung aufweisen, konnte verifiziert werden.

Weitere ungewünschte Aspekte der Urbanisierung sind das hohe Auftreten von metabolischen und kardiovaskulären Risikofaktoren. Unsere Studienkohorte zeigte eine Gesamt-Prävalenz des MetS von 19.5% mit einem signifikanten Unterschied zwischen den einzelnen Gruppen (Gruppe 1 31.7% vs. Gruppe 2 7.9%). Die Berechnung des FRS ergab folgende Werte: 48.0% niedriges Risiko, 43.9% mittleres Risiko, 5.7% hohes Risiko und 1.6% sehr hohes Risiko in den nächsten 10 Jahren eine kardiovaskuläre Krankheit zu erleiden. Der Unterschied zwischen den zwei Studiengruppen war nicht signifikant.

Die Knochendichtemessungen wurden durchgeführt um Rohdaten für weitere Studien zu erlangen und um mögliche Auswirkungen der Urbanisierung zu untersuchen. Unsere Hypothese, dass die städtischen Probanden eine schlechtere Knochendichte aufweisen, konnte partiell bestätigt werden. Zwei Parameter ergaben einen statistisch

signifikanten Unterschied: erstens der SOS-Wert nach Adjustierung für ‚Geschlecht', ‚Alter' und ‚Größe' und der SOS und SI-Wert nach Adjustierung für ‚Geschlecht', ‚Alter', ‚Größe' und ‚Gewicht' (SOS: $p_{s+a+h} = 0.004$, $p_{s+a+h+w} < 0.001$; SI: $p_{s+a+h+w} = 0.025$). Diese signifikanten Unterschiede nach Adjustierung könnten ein erster Hinweis für eine negative Beeinflussung der Knochendichte der Ovahimba nach Veränderung ihrer Lebensweise sein. Der Mittelwert des SI - Z-Werts der Gesamtkohorte lag bei +1.6 ± 1.6 Standard Deviationen über dem Wert einer gleichaltrigen gesunden Person der gleichen Ethnizität. Dies zeigt, dass die Ovahimba eine bessere Knochendichte als Afro-Amerikaner aufweisen.

Zusammenfassend hat unsere Studie gezeigt, dass Urbanisierung mit einem erhöhten Risiko für Glukosestoffwechselstörung in den Ovahimba assoziiert ist. Weiterhin konnten wir zeigen, dass Urbanisierung mit erhöhten Cortisolwerten, einer Veränderung der Knochendichte und der metabolischen Parameter einschließlich des Metabolischen Syndroms, einhergeht.

Limitations of the study

The major limitation of our study is the relatively small study population, which results in a low statistical power. However, it must be taken into consideration that the Ovahimba themselves are a small community of only between 8000 – 10 000 people. In addition, the Ovahimba inhabit a geographically huge area with a population density of only 0.6 persons per km^2. This made the recruitment of a larger study population difficult as it would have meant that the research location would have to be changed more often. Due to the set-up of the research facilities and because of time constraints this was not possible. In order to compensate for the small study population the intention had been to apply a match-pair technique, whereby urban participants would have been chosen to match rural participants in age and gender. However, due to unforeseen weather challenges, the match-pair technique could not be applied. The rural Ovahimba people are a semi-nomadic tribe and their whereabouts are largely dependent on rain, and water and grazing possibilities for their cattle. During the raining season the year before the field work began, the region was hit by an extensive drought thus forcing the people to adapt their normal nomadic routes. For our study this meant that the original time plan had to be changed and the urban group had to be examined first.

Another major limitation of the study is the lack of randomisation when recruiting participants. The recruitment in Opuwo was done by the translators, by word of mouth and by advertising at local churches or organisations. This meant that a selection bias could not be fully excluded. The recruitment of the rural group was always done in the area where the research tent was set up. The location was changed three times, but due to the logistics associated with each location change, more moves were not possible. The rural participants therefore often came from the same families and same homesteads, resulting in the risk of a similarity in diet and lifestyle. Also, medical advice was offered to whomever needed it (also non-participants) once the fieldwork was done for the day (always within the boundaries of the medical knowledge of our team). An inadvertent selection bias for the subjectively unhealthy might have arisen from these circumstances.

The translators were briefed beforehand to interfere as little as possible with the completing of the questionnaire, but it cannot be ruled out that suggestive oral

questioning led to specific answers by the participant. In addition, participants might have given the answer they thought would be most appreciated by the translator. Unfortunately, this limitation could not be eliminated as many participants were illiterate. Furthermore, many participants did not know their date of birth and the age therefore had to be estimated by the translators and participant. It cannot be excluded that some estimations were incorrect.

Another limitation would be that the questionnaire used was not validated, but was put together from various questionnaires and modified to fit the setting of the fieldwork and the study population. Even though great efforts were made to keep the reagents and later saliva samples cooled, it cannot be ruled out completely that the reagents/samples were somewhat damaged by the Namibian heat, which is another limitation of our study. To keep this risk as minimal as possible, we conducted frequent quality controls. Furthermore, there was also the risk that the saliva samples were damaged during their transport from Namibia to Germany. Although, here again, great care was taken to adhere to the required procedures.

No baseline values of the examined parameters in Ovahimba exist. This does not allow for a population-specific comparison of the findings, and in many instances it had to be assumed that Ovahimba people are genetically similar to other ethnic groups in Namibia or SSA. Furthermore, the examination was limited to a cross-sectional analysis, which does not allow for comparison of how the tested parameters have evolved over time. Another major limitation of the study was the lack of psychosocial assessment of the participants. This would have allowed for a more comprehensive analysis of stress and cortisol concentrations in the study population.

In addition, our study is somehow limited due to the fact that during the statistical analysis, the data were not adjusted for multiple testing. Therefore, care must be taken when interpreting the great number of p-values.

Abbreviations

ACTH	Adrenocorticotropic hormone
ADA	American Diabetes Association
appr.	approximately
ADB	African Development Bank
AP-1	Activator Protein-1
ART	Antiretroviral therapy
AUC	Area under the curve
AUL	Area under the line
BEE	Black Economic Empowerment
BIA	Body impedance analysis
BMD	Bone mineral density
BMI	Body mass index
bpm	Beats per minute
BUA	Broadband ultrasound attenuation
CBS	Central Bureau of Statistics
CBT	Community Based Tourism
CD	Communicable diseases
CoD	Congress of Democrats
CRH	Corticotropin-releasing hormone
CS	Cushing's syndrome
CVD	Cardiovascular disease
DALY	Disability-adjusted Life Years
DHS	Demographic and Health Survey
DM	Diabetes mellitus
DPP-4	Dipeptidyl Peptidase-4
DTA	Democratic Turnhalle Alliance
DVO	Dachverband Osteologie e.V.
DXA	Dual-energy X-ray absorptiometry
EGIR	European Group for the Study of Insulin Resistance
EMME	Eastern Mediterranean and Middle East
FNLA	National Front for the Liberation of Angola

FG	Fasting glucose
FPG	Fasting plasma glucose
GDM	Gestational diabetes mellitus
GDP	Gross domestic product
GLP-1	Glucagon-like Peptide-1
GNI	Gross national income
Grp.	Group
HAART	Highly Active Antiretroviral Therapy
HDI	Human Development Index
HDL-Chol	High-density Lipoprotein Cholesterol
HDR	Human Development Report
HPA	Hypothalamic-pituitary-adrenal
IASO	International Association for the Study of Obesity
ID	International Dollar
IDDM	Insulin dependent diabetes mellitus
IDF	International Diabetes Federation
IFG	Impaired fasting glucose
IGT	Impaired glucose tolerance
IHDI	Inequality-adjusted Human Development Index
IKK	Inhibitor of NFκB Kinase-β
IOF	International Osteoporosis Foundation
IOTF	International Obesity Task Force
IRS-1	Insulin Receptor Substrate-1
JIS	Joint Interim Statement
JNK	c-Jun N-terminal Kinase
KPD	Ketosis-prone diabetes
LDL-Chol	Low-density Lipoprotein Cholesterol
MetS	Metabolic syndrome
MPI	Multidimensional Poverty Index
MRDM	Malnutrition-related diabetes mellitus
MoHSS	Ministry of Health and Social Sciences
MPLA	People's Movement for the Liberation of Angola
NAPLA	Namibian People's Liberation Army

NCD	Non-communicable diseases
NCEP/ATP III	National Cholesterol Education Program – Third Adult Treatment Panel
NFκB	Nuclear Factor κB
NGO	Non-Governmental Organisation
NGT	Normal glucose tolerance
NHANES	National Health and Nutrition Examination Survey
NIDDM	Non-insulin dependent diabetes mellitus
NIH	National Institutes of Health
NOFSA	National Osteoporosis Foundation of South Africa
NPC	National Planning Commission
NSDAP	Nationalsozialistische Deutsche Arbeiterpartei
OAU	Organisation of African Unity
OGTT	Oral glucose tolerance test
PBM	Peak bone mass
PMTCT	Prevention of Mother to Child Transmission
PoN	Polytechnic of Namibia
PRS	Poverty Reduction Strategy
QUS	Quantitative ultrasound
RDI	Recommended daily intake
RDP	Rally for Democracy & Progress
SA	South Africa
SACMEQ	Southern Africa Consortium for Monitoring Education Quality
SADC	Southern African Development Community
SADF	South African Defence Force
SEMDSA	Society of Endocrinology, Metabolism and Diabetes of South Africa
SD	Standard deviation
SI	Stiffness index
SOS	Speed of sound
SSA	Sub-Saharan Africa
STD	Sexually Transmitted Diseases
SWA	South West Africa

SWANC	South West African National Congress
SWANU	South West African National Union
SWAPO	South West African People's Organisation
TB	Tuberculosis
UN	United Nations
UNAIDS	Joint United Nations Program on HIV/AIDS
UNAM	University of Namibia
UNDP	United Nations Development Programme
UNITA	National Union for the Total Independence of Angola
UNTAG	United Nations Assistance Group
US	United States
USD	US Dollar
US DPA	US Department of Public Affairs
WB	World Bank
WC	Waist-circumference
WHO	World Health Organisation
WW I	First World War
WW II	Second World War
YLD	Years lived with disability
YLL	Years of life lost

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Appendix

A Approval by the Committee of Ethics of the Philipps's University of Marburg

Philipps Universität Marburg

›Philipps-Universität - 35032 Marburg

Fachbereich Medizin
Dekanat/Ethikkommission
Prof. Dr. med. Gerd Richter (Vors.)

Tel.: 06421 586 6487
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Sek.: D. Raiss
E-Mail: ethikkom@post.med.uni-marburg.de
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Az.: Study 130/10

Marburg, den 24.02.2011

To whom it may concern:

This is to certify that a positive vote of the Ethics Commission in Medical Research of the Philipps University of Marburg, Germany has been given to the following research proposal:

"Do cultural change and the alteration of the style of living modulate the risk for Diabetes Mellitus Type 2 and Osteoporosis? A study in an indigenous Namibian population group"

The above mentioned Ethics Committee has therefore given its consent to the ethical conception, the proposed methods to be used, the implementation and observation of the study as well as the proposed participant information and consent. In this the Ethics Committee has an advising function, the medical as well as the legal responsibility lies entirely with the supervisor of the research study.

The Ethics Committee has to be informed of any changes made to the implementation of the above mentioned research as well as any unwanted, profound or unexpected events.

Yours faithfully

Prof. Dr. med. G. Richter
(Chairman)
Ethics Commission in Medical Research
Philipps University of Marburg

Sekretariat : Frau Raiss Montag – Donnerstag 8.00 – 12.00 Uhr, Freitag 8.00 – 11.00 Uhr
Frau Backes Montag – Donnerstag 14.00 – 16.00 Uhr

B Approval by the Committee of Ethics of the University of Namibia

UNIVERSITY OF NAMIBIA
Private Bag 13301, 340 Mandume Ndemufayo Avenue, Pionierspark, Windhoek, Namibia

FACULTY OF HEALTH SCIENCES
SCHOOL OF MEDICINE

April 20th, 2011

The Permanent Secretary
Ministry of Health and Social Services
Private Bag 13198
WINDHOEK

Dear Sir,

RECOMMENDATION OF RESEARCH PROTOCOL FOR ETHICAL CLEARANCE –
Does Change in Lifestyle influence the risk for Diabetes Mellitus Type 2 and Osteoporosis? A study in an indigenous Namibian population group

We at the School have reviewed the attached research proposal and find this to be a good research project. It addresses a problem/challenge in the management of DM II. The project is well written and it has sound scientific basis. The methodology is clear and the expected outcome is realistic.

Personal/cultural sensitivities are well protected and there are no obvious risks.

Ethical approval is highly recommended.

Yourssincerely,

Prof. Philip O. Odonkor
Chairperson Research and Conferences Committee
UNAM School of Medicine

C Approval by the Ministry of Health and Social Services

9 - 0/0001

REPUBLIC OF NAMIBIA

Ministry of Health and Social Services

Private Bag 13198 **Ministerial Building** **Tel: (061) 2032510**
Windhoek **Harvey Street** **Fax: (061) 227786**
Namibia **Windhoek** **E-mail: eshaama@mhss.gov.na**
Enquiries: E.N Shaama **Ref.:** 17/3/3 **Date:** 16 February 2011

OFFICE OF THE PERMANENT SECRETARY

Anneke Voigts
Baldingerstrasse
D 35033 Marburg
Germany

Dear Ms. Voigts

Re: Does change of life style influence the risk for Diabetes Mellitus Type 2 and Osteoporosis?

1. Reference is made to your application to conduct the above-mentioned study.

2. The proposal has been evaluated and found to have merit.

3. **Kindly be informed that your proposal is approved in principle pending the following:**

   3.1 Submission of approval letters in the official language (English) from both University of Namibia and Phillips-University of Marburg's Ethics Committee.
   3.2 More clarity on informed consent and exclusive utilization of the sample for analyzing whether change in life style influence the risk of Diabetes Mellitus Type 2 and Osteoporosis and no other tests/laboratory investigations.
   3.3 A clear explanation on where samples will be investigated, as well as a detailed description of how the samples will be handled and discarded after investigation.
   3.4 Clearly indicate whether samples will be exported to Germany as it is indicated that validation will be done there. If so, how will this be done?

"Health for All"

Yours sincerely,

MR. [illegible] KAHUURE
PERMANENT SECRETARY

D Information for participants

Information for participants

Prof. Dr. Peter Nyarango
Faculty of Medicine
University of Namibia
Private Bag 13301
340 Mandume Ndemufayo Avenue
Pioneerspark, Windhoek
Namibia

Prof. Dr. Dr. Peter Herbert Kann
Faculty of Medicine
Philipp's University Marburg
Division of Endocrinology & Diabetology
Baldinger Street
D – 35033 Marburg
Germany

Information for the participants

Does the alteration of lifestyle influence the risk for Diabetes Mellitus Type 2 and Osteoporosis? A study in an indigenous Namibian population group

Dear Ladies and Gentlemen,

We ask you kindly to take part in the study mentioned above. This information leaflet should explain to you the scientific background of the study. It should also give you the opportunity to learn about the benefits and risks of this study. Should you have any questions, please do not hesitate to ask the accompanying doctor.

Reasons for this scientific research

Diabetes mellitus – or commonly known as sugar sickness – is a chronic condition in which the hormone insulin is either produced too little or not at all anymore by the pancreas. Another possibility is that the insulin does not work anymore in the body. This will result in a damaged metabolism of carbohydrates, proteins and fats in the body. This can lead to many symptoms including for example weakness, tiredness and frequent urination.

If the diabetes mellitus is not treated appropriately, more damaging symptoms can arise after a few years. These could include for example difficulties in sight which can lead to blindness, loss of sensation in the legs with open, badly healing wounds, but also heart and kidney problems. Diabetes mellitus can also lead to a very acute, life threatening condition, a coma, due to a metabolic imbalance.

Diabetes mellitus type 2 often occurs only in elderly people (from the age of 50-55 years). It has different risk factors which can mostly be prevented. These risk factors include obesity, lack of physical activity and a bad diet.

Over the past few years there has been a tremendous increase in the number of people suffering from diabetes mellitus type 2 worldwide. Reasons for this are the ever increasing risk factors, which have been named above.

The planned study is asking the question whether a move from a rural area to a village or town will increase the risk for diabetes mellitus. This is, because a move to a village or town is often accompanied with a change in life style. Often the healthier rural and traditional lifestyle is exchanged for a more unhealthy lifestyle consisting of an unhealthy diet, alcohol, smoking and too little physical exercise.

These changes in the eating and exercise pattern can also lead to the appearance of osteoporosis. This is a condition where the bone is slowly lost and which is accompanied by bone fractures. This is the reason why the bones will be examined in this study.

From the results of this study one can see whether you personally are suffering from such a metabolic disorder as described above. For the Namibian society as a whole one could see whether it would be wiser to keep a traditional lifestyle or at least integrate aspects of the traditional way of life into the lifestyle of people in villages or towns.

Should the number of people suffering from diabetes mellitus be very high in Namibia, one can also suggest that the Namibian health system should do more in order to educate about, prevent and treat this condition.

Procedure of the examination:

The examinations will be done on one day over a couple of hours. The following points will be done:

1. A day **before** the examination you will receive 2 little containers, in which we ask you to fill in some saliva using the straw provided. Once at sunrise and once at sunset.

2. We will also ask you to give a urine sample into a cup which we will give to you. This is to measure the glucose and proteins in your urine.

3. Then we kindly ask you that you do not eat anything from sunset until the end of the sugar measurement the next morning.

4. The next morning we will take 1-2 drops of blood from you with a little prick to your finger. This is to examine fatty acids and haemoglobin in your blood and to measure your sugar concentration in the blood.

5. After that we ask you to drink a cup of sugar dissolved in water. Then we ask you to not move around a lot, not do any tough physical activity or to eat anything until the examinations are finished.

6. After 2 hours we will once again take 1-2 drops of blood from you to measure the sugar concentration again. This will allow us to see whether you are suffering from sugar intolerance.

7. With a centimeter tape, a scale and a body fat machine we will measure your height, weight and body impedance.

8. Then you will be allowed to eat a meal.

9. After you have rested for an hour your blood pressure and pulse will be taken when lying down after which you will have to climb stairs up and down for 10 minutes. Your blood pressure and pulse will be measured again.

10. To finish off the examination we will ask you questions regarding your eating habits and physical activity.

Risks and complications:

The machines and methods that are being used will not pose any risk to you and it is not expected that there will be any complications. The science of the ultrasound is based on the measurements of mechanical oscillations in your body and is completely free of any negative rays. Your finger will be sufficiently disinfected before we take the few drops of blood to make sure that there will be no infection.

Privacy of data:

The collected data will be saved electronically. For the scientific interpretation the data will be pseudoanonymised. This means that each participant will get a number, which will be noted in a participant's identification list and it is with this number that the data will be analyzed and interpreted, **not** with the name of the participant.

Once the study has been finished, the participant's identification list will remain with the primary investigator of the study in Marburg/Germany. It may be that the participant's identification list will be used in future years to contact the participants in order to do a follow up study. The participant's identification list will be destroyed after 15 years.

Data that is connected to a participant will be saved electronically in the participant's folder. No data belonging to a participant will be handed over to an internal or external person that does not oblige to the patient's/participant's confidentiality. Neither will any data be transferred electronically to a third party.

The urine and saliva samples collected from you will only be used for this study and only for the purpose explained above. After the analysis all the samples will be destroyed. No samples will be kept or used for other tests or analysis.

E Participant consent form

Participant consent form

Prof. Dr. Peter Nyarango
Faculty of Medicine
University of Namibia
Private Bag 13301
340 Mandume Ndemufayo Avenue
Pioneerspark, Windhoek
Namibia

Prof. Dr. Dr. Peter Herbert Kann
Faculty of Medicine
Philipp's University Marburg
Division of Endocrinology & Diabetology
Baldinger Street
D – 35033 Marburg
Germany

Participation consent form

Does the alteration of lifestyle influence the risk for Diabetes Mellitus Type 2 and Osteoporosis? A study in an indigenous Namibian population group

I, _____ (name of participant) have been fully informed about the nature, intent and consequences of the above mentioned study. I read (alternatively the information was read and explained to me) and I understood the patient information. All my questions about the above mentioned study were answered to my full satisfaction by Mr/Ms_____.

I have been given enough time to decide on my participation in the study and I agree to partake. I know that the participation in this study is out of my own free will. I know that I am allowed to withdraw from the study at any given time without having to give a reason and without any negative consequences for myself resulting from my decision.

It is known to me that my personal data as well as my saliva and blood samples will be saved in an encoded way. I agree to the storage and handling of my personal data and my saliva and blood samples as part of this study in the way as was explained to me in the participant information.

I have received a copy of the patient information and patient consent.

_____ (Town, date, doctor's signature)

_____ (Town, date, participant's signature)

F Questionnaire

Diabetes Questionnaire

1. Location _____
2. Research ID number _____
3. Date _____
4. Date of birth _____ Age _____
5. What is your education?
   a) No school education
   b) Elementary school Which grade_____
   c) Secondary school Which grade_____
   d) High school Which grade _____
   e) Tertiary education – Polytechnikon Which degree _____
   f) Tertiary education – University Which degree _____
6. What kind of work do you do most of the year?
   a) Farming, looking after the cattle
   b) Looking after the children, doing work around the house
   c) Office work
   d) Factory work, building, mining
   e) Studying
   f) Pensioner
   g) Unemployed

Health Status

7. Have you ever been diagnosed with Diabetes?

   a) No

   b) Yes

   c) Yes, with Diabetes during pregnancy

8. Does your biological father suffer from Diabetes?

   a) No

   b) Yes

9. Does your biological mother suffer from Diabetes?

   a) No

   b) Yes

10. How many brothers or sisters do you have _____

11. Does any of your brothers or sisters suffer from Diabetes?

   a) No

   b) Yes

12. Do you suffer of any of these diseases?

   a) High blood pressure, hypertension

   b) Heart problems

   c) Chest pain during exercise

   d) Heart attack

   e) High cholesterol, other disease of high lipids in your blood

   f) Any psychiatric illness

   g) Any other chronic illness Which illness _____

13. Do you take any medication or other supplements? If you do not remember the name, please write down why you are taking the medication.

Name	dose	how often taken
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Smoking

14. Have you ever smoked?

a) No

b) Yes

15. Do you smoke now?

a) No, not at all

b) Yes, sometimes

c) Yes, every day How many per day _____

16. Do you use snuff?

a) No, not at all

b) Yes, sometimes

c) Yes, every day How many times per day _____

Physical activity

17. How hard is your work? If you do not work, please mark a.

a) I do my work mainly sitting down and I do not walk around a lot during the day.

b) I walk around a lot during my work, but I do not have to lift or carry heavy objects.

c) I have to walk a lot and lift heavy objects and walk uphill.

d) My work is heavy labor, I have to lift and carry heavy objects, dig, shovel or split wo

18. How many minutes to you walk to your work and back home?

a) I do not work, I work at home, I use a car, taxi or bus to get to work.

b) Less than 15 minutes

c) 15-29 minutes

d) 30-44 minutes

e) 45-59 minutes

f) More than 1 hour a day

19. Do you do any sports or other activity when you are not working?

a) I read, watch TV, do work in the house or visit friends.

b) In my free time I walk, cycle or do other exercise.

How many times per week _____ For how long _____

c) In my free time I do a lot of sport like soccer, running, ball games.

How many times per week _____ For how long _____

Nutrition

20. How many meals and snacks do you eat during the day? Snack is fruit, chocolate, sandwich, juice or beer.

a) 1-2 meals and snacks

b) 3-4 meals and snacks

c) 5-6 meals and snacks

d) More than 7

21. How many times a week do you eat the following food?

a) Sausage _____ times

b) Chicken _____ times

c) Beef/goat/sheep/pork _____ times

d) Fish _____ times

e) Vegetables _____

22. How much fast food do you eat? 1 serving is for example a hamburger, meat pie, pizza, chips, potato chips (Simba, Lays…), salted nuts

a) 1 or more serving a day

b) 4-6 servings per week

c) 1-3 servings per week

d) 1-3 servings per month

e) Less than 1 serving in a month

23. What kind of fat or oil is used mostly in your household?

a) Mostly vegetable oil (like sunflower oil)

b) Margarine spread (like Rama)

c) Vegetable margarine (like Flora)

d) Butter

e) No fat at all

24. Is the food in your household cooked with cream? Do you eat cream?

a) No, I do not eat cream. No cream is used for cooking in my household.

b) Cream for food preparation, crème fraiche

c) Whipped cream, crème fraiche, sour cream

25. How much vegetables do you eat? 1 portion is for example 1 salad, 2 tomatoes, 1 big carrot.

a) 2 portions or more per day

b) 1 portion per day

c) 4-6 portions per week

d) 1-3 portions per week

e) Less than 1 portion per week or none

26. How much fruit do you eat? 1 portion is for example 1 apple, 1 banana, 1 orange

a) 2 portions or more per day

b) 1 portion per day

c) 4-6 portions per week

d) 1-3 portions per week

e) Less than 1 portion per week or none

27. How much milk products do you eat or drink per day? Milk, soured milk, yoghurt

a) I do not usually use any milk products

b) Milk products with low fat _____ cups per day

c) Normal milk products _____ cups per day

28. How much bread or cereals do you usually eat per day?

a) _____ slices of white bread or rolls

b) _____ slices of brown bread

c) _____ slices of sweet bread

d) _____ bowls of porridge

e) _____ bowls of cereals (cornflakes, rice crispies, wheat bix)

29. Which spread do you normally eat on your bread?

a) Margarine spread (like Rama)

b) Vegetable margarine (like Flora)

c) Butter

d) Nothing

30. How much sweet food such as cake, cookies, ice cream, chocolate or pudding do you eat per day? 1 portion is for example a piece of pie, a chocolate bar, a doughnut, 3-4 cookies

a) 2 portions or more per day

b) 1 portion per day

c) 4-6 portions per week

d) 1-3 portions per week

e) Less than 1 portion per week or none

31. How much sugar, honey or sweets do you eat? 1 portion is 2 teaspoons of sugar or honey or 5 sweets.

a) 2 portions or more per day

b) 1 portion per day

c) 4-6 portions per week

d) 1-3 portions per week

e) Less than 1 portion per week or none

32. How much of the drinks below do you normally drink per week? If none, then write 0.

a) _____ cups of tea

b) _____ cups of coffee

c) _____ bottles of soft drink (like Coca-Cola, Sprite, Fanta)

d) _____ bottles of sugar-free soft drink (like Coca-Cola light)

e) _____ glasses of juice

f) _____ bottles of beer or cider

g) _____ glasses of wine

h) _____ portions of spirits (like vodka, whisky, gin, brandy)

33. Have you changed what you eat or drink in the last year?

a) I have not changed anything.

b) I eat less fat.

c) I eat more vegetables and fruit

d) I eat less fast food and sweet food.

e) I drink less alcohol.

34. Have you lost weight in the last year?

a) No

b) Yes, a little bit

c) Yes, a lot

G Results paper

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Personal results of examination as part of a Diabetes Mellitus Type 2 study

Name: _____

Date of Birth/Age: _____

Date of examination: _____

Results Oral Glucose Tolerance Test:

Fasting glucose: _____ 2-h plasma glucose: _____

Impaired Fasting Glucose: yes / no

Impaired Glucose Tolerance: yes / no

Diabetes Mellitus: yes / no

Glucose concentration urine: _____

Albumin concentration urine: _____

HbA1c concentration capillary blood: _____

Haemoglobin capillary blood: _____

Blood pressure: _____ Pulse: _____ BMI: _____

Results lipid metabolism:

Total cholesterol capillary blood: _____ Total triglyceride: _____

LDL-cholesterol: _____ HDL-cholesterol: _____

Bone ultrasound (speed of sound/bone ultrasound attenuation, calcaneus):

within normal range / below normal range

_____ _____

Prof. Dr. Dr. P H Kann (supervisor) Date, place, stamp

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Baum	Gress	Kühnert	Pantazis	Strik
Baumann	Haberhausen	Kuhnt	Plöger	Subtil
Becker	Hertl	Kunsch	Renz	Thum
Bepler	Heyse	Kussin	Richter	Timmesfeld
Berger	Höffken	Leube	Riera-Knorrenschild	Toussaint
Bien	Hofmann	Lohoff	Rißе	Vogelmeier
Bössner	Hoyer	Mahnke	Ritz	Vogt
Carl	Hundt	Maier	Roelcke	Vorwerk
Czubayko	Jerrentrup	Maisch	Ruchholtz	Wagner
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Dodel	Kann	Möller	Schäfer	Werner
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