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Exploring the impact of diabetes in Sudan:

Out-of-pocket expenditure and social consequences of diabetes on patients and their families

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Exploring the impact of diabetes in Sudan:

Out-of-pocket expenditure and social consequences of diabetes on patients and their families

THESIS FOR DOCTORAL DEGREE (Ph.D.)

By

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To the legend, the late Professor *Hans Rosling,*

My main supervisor during the initial phase of my studies in Sweden, for opening the doors for me, arousing my curiosity and interest into surprising horizons of knowledge, encouraging my individuality and accepting our difference of culture.

ABSTRACT

Diabetes mellitus in Sudan is a growing health problem in all socio-economic classes. The natural history of the disease is associated with poor of glycaemic control, a high prevalence of complications and a low quality of life.

Objectives: The studies aimed to evaluate the social and economic burden and impact of diabetes. The direct costs and intermediate benefits of attaining good glycaemic control were estimated, and specifically the contribution by adult patients with type 2 diabetes to manage their disease without reported chronic complications, and further to describe and analyse health-related quality of life, compared to a matched control group of people without diabetes.

Design and methods: Four cross-sectional studies using structured questionnaires were conducted in Sudan among parents of 147 children with type 1 diabetes and 822 adult patients with type 2 diabetes. Data on family and patient incomes, cost of diabetes care and metabolic control of the patients, was also obtained, with glycosylated haemoglobin A1c (HbA1c) as determining parameter. Subsequently, another 375 people with diabetes were compared with 375 controls using data on out-of-pocket medical expenses and social impact. The Health Utility Index was used to assess health-related quality of life.

Results: The median annual expenditure of diabetes care during childhood was USD 283, of which 36% was spent on insulin. The direct median cost of diabetes care for type 2 adult diabetes patients was USD 175 per year. These costs represent 23% and 9% of incomes of the families of the children with diabetes and of adult patients, respectively. More than half of the income of adult patients was contributed by the spouse or siblings. The median total annual medical expenditure was fourfold higher among people with diabetes, compared to those without diabetes (USD579 vs USD148, respectively). Moreover, those with diabetes were significantly more likely to suffer from serious comorbidities, and reported a higher proportion of personal adverse social effects, such as being prevented from doing paid work or participation in education, both for themselves and their families. Recall of levels of blood glucose monitoring indicated poor glycaemic control in 86% of children with diabetes. HbA1c was at unsatisfactory levels in 77% of adult patients. Patients attending private clinics had both higher income and higher costs than those attending public clinics. However, both groups had poor glycaemic control, which may reflect the low direct costs and the minimal care given to all patients with diabetes. Both self-rated health and the Health Utilities Index were lower in people with diabetes, compared with those without diabetes, and were associated principally with pain, visual impairment and negative emotions.

Conclusions and recommendations: These studies have emphasized the intensity of the economic burden on Sudanese patients with diabetes. This economic burden has generally not been translated into optimum diabetes care, and can be considered as a depletion of family resources and the consequences of an inefficient healthcare system. Patients with diabetes and their families pay a considerable part of their income to maintain health, and in return they receive insufficient care. The implications for health policy are that primary care services should be supported so that patients attain better diabetes control, and that the economic burden on patients with diabetes must be alleviated. Evidence-based programs for diabetes management and prevention in low-resource communities should be developed. Future research is needed to gain a greater understanding both of how families cope, and of efficient mechanisms to improve services in a cost-effective way.

Keywords: Diabetes mellitus, direct costs, out-of-pocket expenditure metabolic control, low-income countries, and health related quality of life, Sudan.

LIST OF SCIENTIFIC PAPERS

I. **Elrayah H**, Eltom M, Bedri A, Belal A, Rosling H, and Östenson CG. Economic burden on families of childhood type 1 diabetes in urban Sudan. Diabetes Res Clin Pract. 2005 Nov Nov; 70 (2):159-6.

II. **Elrayah-Eliadarous H**, Yassin K, Eltom M, Abdelrahman S, Wahlstrom R and Östenson C-G. Direct costs for care and glycaemic control in patients with type 2 diabetes in Sudan. Exp Clin Endocrinol Diabetes. 2010 Apr; 118(4):220-5.

III. **Elrayah-Eliadarous H**, Östenson C-G, Eltom M, Johansson P, Sparring V, Wahlström R. Economic and social impact of diabetes mellitus in a low-income country: A case-control study in Sudan. J Diabetes. 2017 Feb 22. doi: 10.1111/1753-0407.12540. [Epub ahead of print]

IV. **Elrayah-Eliadarous H**, Wahlström R, Östenson C-G, Eltom M, Sparring V. Health-related quality of life in individuals living with diabetes in Sudan. Submitted.

The publications and manuscript will be referred to in the text as Study I-IV.

Study I and II were part of the licentiate thesis.

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List of abbreviations

AACE	American Association of Clinical Endocrinologists
ADA	American Diabetes Association
DALYs	Disability-Adjusted Life Years
DM	Diabetes Mellitus
DOOP	Direct out-of-pocket
EQ-5D	EuroQol five-dimensional questionnaire
FMOH	Federal Ministry of Health
GAP	Global Action Plan
GDP	Gross Domestic Product
GGE	General Government Expenditure
GGHE	General Government Health Expenditure
GHE	General Health Expenditure
HbA1c	Glycosylated haemoglobin A1c
HRQoL	Health-Related Quality of Life
HUI	Health Utilities Index
IDF	The International Diabetes Federation
INT$	International Dollar
LIC	Low-Income Country
LMIC	Low- and Middle-Income Country
NCDs	Non-Communicable Diseases
NHIS	National Health Insurance System
OOP	Out-of-pocket
PHC	Primary Health Care
QALYs	Quality Adjusted Life Years
SDG	Sudanese Pound
SMOH	State Ministry of Health
SPSS	Statistical Package for the Social Sciences
SRH	Self-Rated Health
UKPDS	United Kingdom Prospective Diabetes study
USD	United State Dollars
WHO	World Health Organization

1. INTRODUCTION

1.1 Definition of diabetes and classification

Diabetes mellitus (DM) is a chronic disease that impacts upon the quality of life of an individual by hindering the body's capacity to effectively use energy derived from food. Food is broken down into glucose in the process of digestion, and this glucose fuels the body's metabolic activities. For this process of metabolism to occur, glucose is taken up by the cells with the aid of insulin that is produced in the beta cells that are found in the islets of Langerhans of the pancreas. Diabetes occurs as an inability to produce sufficient insulin that the body requires, or as an inability to effectively use the available insulin, and a combination of these two defects is common[1-3].

Since insulin is a hormone that regulates blood glucose concentration, alterations in the production and utilization of insulin affects blood glucose concentrations. Failure to utilize glucose leads to hyperglycemia, or raised blood glucose levels in the body. This condition, if untreated can in turn lead to both short-term consequences and also long-term micro- and macro-vascular complications. These complications can be experienced by all body systems including nerves, eyes, kidneys and blood vessels. There are primarily two clinical classes of diabetes, namely type 1 diabetes mellitus (previously called "juvenile diabetes") and type 2 diabetes mellitus (previously "maturity-onset diabetes") [1-3].

Diabetes mellitus is a growing public health concern that is affecting people globally in all countries, and poses a major socio-economic challenge [4,5]. The complications of diabetes that arise from poor glycemic control involve the cardiovascular system the kidney, and the eye, and chronic diabetic ulcers may additionally lead to amputations of the extremities. These effects of diabetes that occur throughout the body systems pose strong challenges to quality of life, and may restrain the daily activity of patients [6]. With this state of affairs, patients are compelled to suffer from diabetes complications especially in low-and middle-countries, where the treatment and management of diabetes is not fully developed [7]. These and other reasons make diabetes a global epidemic that requires special and immediate attention, both clinically and in the public health arena [8-10].

1.2 Rising burden of non-communicable diseases in low-and middle-income countries

Non-communicable diseases (NCDs) contribute to two thirds of all global deaths. They also contribute to 40% of all deaths of patients below 70 years of age. Most of these premature deaths due to NCDs (82%) are from low-and middle-income countries (LMICs) [11]. This implies that these NCDs, in particular stroke, diabetes, ischemic heart diseases and respiratory conditions have started to dominate the continuum of causes of mortality in low-and middle-income societies [12]. The increase in prevalence of these diseases is thought to be due to adoption of Western lifestyles and urbanization [13]. This current trend of events has led to a double burden of disease in low-income countries, with both communicable and non-communicable diseases being highly prevalent [14]. This makes all efforts to prevent this rising trend of NCDs very timely, especially in regard to raising awareness of their potential complications and possible

modes of prevention. Preventing and treating NCDs has received global attention, and NCDs are now referred to as the world's biggest killers, according to the World Health Organization (WHO) [15]. In the case of diabetes, this entails a keen emphasis on timely and early diagnosis that would facilitate monitoring and proper glucose control, allied with health education both for the patients and health care providers [14].

NCDs have hampered progress and economic development in low-and middle-income countries through their direct impact on the social-economic construction of societies. They have become a part of human suffering, and have overwhelmed the capacity and resources of health systems in these countries [16]. Hypertension alone causes about 9.4 million deaths globally every year [17]. It is because of these factors that global targets have been set to halt the escalating prevalence of NCDs. One of the global targets for NCDs is to "halt by 2025, the rise in the age-standardised adult prevalence of diabetes at its 2010 levels"[13page 1513 (line 9-10)]. The prevalence of type 2 diabetes varies greatly between different parts and populations of the world, with an average of approximately 3-4% in Sub-Saharan Africa [14]. Unlike the situation in Africa and Asia, the trend has been mostly constant especially in North-Western Europe. Explanations for this could include the rising trend of obesity in these regions, which represents one of the major risk factors for diabetes [18].

A Global Action Plan (GAP) that was designed for the prevention of NCDs to control escalating NCD prevalence between 2013 and 2020 has been published by the WHO, and was eventually adopted by the United Nations (UN) General Assembly in 2013 [15,19,20]. One of the six objectives of this declaration was to prioritise disease prevention through international cooperation, strengthened national capacity for prevention and control, reduced risk factors via health promotion, greater people-centred primary health care, promotion and support of quality research, and the monitoring of trends and determinants of NCDs. With regards to diabetes, resolutions and work plans like this are critical in the face of a rising pandemic, particularly in low- and middle-income countries [15,21]. The International Diabetes Federation (IDF) estimates that 415 million individuals are currently living with diabetes, although half of these individuals may not be aware of their diabetes status, and this number continues to increase annually [21].

1.3 Diabetes is a challenge for health systems

It was estimated that 5.1 million people died of diabetes and related causes in 2013 alone [22]. It is currently one of the largest emergencies in terms of global health, and shows an increasing prevalence in LMICs. Global figures show an estimate of 415 million adults with diabetes, and more worryingly, an additional 318 million adults have impaired glucose tolerance and are therefore highly likely to develop diabetes [21]. Unlike previous decades, in which infectious diseases have dominated the disease burden of Africa, diabetes has become a living reality in this context with an estimate of 14 million people having the disease. Projections have shown that with a constant trend, this number could double to 28 million by 2030 [21]. Studies have illustrated that this increase will be more pronounced in urban areas [23].

The major and leading attributes of diabetes, including diet and lifestyle, have been observed to change in Africa, with an increasing middle class characterized by minimal physical activity and high calorie diets [24]. This has led to a rising trend in obesity and subsequently diabetes [25]. Like other parts of the world, overweight and obesity due to lifestyle change have been

identified as the main drivers of the increasing diabetes statistics in Africa [26]. A systematic review that was conducted in 2011 on studies performed in Sub-Saharan Africa showed that diabetes is highly prevalent, especially in the Northern part of Africa [27,28].

1.4 The state of diabetes in Sudan

Diabetes was previously considered a rare condition in Sudan, but this situation has changed dramatically in the last four decades, when the trends in prevalence have started to rise. As in many other LMICs, the prevalence is estimated to be 8%, but could be even higher in some Northern states of the country, reaching figures of about 19% [29 30,31]. Although in some cases, genetics has a bearing on the illness, a staggering 40% of the cases have been attributed to obesity [3]. Research has revealed that there is poor glycaemic control in this population, with a poor quality of life that is often due to the acute and eventually chronic complications of diabetes [32-34]. The reasons behind poor glycaemic control in patients may be that treatment has been consistent, since most people cannot afford the medicine and treatment is not readily available. There were lower attendance rates at in clinics (55%) and non-compliance to dietary requirements (79%), since most of the patients never receive diabetes education and care [7]. The sedentary lifestyle and unhealthy diet that characterize the Sudanese community has made it complex environment for preventive measures, but in addition, those with diabetes require lifelong treatment that is hard to adhere to in a state where out-of-pocket payments are the reality of the day. This therefore affects the daily quality of life of these patients, and hinders further progress in these societies [35].

1.5 Economic burden and impact of diabetes

The health care system globally has been compelled to bear a heavy toll due to diabetes, and this could be due to the associated direct costs required for the medical management, but also because of indirect costs with regards to loss of productivity, early and premature mortality, and at the same time the loss to a nations' gross domestic product (GDP) [36 37]. The direct medical costs can be very high, depending on the stage and state of diabetes, and entail both inpatient and outpatient care, as well as resources for medication and medical supplies including all of the consumables required for short term and long term care [37]. The major bearers of the costs are hospitals and outpatient care systems [37], but these can vary widely depending on who bears the cost of payment, i.e., private vs. public modes of payment.

The multidisciplinary costs associated with diabetes management make it extremely expensive to sustain, especially in countries like Sudan, where the finances for health are already overwhelmed by communicable diseases. Previous scholars have categorized the economic cost of diabetes into direct costs on health care, indirect health care costs, and intangible costs [38]. The costs incurred to buy medicines, supplies like glucometers, hospitalization and financing of health care staff are all recognized as direct costs to health care [38]. All care that may be offered by relatives, friends, as well as nursing homes and productive hours lost that could have been spent on work, are referred to as indirect costs [39]. The losses in welfare due to psychological and physical pain, stigma attached to diabetes and the social costs that burden the affected families make up for the intangible costs [40].

Because of long distances to health care facilities and waiting times there, patients with diabetes in low-income environments have been compelled to lose resources in order to take care of their diabetes. It is not surprising that some patients have given up on treatment to concentrate on earning a living [40]. This financial loss on the individuals subsequently reflects in the countries' economies due to losses in productivity [41]. Data concerning this total loss due to diabetes in Sudan is limited [41]. In 2007, the International Diabetes Federation (IDF) estimated the direct costs of diabetes to the healthcare sector in various countries. The study, which was based on a model that assumed that the prevalence of diabetes in each country would be 6%, concluded that the cost of health care for a person with diabetes is 2.5 times greater than that of a person without diabetes [42].

Several studies have shown that the health care costs related to diabetes are a substantial burden on society [43-45]. The 2015 version of the IDF Diabetes Atlas estimated global health expenditure due to diabetes to be USD 673 billion or INT$795 billion (2011 purchasing power parity) [21]. Furthermore, a study from the NCD Risk Factor Collaboration calculated global direct costs of INT$825 billion (2011 purchasing power parity) for 2014, almost 60% of which arose in LMICs, where substantial parts of treatment costs were paid out-of-pocket [13,39]. Boomer and colleagues reported estimates of the global direct and indirect economic burden of diabetes, but they did not provide a detailed breakdown of costs by country or world region, and did not consider all relevant productivity losses for calculation of indirect costs [46].

1.6 Health-related quality of life

Diabetes as a chronic disease has both short-and long-term consequences [23]. The worry that comes with the awareness of hyperglycaemia, coupled with micro- and macro-vascular complications, causes a change in lifestyle that may result in a reduction in the health-related quality of life (HRQoL). Studies have revealed a reduced HRQoL among individuals with diabetes, as compared to their counterparts in similar age brackets without diabetes [47,48]. These studies revealed that the quality of life was subsequently reduced with worsening of diabetes symptoms and complications [49-52]. In order to compare the differences between individuals with varying diabetes duration, and the differences between individuals with diabetes and in the general population, a generic instrument is the most appropriate choice. The literature supports the use of generic HRQoL instruments for measuring health status in individuals with diabetes [53-56]. HRQoL can be measured with an ordinary scale or by such instruments as the Short Form 36 (SF-36), the Health Utility Index (HUI), and the EQ5D, although many other instruments are available [56-60]. There is a lack of evidence concerning the burden of diabetes on quality of life among Sudanese populations. To the best of our knowledge, this study is the first to analyze the association between diabetes and HRQL in Sudan using the HUI instruments.

2 BACKGROUND

2.1 Country context

Sudan is one of the most geographically diverse and complex countries in Africa. With a land area of 1.8 million square kilometres, traversed by the Nile and its tributaries, Sudan shares its borders with South Sudan, Central African Republic, Chad, Libya, Egypt, Eritrea and Ethiopia. It has access to the Red Sea with an 853 kilometre-long coastline. Its terrain is generally a flat, featureless plain, with mountains in the northeast and west, while desert dominates the north [61]. Its population is highly divided along lines of ethnicity, tribe, religion and economic activity. The people in the northern region are Arab-speaking Muslims with a diversity of many other indigenous languages [62]. Although fifty-seven years have passed since independence, the country appears poorer, hungrier and more divided than ever before, with pronounced disparities in the level of development between regions, such that an estimated 50% of the country's national income is concentrated in the capital city of Khartoum. The UN categorizes Sudan as a low-income, poor and highly indebted country that ranks number 165 out of 188 countries and territories on the 2016 Human Development Index[1]. By comparison, the country ranked 154 out of 169 countries in 2010 and 150 out of 182 countries in 2009, reflecting a progressive trend towards deepening poverty [63]. Sudan's total population is 35 million, which is growing annually by 2.5%, and is expected to double in 30 years [61]. In terms of the percentage of the population living below poverty line, Sudan ranks at the bottom, with about 47% of the population earning less than 1 US$ a day [63].

Figure 1 Map of Republic of Sudan

Source: http://www.mapsopensource.com.

2.2 Political landscape

Sudan is a federally-organized democratic republic with a multi-party system, in which the President is head of state, head of government and commander-in-chief of the Sudan People's Armed Forces. Both the government and the bicameral parliament - the National Legislature, with its National Assembly (lower chamber) and the Council of States (upper chamber) – possess legislative power. The judiciary is independent and operates through the Constitutional Court [64].

The country comprises 18 states each divided into localities, which in total are 184, but which vary with time due to redrawing the boundaries of the existing ones. Sudan has devolved certain powers to the states under the Local Government Act (2003), often referred to as the Decentralisation Act. However, precise legislative and organisational arrangements may vary from state to state. The President, elected through a popular vote, is both the chief of state and head of the government. A Council of Ministers appointed by the President runs state business, and is responsible to the elected National Assembly. Each state is headed by a Governor, elected through a popular vote. The Governor appoints the state cabinet, which is responsible to the directly elected state legislature. Likewise, each locality has an elected local council.

2.3 Economy

Sudan possesses many natural resources, including oil and agriculture. Increased oil production in 1999 lead to a boom in the Sudanese economy, and subsequently higher oil prices and a significant degree of foreign investment. Despite the presence of sanctions and safeguard measures imposed by western countries, Sudan possessed one of the fastest growing economies in the world until 2008, with an average annual growth of 5-7% until 2010. However, this economic growth was mainly felt in the major cities, leading to increased economic disparity between urban and rural areas, and also between the country's constituent states and geographical regions. When southern Sudan gained independence to form the state of South Sudan in July 2011, 75% of oil production was removed by the new nation. This resulted in a significant impact on government revenues, since oil production corresponded to about 30% of the original country's budget. Furthermore, the independence of South Sudan also impacted upon the economic forecasts and the fiscal resources for social services such as health care [65].

2.4 Health care system

The health system is divided into three levels of management: the federal level, the state level and the locality level (Fig. 2). The federal level includes the planning, coordination, policy-making and supervising organs, and is exclusively responsible for making partnerships and international relations. The state level is concerned with the daily running and implementation of policies and service delivery at the hospitals and health facilities. In each of the 18 states of the country, the governor (Wali) works as the state administrator, with a cabinet of 5-7 ministries and 5-12 localities. For every locality, there is a commissioner responsible for its administration [65]. This top to bottom approach facilitates adequate service delivery to the people, although poor resource allocation and uneven distribution of resources among regions have rendered the system ineffective.

The system also has several partners involved in provision of health care, and especially Primary Health Care (PHC). Recently, the Federal Ministry of Health (FMOH) has stipulated that the minimum package for PHC services should include: vaccinations of children, the Integrated Management of Child Illnesses, as recommended by WHO, reproductive health, essential drugs, nutrition, health education, and treatment of common illnesses[65].

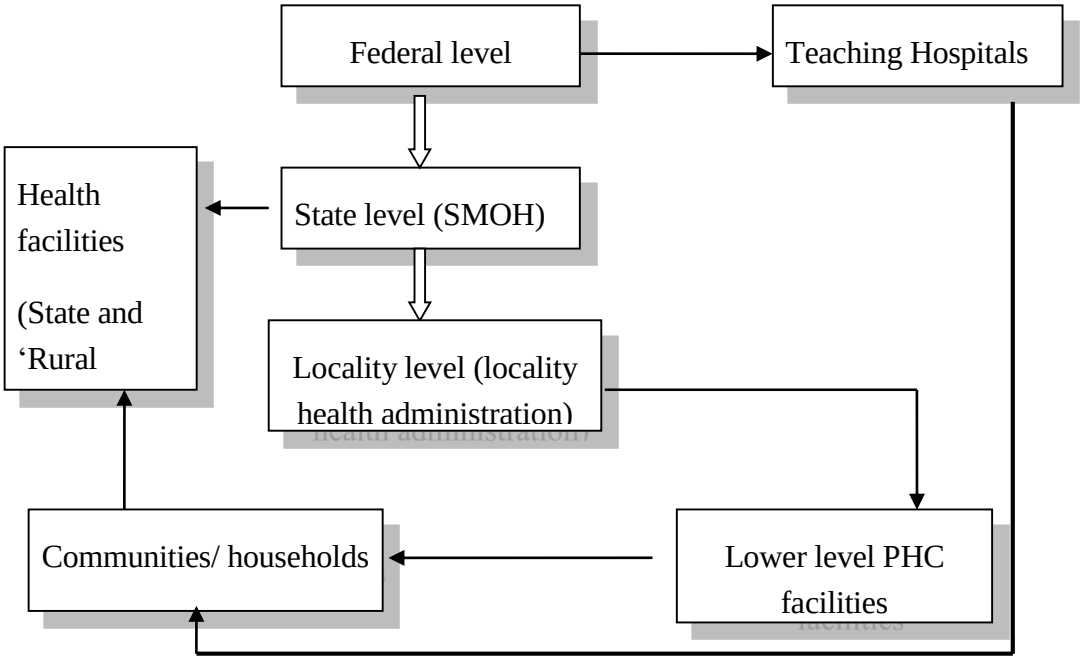

Figure 2 Heath care system of Sudan (Source [66]).

A number of health challenges put the increasingly ageing population of the Sudan at risk. These include rising rates of both communicable and Non-Communicable Diseases (NCDs). For example, in the Sudan Household Survey 2011, 26.8% of children of 5 to 59 months of age had diarrhea, and 18.7% suffered from suspected pneumonia in the two weeks before the survey. In children under 5, protein energy malnutrition and micronutrient deficiencies are a major problem, with severe underweight and stunting observed in 12.6% and 15.7% of infants, respectively. The most common micronutrient deficiencies are iodine, iron and vitamin A [66]. Main health status indicators are shown in Table 1.

Table 1 Sudan health indicators

Indicator	
Crude birth rate (%)	33.4
Crude death rate (%)	17.5
Total fertility rate (per woman)	4.42
Life expectancy at birth (years)	63
Infant mortality rate (per 1000 live births)	51
Under-five mortality rate (per 1000 live births)	76
Maternal mortality ratio (per 100 000 live births)	360
Dependency ratio	96.1

Source: http://rho.emro.who.int/rhodata 2013

2.4.1 Healthcare infrastructure

For the provision of service, health care delivery, as in most countries, is organized at three levels: primary, secondary and tertiary care. Health services are provided by the public and private sectors (for profit and not for profit). In addition to the federal and state ministries of health, the public sector finances the army, the police, the ministries of the interior, higher education, and insurance schemes providing health services.

The private sector is growing but is concentrated in major cities, and focuses on curative care. Primary care is provided through urban and rural family health centres and units, respectively. The public sector operates 3,726 family health centres/units, 141 locality hospitals and 55 hospitals [67].

2.4.2 Human resources for health

Sudan has a good tradition in the education of health professionals. It has seats of learning, such as the University of Khartoum and the University of Gezira, to mention a few. However, both a brain drain and migration have impacted on the availability, quality and skill mix of the health workforce. The number of health workers has expanded in recent years, although it remains below needs-based targets (for example, it is below the 2.3 health worker per 1000 population target), particularly in the marginalized states/locations [68] . The distribution of the workforce is also uneven, i.e., almost 70% of the health personnel work in urban areas, serving 30% of the population, with a third of these being in Khartoum. The overall ratio of doctors per 100,000 population is 35, with the highest concentration in Khartoum, which has 55 doctors, while South Darfur has only 3 doctors.

2.4.3 Out of pocket payments

In many health care systems, so-called out-of-pocket payments (OOP; payments by patients to public and/or private health care providers at the point of receipt of health care services) comprise a substantial part of total health care spending [69]. Households use 79% of health expenses on curative care, while preventive and dental care receives about 1% each (Fig 3). That is, awareness of the importance of these health care activities is low amongst the Sudanese population. Nineteen percent of household out-of-pocket expenses are used on drugs and medical consumables. This is far below that in 2008, which may be due to better data for 2011 health accounts [65]. Direct payments by patients accounted for 70% of total health expenditure in 2011, which in effect causes a high financial burden on families [70] .

The high share of out-of-pocket payments in total health expenditure has implications on the affordability, equity, and utilization of health care services. For 47% of households, health care expenditure had an impact on household income; 14% had faced catastrophic expenditures, and had to sell some of their assets. Almost half of the expenditure is made by people of the highest quintile (46%), whereas those of the lowest quintile spend only 7% of the total [71].

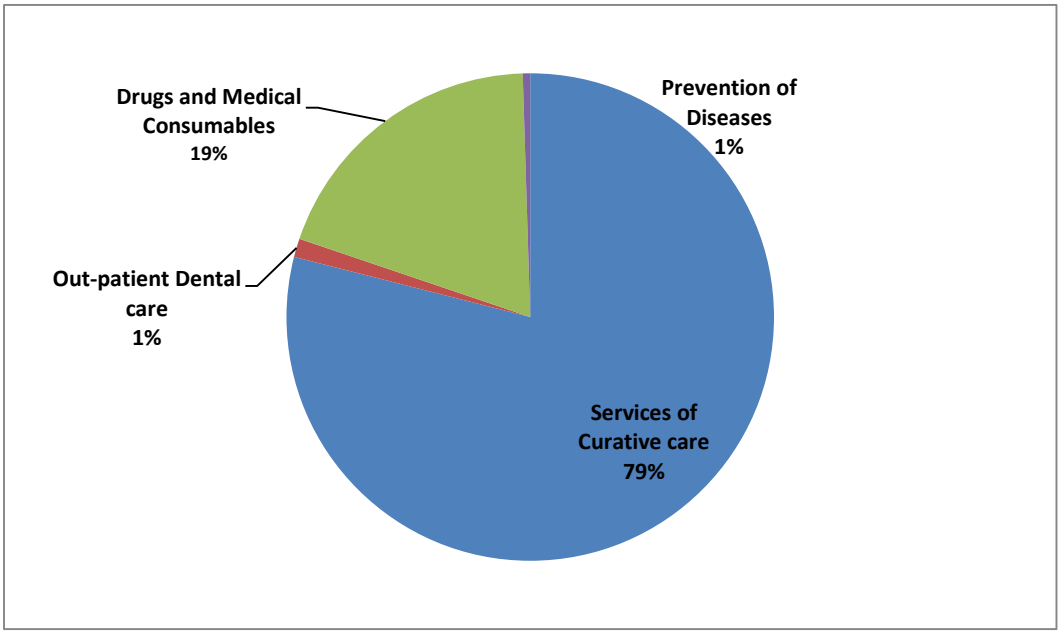

Figure 3 Out-of-pocket expenses to Sudanese households by type of service

Sudan household survey 2011[71]

2.5 Health financing system

The public sector funds 22.3% of total health care resources, while the private sector share is 73.1%. The rest of the world and/or international assistance contribute 4.5% of financing sources for the health care (Fig 4). According to the national health accounts (2011), 73% of funding for health came from private sources, out of which about 70% was out-of-pocket health expenditure by households. The public sector funding in 2011 was 15% higher compared to 2008. The major financing schemes, in addition to the private insurance market, include: the ministries of health, a national health insurance fund, the armed forces employees health insurance schemes, and other parastatal institutions.

Table 2 Levels of health funding

Indicators	**Value (USD) 2008**	**Value (USD) 2011**
Per capita total health expenditure.	111	120
Per capita general government health expenditure (GGHE)	32	27
Total health expenditure as % of gross domestic product (THE / GDP)	6%	6.4%
General government health expenditure as % of total health expenditure (GGHE / THE)	28.9%	22.3%
General government expenditure (GGE) as % of GDP (GGE / GDP - fiscal space)	18.6%	19.0%
GGHE as % of GGE (GGHE / GGE - fiscal space for health)	8.7%	8.2%
External funding for health as % of total health Expenditure (donor dependency)	4.0%	4.5%

Source: National Health Account, 2008 and 2011 [65].

2.6 Diabetes health delivery system in Sudan

Diabetes management is part of the health care system and is integrated at the three levels of the health care system. Diabetes is managed in the localities at primary health centres (PHCs), which are usually where most of people with diabetes are diagnosed. There are no specialised units at the PHCs, and referral of patients is made based on the extent of disease and the presence of complications, to the secondary and tertiary units. At the PHCs, initial management is performed by medical practitioners who are most often nurses, and these may be assisted by locally-trained personnel. Due to scarcity and a lack of readily available equipment and personnel, diagnosis is often made using a urine dip-stick, and any complex biochemical analyses, including access to HBA1c machines, are only performed in urban centres. Patients with glucose in urine are referred to secondary centres that are free of charge, but those that can afford the choice are given the option of private clinical care at a cost. Most patients with diabetes are attended to by either the primary health care centres or by the private clinics.

Sudan has ten specialists in diabetology, who are located at the tertiary centres, eight of whom are found in Khartoum state. These individuals are also part of the teaching hospitals, and each outpatient clinic at the tertiary institutions is headed by a diabetologist, although resident doctors and medical officers are also involved in outpatient management at the tertiary centres. This highlights the fact that there are endless shortages of attending health workers, due to the different roles that they play at the hospital, in addition to the fact that more and more emigrate to other countries for better wages and opportunities.

At outpatient clinics, patients are usually stabilised and monitored for complications. Despite this organisation, there is no follow-up system for patients, neither are there any formal home visits for follow-up. In addition, there are also three stand-alone ‘public’ diabetes care centres. These are supervised by the Ministry of health, but the mode of payment is a user fee system. There are also three private diabetes care centres, which are also supervised by the Ministry of health, but the mode of payment is out-of-pocket. This system of referral applies for both children and adults, and the tertiary institutions are usually equipped with the laboratories for easy monitoring of control and possible complications. Systemic complications that require either medical or surgical interventions are managed through the referral systems at the tertiary institutions.

3 AIMS OF THE STUDY

3.1 Aims and objectives

The aims of this study were to evaluate the social and economic burden and impact of diabetes mellitus on patients and their families in Sudan, and further to describe and analyse health-related quality of life, compared to a matched control group of people without diabetes.

The specific objectives were:

1. To estimate direct costs of care for children with type 1 diabetes, and to assess their glycaemic control (I).

2. To estimate the direct costs of care in patients with type 2 diabetes, and to estimate those costs in relation to the patient's income and to the level of diabetes control (II).

3. To examine the economic and social impact attributed to diabetes in Sudan by calculating out-of-pocket medical expenditure and the health and social impact of the disease for persons with diabetes and their families (III).

4. To describe and analyse HRQoL in patients with diabetes, compared to control individuals matched for sex, age and region (IV).

4 METHODS

The provision of high-quality, affordable health care services is an increasingly difficult challenge. This thesis focuses on investigating and interpreting healthcare utilization, the cost of medical care, HRQoL and the social impact for individuals and populations. It is a cross-sectional examination of four diabetes studies with elements of case-control analyses in two studies.

4.1 Study context

Descriptive studies I and II were performed in the state of Khartoum in Sudan. Khartoum State serves as the capital city and the commercial centre of Sudan. The confluence of the White Nile and the Blue Nile forms the natural separation of the three towns: Khartoum, Khartoum North and Omdurman. With 20% of the country's population, Khartoum has 6 million inhabitants. The state has a relatively higher level of healthcare compared to elsewhere in the country. Most healthcare services have relatively adequate numbers of practitioners and specialists. Study I was conducted among the parents of children with type 1 diabetes. The second study (II) was performed among patients that had type 2 diabetes.

Studies III and IV were performed at outpatient diabetes clinics, and compared patients with diabetes to those without in a case-control study. These individuals were from the same area of residence and were matched based on age and sex. These last two studies (III and IV) were conducted in four states in different parts of Sudan: Al Jazirah, Darfur, Khartoum and Sennar. Al Jazirah is located between the Blue Nile and the White Nile in the eastern–central region of the Sudan. Darfur is found in the western part of Sudan, whereas Sennar is located in the south-eastern part of Sudan. Each of the selected states has a diabetes centre, and these four centres deliver services to more than 70% of all patients receiving diabetes care in the study area.

4.2 Study population

Information regarding the study was given to all parents of children with diabetes and to those adults that had diabetes. This invitation to participate in the study was made once every week at each of the facilities. In study I, 147 (90%) of the identified 164 children agreed to participate and attended the scheduled appointments for the interviews.

In study II, patients above 30 years of age, who had had type 2 diabetes for a duration of between one year and five years, were invited to participate, and 822 of such patients who were attending public or private diabetes clinics agreed to participate and were interviewed. The patients, who agreed to participate, represented 92% of the total attendees for the clinics on those particular days. This gave a representative sample for Khartoum state, and could equally be comparable to other urban areas in the country. In all, 52 and 71 adults were randomly selected from public and private clinics, respectively, which made a total number of 123 adults with diabetes. From these, venous whole blood samples were drawn in EDTA-containing tubes for the HbA1c test. The data for statistical power calculations for an economic study in sub-Saharan Africa are not available. For study III and IV, 375 cases and controls were recruited, and these were representative of the population and helped to minimize the variations due to the outliers. This sample size gave a

statistical power of greater than 90% to detect a difference in proportions of 10 percentage points or larger at an alpha of 0.05. For the purpose of the present study, this understanding was applied to gain access to the health quotient of the population.

4.3 Data collection

4.3.1 Procedure

Study I and II were conducted in two main hospitals in Khartoum State, i.e., Khartoum and Omdurman Teaching Hospitals plus Jabir Abu Eliz (the only public diabetes centre in Khartoum State), Mulazmin Diabetes Center (a private centre) and at private diabetes specialist clinics. These deliver care to patients with diabetes in Khartoum State. The first two sub-studies presented in this thesis consist of interviews with children's parents and adult patients with diabetes who were these attending public and private diabetes clinics. Glycosylated haemoglobin (HbA1c) was used as a measure of glycaemic control, and was determined in samples randomly collected from the adult patient cohort.

For studies III and IV, patients that attended the diabetes clinics were asked for informed consent and those that agreed were subsequently scheduled for individual interviews. The controls for these studies were concurrently recruited and were matched by age (within 5 years) and sex (male or female). These controls were individuals who had no self-reported history of diabetes or diagnosis of diabetes by a physician. These were either individuals accompanying those that were attending the diabetes clinic, or those that resided in the same geographical area, and this process of recruitment took place within 48 hours of recruiting the index cases. These controls were subjected to a questionnaire identical to that of the cases, and there was one control for each completed case interview.

During the process of recruiting the cases with diabetes, the patients with diabetes were requested to suggest five persons living closest to them who were of the same age (±5 years) and sex. This provided potential clues and information about controls that were later contacted. The names of the controls that were suggested were randomly ordered on the list of five and each of these individual's households were approached in that order, either through phone calls or direct household visits. Those that were found at home and were willing to be interviewed were recruited immediately, otherwise a meeting at a later date was scheduled. In case the intended individual was not reached, another control who was next in line was chosen according to the order they appeared. The interviewers never left the locality until they found a potential control, and in the case that all the five possible controls were not forthcoming, other possible controls were sought from the same area.

4.3.2 Questionnaires

A semi-structured questionnaire was used for studies I and II to interview both the parents of children with diabetes and the adults with diabetes. Information was gathered regarding metabolic control and frequency of episodes of hypoglycaemia and hyperglycaemia. The interviews also included collection of data on socio-demographic characteristics, and school performance of the children with diabetes before and after the diabetes diagnosis. Family income

both for the children with diabetes and adult patients in the previous month and year were also obtained. For the adult patients, income contribution for the spouses and siblings was also obtained.

The respondents were asked to state their income by stating all the income that they had received in a given period. The noted sum was converted to US dollars, and rounded off to the nearest whole dollar. The family's health expenditure on diabetes for both children and adults was obtained for a 24 hours, and for periods of 3 months and one year. All information on the costs of insulin, syringes, drugs, urine and blood tests, as well as the number of visits to doctors, and the number and length of hospital stays during these periods, was obtained. When a case or a control subject was unable to speak, or had insufficient recall to complete the interview alone, the involvement of surrogate respondents was permitted. In such cases, the interviewer requested the surrogate family member to respond to the survey questions on the subject's behalf.

A predefined questionnaire (the research tools developed by the International Diabetes Federation (IDF)) (appendix I) was used for studies III and IV. This questionnaire gathered information about the use of medical services, payments made for medical care services, cost of medicines and acquisition of these medicines. The costs also included costs of medicines and medical care for hyperglycaemia, dyslipidaemia, hypertension, and in-patient and out-patient hospital expenses. The interview asked about expenses in the previous 90 days in order to reduce recall bias i.e. patients were asked to name and associate a well-remembered event that had occurred approximately 90 days previously.

4.3.3 Responders and non-responders

If it proved impossible to complete an interview once it had begun, and it could not be completed on another day, this case or control were removed from the study sample and replaced with another person per protocol. The interviewer terminated the interviews of all control subjects who said that they had been diagnosed with diabetes, or whenever in the interviewer's judgment the subject was not responding truthfully or accurately, or no longer wished to participate in the study.

4.4 Outcome measures

4.4.1 Costs

The participants were asked about the medicines they had bought in the last 90 days in order to estimate their expenditure on medicines. For the patients that were admitted overnight to hospital, they were asked to recall their total point-of-service payment. This included charges for medicines and tests that were done and in case there was any out-of-pocket payment. The fees paid at the hospital entail all charges on medication and these were eventually used to determine length of stay and means of payment during each admission. The visits that were made by participants to the other providers like the specialist doctor or surgeon, primary care doctor, nurse, traditional healer (including herbalists and fortune tellers, magicians, and oracles), pharmacist, dispensary, visit to a clinic to collect medication, health educator such as a diabetes educator, or community

health worker, were calculated separately. This method was also used to calculate the expenses at the emergency room and the impatient stay in the hospital.

The average daily price was calculated using data on the most recently purchased item i.e. the number of pills or units of insulin purchased at that time, and the number of pills or units prescribed per day. We then multiplied this result by an adjuster for self-reported adherence, the average number of days per week that the participant indicated that he or she adhered to the prescribed regimen for a given medicine, divided by seven. This gave us a payment per day as used. Mean daily payments were multiplied by 365 to obtain an annual mean expenditure. All the currencies reported here are in USD, and the conversion rate applied was the one that was used at the time of the data collection by the central bank of the Sudan (1USD = 4.30 SDG).

4.4.2 Health-related quality of life

HUI3 is a multi-attribute utility measure that defines health states according to eight attributes (vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain), with five or six levels of functioning for each [72]. Overall scores on the HUI3 range from -0.36 (the worst possible HUI3 health state) through 0.0 (dead) to 1.0 (perfect health) [72]. Single-attribute utility scores range from 0.0 (lowest level of functioning) to 1.0 (full functional capacity). Differences of 0.03 or more in overall HUI3 scores and 0.05 or more in single-attribute utility scores are considered to be clinically important [60]. The construct validity of HUI3 in large, representative samples lends support for the use of HUI in studying HRQoL among people with diabetes [73,74].

4.4.3 Laboratory analysis

Glycosylated haemoglobin analysis was conducted using high performance Liquid chromatography. The level for acceptable glycaemic control was <6.5%, which concords with the recommendation from the European Diabetes policy group.

4.5 Data analysis

Table 3 Overview of statistical tests performed in the four studies

Study	Variables[1]	Chi-square / Fisher's text*	Independent samples t-test	Mann-Witney U test	Regression	McNemar two-sided change test
I	Cost of health care utilization, visit to different types of health care facilities, income		Compare mean income and cost between parents attending private & public clinic			Test metabolic control with school performance and parents education
II	Cost of health care utilization, and monitoring and treatment of diabetes		Glycaemic control between males and females	Testing the difference of Income and cost between groups		
III	Cost of health care utilization, case/control, sex, age, marital status, level of education	Socio-economic characteristics	Comparison of health conditions and social impact of patients and their families between cases and controls	Comparison of mean expenditure between different groups among cases and controls		
IV	HRQoL, index case/control, sex, age, marital status, level of education	Socio-economic characteristics	Mean difference in HUI3 index between cases and controls		Associations of HUI3 Index with diabetes diagnoses and demographic characteristics	

[1]DV=dependent variables, IV=independent variables *
[2]For all the studies, data was analysed using SPSS [75]

In studies I, II, and III**,** results are presented as mean ± SD, or as median and interquartile range. Pearson's chi-square test, Fisher's exact test, Student's t-test and the McNamara two-sided change test were used for evaluation of statistical significance. In study IV, differences between pairs of groups were tested by Student's test and Mann-Whitney's U-test. The independent samples t-test was used to verify whether there were differences in the mean HUI3 index between individuals with diabetes and control individuals. In all tests, $P<0.05$ was defined as being significant. The confidence intervals (CI) were calculated for percentage of unsatisfactory results in blood glucose level, compared between public and private patients.

In study III and IV, data were analysed using SPSS [75] a descriptive analysis was performed for all variables and unadjusted comparisons between case and control were made using a T-test (for continuous variables) or a chi-square test (for discrete variables). When appropriate, longitudinal models were created for outcome variables. All data were presented before and after adjustment for confounders and interactions. Basic presentations of data included number and percentages of cases with diabetes by age, sex, location of residence, and in relation to different known risk

factors. The Chi-square test was used to assess the association between diabetes and different risk factors. All statistical tests were carried out at the 5% significance level.

In study IV the main outcome measures were the self-reported health quotient as expressed in the HUI, the HUI mark three index and the global self-rated health (SRH) parameter. The HUI index was calculated by averaging the preferences of the community. The preference scores were measured as per the utility function. To test whether there was a difference in socio-demographic characteristics between individuals with diabetes and control individuals, as well as the percentage of reported problems in the HUI3 attributes, multivariable regression analysis was performed to identify the independent variables (sex, age, diabetes diagnosis, the level of education, employment status, and region) that could explain the variation in the dependent variable HUI3 index.

4.6 Ethical consideration

For all the four studies, ethical approval was sought and obtained from the Ministry of Health in Sudan, and from the Ahfad University for women. Study I and II were also assessed by the Ethics Committee of Karolinska Institutet, Stockholm, and there was no objection. Through the use of consent forms, participants were informed about the purposes and objectives of the study and those that verbally expressed willingness to participate were recruited. Participants received both written and verbal information about the study. Confidentiality was assured to the participants, and they were informed that their participation in the project would not change their treatment at the clinic. The participants were given assurances that they could leave the study at any time for any reason, and they would not be asked to disclose a reason for this. No incentives were provided to any of the participants, and they agreed to participate for scientific reasons. The interviewers that were involved were trained by the primary investigator following instructions by the IDF.

5 RESULTS

5.1 Patient characteristics and family income

In Study I, the estimated mean annual income of the households of children with diabetes was USD 1810; nevertheless, due to the skewed distribution, the median household income was estimated as low as 1222. In the quartile of families with lowest income, the annual income was less than USD 600. In this study, we considered income as permanent revenue like salaries, but also temporary sources of income, generally donations from relatives and friends, were included. These temporary sources accounted for 16% of the mean total family income. From those families of children with diabetes, those who attended private clinics had significantly higher mean salaries than those who attended public clinics (USD 56, $p<0.03$), although there was no significant difference in total income between the two groups.

In study II, besides personal income, we included contributions from other sources, which mostly were from the spouse and siblings. The median annual income was estimated as being USD 1923. Patients over 60 years of age had an average annual median income of USD 1923, which was more than in those below this age (USD 1846, $p<0.05$). The proportion of income received by the older age group of patients from their siblings or relatives was significantly higher (USD 1265) than that received by the younger age group (USD 1135, $p<0.01$). However, the nuptial economic input received by the females was significantly higher than the one received by the males from their partner ($p<0.01$). The same was true for sibling contributions, thus making the total average income of females not significantly lower than that of males. Those patients who attended private clinics had a higher median income than those who attended public clinics.

Income seemed to have a clear impact on the behaviour of seeking medical treatment for patients and their families in patients with type 1 and type 2 diabetes. This is reflected by our finding that the mean income of patients attending private clinics was significantly higher than of those attending public clinics. This gives an indication of the patients' ability to pay, as we expect the cost of treatment to be higher in private clinics, relative to public ones.

For study III & IV, interviews were completed by 375 persons with diabetes (75% response rate), who were included in the final dataset together with their 375 controls. The mean age was 50 years; 61% were women and 44% lived in Khartoum state. Case participants had a lower education level, but the same employment status as controls (Table 4). There were no differences between people with diabetes and individuals without diabetes except for marital status. Case participants were significantly less likely to be married or cohabitating compared to control participants (67% vs. 75%). (Table 4). The majority of diabetes patients had had diabetes for five years or more. It is important that people have an early diagnosis of diabetes for several reasons, for example, knowledge of the presence of glucose intolerance makes it possible to stop the progression of the disease and its consequences.

Table 4 Demographic characteristics people with diabetes (n=375) and control individuals (n=375)

		Diabetes patients		Control individuals	
		n=375	(%)	n=375	%
Sex	Male	147	(39)	147	(39)
	Female	228	(61)	228	(61)
Age group (years)	20-39	61	(17)	70	(19)
	40-59	197	(53)	216	(58)
	60 and above	114	(30)	89	(24)
Marital status	Single	56	(15)	41	(11)
	Married	248	(66)	279	(74)
	Widowed	56	(15)	40	(11)
	Separated or Divorced	13	(3.5)	14	(3.7)
	Cohabiting	2	(0.5)	1	(0.3)
Education level	Unfinished primary school	166	(44)	130	(35)
	Finished primary school	85	(23)	102	(27)
	Finished secondary school	71	(19)	82	(22)
	University students	15	(4)	17	(4.5)
	Finished university	38	(10)	44	(12)
Employment status	Employed	118	(32)	132	(35)
	Unemployed/Not working[1]	104	(28)	91	(24)
	Retired or pensioner	31	(8)	43	(12)
	Housewife	111	(30)	96	(26)
	Student	11	(2.9)	13	(3.5)
Region	Khartoum	166	(44)	166	(44)
	Other states	209	(56)	209	(56)
Duration of diabetes	1-4 years	124	(33)	NA	NA
	5 years or more	251	(67)	NA	NA

[1]Not working due to health problems.

5.2 Expenditure on health

In Study I the family expenditure on health for the previous years showed that 65% of the resources was spent on the child with diabetes, where the older took 16% and the younger sibling 5% of the total health expenditure.

The total median direct cost of diabetes care was USD 283, from which more than 1/3 was used for insulin. Families of children with diabetes who attended private facilities showed a significantly higher total expenditure on health services and glucose tests than the families who attended public health facilities (Table 5). During the previous six months, children with diabetes had attended a practitioner's consultation six times on average. The recall showed that the mean frequency of visits of patients to doctors in public health centres (6.4+5.0) (mean + S.D) was significantly higher than that to doctors in private centres (4.9+4.4, $p<0.05$).

Table 5 Cost of diabetes care for parents of children with diabetes attending public and private health centers

Expenditure	Public health centres*	Private health centres*	*P*-value
Insulin	109 ±74	123 ±73	N.S.**
Urine test	40 ± 36	34 ± 25	N.S.
Blood test for glucose	43 ± 69	121 ± 214	0.01
Hospital admission	102 ± 160	75 ± 57	N.S.
Doctor fees	87 ± 108	80 ± 101	N.S.
Total cost	378 ± 162	435 ± 267	0.01

*Data (mean ± SD) are expressed in USD. ** N.S. Not significant

In study II, 73% of the total number of patients had received ambulatory care in private clinics. During the last six months, 85% of patients visited their doctor more than twice. The annual median direct cost of diabetes control, including ambulatory care and drugs, was USD 175. Patients with diabetes who used private clinics had a significantly higher average expenditure on diabetes control than those who used public clinics. The cost of ambulatory care (doctor's fees and cost of investigations) was specifically higher for private facility users (USD 147) than for public facility users (USD 79) ($p<0.01$). Those patients with diabetes who were 60+ years old had significantly higher expenditure on ambulatory care items than the younger patients, excluding drugs (USD 159 vs. USD 135; $p<0.01$).

Males older than 60 years spent significantly more than those younger than 60 years on total diabetes care, while older females spent significantly more on ambulatory care (doctor's fees and investigations) than younger females (Table 6**).** The results showed that in patients attending public clinics, there was no significant difference in the cost of diabetes care between different age groups. However, for patients older than 60 years of age and attending private clinics, the cost of diabetes care was higher than for those of less than 60 years of age.

Table 6 Median (interquartile range) annual cost of diabetes care in USD for age groups and divided by sex

Categories / Item	**Age Group yrs**	**Males N = 331**	***P*- value**	**Age Group yrs**	**Females N = 491**	***P*- value**
Diabetes drugs	30 - 60	97 (55 -162)	ns	30 - 60	92 (55 -208)	ns
	>60	115 (69 -335)		>60	92 (56 -139)	
Ambulatory care (Out-patient)	30 - 60	119 (69 -199)	ns	30 - 60	144 (89 – 197)	**0.05**
	>60	154 (83 -211)		>60	159 (105 - 203)	
Total cost of Diabetes control	30 – 60	139 (73 - 211)	**0.001**	30-60	175 (107 – 262)	ns
	> 60	192 (116 - 308)		> 60	192 (149 - 264)	

Table 7 Median (interquartile range) annual cost of diabetes care in USD for age groups and in relation to private and public clinics

Categories / Item	**Age Group yrs**	**Attending public clinics N = 69**	***P*- value**	**Age Group yrs**	**Attending private clinics N = 753**	***P*- value**
Diabetes drugs	30 - 60	125 (51- 314)	ns	30 - 60	92 (55- 190)	ns
	>60	92 (62- 505)		>60	92 (55- 185)	
Ambulatory care (Out-patient)	30 - 60	92 (41- 140)	ns	30 - 60	142 (82- 200)	0.006
	>60	159 (49- 88)		>60	147 (106- 212)	
Total cost of Diabetes control	30 - 60	98 (42- 213)	ns	30 - 60	169 (97- 242)	0.001
	> 60	192 (73- 316)		> 60	177 (138- 287)	

The median and quartiles in study III were reported together with the mean, since the data on cost was skewed. The median annual medical expenditure for the case participants was four times higher than for the control participants. This medical expenditure included costs for in- and out-patient services plus the cost of medicines used. The participants with diabetes had a mean expenditure that was 85% higher than that of participants without the disease (USD 1004 vs. USD 544). The expenditure on out-patient services for case participants was almost nine times higher (USD 345 vs. USD 40) and almost ten times higher for medication (Table 7). This difference in expenditure was similar for women and men. The case participants spent significantly more on medical costs across all the three age groups (20-39 years; 40-59 years; 60-79 years), in comparison to the control participants. For the age group 20-39 years, the case participants had a higher cost for out-patient services and medicines, in comparison to the respective control group. More than half (59%) of the case participants with diabetes reported the lack of economic resources required to cover the cost of care as a reason for not receiving regular medical services, and 48% of the case participants that were on insulin therapy reported inability to afford the treatment.

Table 8 Comparison of annual mean expenditures on in-patient hospital services, out-patient clinics, medicines, and total costs between persons with diabetes (cases) and individuals without diabetes (controls)

	Inpatient expenditure (US$)			**Outpatient expenditure (US$)**			**Medication expenditure (US$)**			**Total expenditure (US$)**		
	Cases	**Controls**	***P*-value**	**Cases**	**Controls**	***P*-value**	**Cases**	**Controls**	***P*-value**	**Cases**	**Controls**	*P*-value
Total			<0.001			<0.001			<0.001			<0.001
Mean ± SEM	247 ± 54	143 ±37		657 ± 47	345 ± 35		101± 9	56 ± 8		1004 ± 72	544 ± 64	
Median (IQR)	0 (89)	0 (0)		345 (771)	40 (396)		59 (131)	6 (65)		579 (973)	148(597)	
Male			<0.001			<0.001			<0.001			<0.001
Mean ± SEM	253 ±73	167 ±75		670 ± 75	320 ± 56		107 ± 16	60 ± 18		1030 ± 102	546 ± 98	
Median (IQR)	0 (42)	0 (0)		119 (774)	25 (316)		58 (131)	0 (65)		536 (1009)	132(596)	
Female			0.001			<0.001			<0.001			<0.001
Mean ± SEM	243 ±50	128 ±38		649 ± 590	361 ± 47		97 ± 10	53 ± 7		989 ± 98	542 ± 83	
Median (IQR)	0 (95)	0 (0)		407(774)	45 (453)		62 (130)	7 (66)		635 (908)	163(617)	
Age groups(years)												
20–39			0.005			<0.001			<0.001			<0.001
Mean ± SEM	309±111	165 ±72		781 ±150	259 ± 66		101 ± 15	45 ± 11		1192 ± 173	469 ±110	
Median (IQR)	0 (236)	0 (0)		429 (843)	0 (178)		70 (106)	0 (49)		844 (999)	77 (419)	
40–59			0.001			<0.001			<0.001			<0.001
Mean ± SEM	229 ±84	132 ±71		623 ± 55	358 ± 53		97 ± 11	60 ± 13		950 ± 103	551 ± 93	
Median (IQR)	0 (86)	0 (0)		352 (753)	32 (326)		58 (108)	7 (65)		563 (858)	135 (561)	
60–79			0.021			<0.001			0.010			<0.001
Mean ± SEM	243 ±83	152 ±90		645 ± 83	381 ± 63		106 ± 19	55 ± 9		994 ± 117	589 ±109	
Median (IQR)	0 (23)	0 (0)		287 (698)	109(572)		58 (152)	15 (73)		477(1123)	206(662)	

1. P-values were calculated using the Mann–Whitney U-test because the variables were not normally distributed and are given for comparisons between case and control participants.

2. IQR, interquartile range= difference between median values for quartile 3+4 versus quartile 1+2

5.3 Diabetes control and acute complications

Responses from the parents of children with diabetes (Study I) showed that the most frequent pre-meal or fasting blood glucose levels during the last 6 months were unsatisfactory in 86% of the cases. Their most frequent pre-meal blood glucose level was 9 mmol/l or higher. However, it was noted that 26% of the study group had not tested their blood glucose during the last six months. There was a negative correlation between the mother's educational level and the fasting blood glucose level of children with diabetes ($p<0.02$), but the father's educational level was not of significance. There was no correlation between the parents' income and glycaemic control, nor was there a difference in diabetes control between children attending private and public clinics. Acute complications of diabetes, as evidenced by ketone bodies in urine, were reported in 46% of the children. Hypoglycaemia that needed special attention had occurred in 37% of the patients, and 57% had been admitted at least once to the hospital within the last year, the main causes of admission being diabetic ketosis (72%), hypoglycaemia (6%), malaria (11%) or other medical disorders or surgical interventions (9%).

Adults with type 2 diabetes (Study II) did not show better outcomes, in comparison with children with diabetes. Glycosylated haemoglobin or HbA1C was determined to be unsatisfactory (HbA1c more than 6.5%) in 77% of patients (Mean + SEM: 8.2 + 0.12). On recall of the most frequent blood glucose levels in the last 3 months, fasting blood glucose levels of 4.4-6.7 mmol/L were reported by 15% of patients. However, almost two thirds reported fasting blood sugar levels of more than 8.9 mmol/L. There was no significant difference in the reported levels of fasting blood glucose during the last three months between males and females.

Of the patients studied, 81% performed their blood and urine tests in private laboratories, 7.5% visited public laboratories and 2.3% conducted their tests using both facilities. Home Blood Glucose Monitoring (HBGM) was carried out by only 9% of the patients, with no gender difference. Only 11% of patients who were conducting HBGM had tested their blood for glucose more than three times during the previous months. Patients who needed special attention to control hypoglycaemia accounted for 16% of the study population. Regarding complications, 25% of the patients had had hospital admissions during the previous year. Of these, 37% had acute infection and ketosis, 8% had hypoglycaemia, 13% had malaria, 35% had surgical causes and 7% had other complications and causes for in-patient treatment. In Study III, a higher prevalence of co-morbidities was reported among the case participants, and these included erectile dysfunction or loss of libido, hypertension cardiac diseases, kidney disease, foot or leg ulcers, peripheral neuropathy and depression (Table 9).

Table 9 Comparison of reported health conditions as told to a doctor, for persons with diabetes (cases) and those without diabetes (controls)

	Cases n =375		**Controls n =375**		
	n	**%**	**n**	**%**	**P-value[1]**
Heart attack, heart failure or other heart disease	36	9.6	14	3.7	0.001
Stroke	13	3.5	10	2.7	0.51
High blood pressure	124	33	98	26	0.03
Asthma or other lung disease	56	15	48	13	0.40
Erectile dysfunction or loss of libido	36	8.5	14	2.8	0.001
Kidney disease	37	9.9	18	4.8	0.01
Peripheral neuropathy	156	42	33	8.8	<0.001
Foot or leg ulcer	34	9.1	4	1.1	<0.001
Amputation of toe, foot or leg	30	8.0	5	1.3	<0.001
Eye surgery	38	10	24	6.4	0.063
Laser treatment for eyes	31	8.3	11	2.9	0.001
Depression	68	18	28	7.5	<0.001
Other permanent problem	53	14	58	16	0.61

[1]Pearson's chi-square comparison test between cases and controls

5.4 Social impact

In study I, school performance reported by parents showed a significant deterioration among children with diabetes from the onset of diabetes to the current date ($p < 0.001$). For Study III, case participants were significantly more likely to report a negative impact on all social indicators (Table 9). As a result of their diabetes, 21% of the individuals reported being prevented from doing any work, or as much paid work as they would like (controls: 6.1%). There was a similar impact on family members of the case participants (Table 9). There was a significantly higher likelihood of limited ability to grow food, do farming and housework for case participants and their families, compared to controls, and these case participants were five times more likely to report being prevented from enrolling in training or school due to their diabetes (8.5% vs. 1.6%), and hence limiting their future income. About one third (32%) of the case participants reported not getting enough to eat compared to the controls (8.5%). For the family members of the case participants, 20% reported lack of enough food to eat (controls: 6.9%) (Table 10).

Table 10 Proportion of persons with diabetes (cases) reporting that their health problems were affecting their or their family members' lives compared with control participants

	Cases n=375		**Control n=375**		
	n	**%**	**n**	**%**	**p-value[1]**
Prevented or kept from doing any paid work or doing as much paid work as wanted	77	21	23	6.1	<0.001
Having done more paid work than would do otherwise	32	8.5	8	2.1	<0.001
Family member prevented from doing work or kept from doing as much paid work as wanted	67	18	40	11	0.005
Family member having to do more paid work than wanted	84	22	57	15	0.012
Prevented from growing any food or doing any work in the house or kept from doing as much farming or housework as wanted	86	23	26	6.9	<0.001
Family member prevented from: growing any food; doing any work in the house; or doing as much farming or housework as wanted	55	15	37	10	0.045
Prevented from enrolling in school or training	32	8.5	6	1.6	<0.001
Family member prevented from enrolling in school or training	62	17	36	10	0.005
Kept from getting enough to eat	120	32	25	8.5	<0.001
Family member kept from getting enough to eat	74	20	34	6.9	<0.001

[1] Pearson's chi-square comparison test between cases and controls

5.5 Impact on health and health-related quality of life

5.5.1 Reported problems in HRQoL

Twenty-six percent of the case participants reported less than good self-rated health (SRH), in comparison to 12% of control individuals ($p<0.001$). People with diabetes had a multi-attribute index HUI of 0.61 (SD 0.31), compared to 0.79 (SD 0.20) for control individuals ($p<0.001$). People with diabetes reported more problems, and increased levels of severity, in the different HUI3 attributes, compared with control individuals (Table 10). These included pain, visual impairments, and emotional problems. Problems related to hearing, mobility and hand functions were significantly different among the two groups. For the participants with diabetes, the lowest single attribute HUI index was found in the attribute pain (0.90) followed by emotion (0.91), while the same figures for control individuals were 0.95 and 0.94, respectively.

5.5.2 Influence on HRQoL

The HUI score was used as the main outcome measure in the multivariable regression analysis (Table 11). Sex, being 40 years of age or older, and being diagnosed with diabetes, had a negative significant impact on the HUI3 index in the full regression model, while being a housewife or widowed had a significant positive impact on the HUI3 index. There were no significant differences regarding level of education or area of residence (whether the individuals lived in Khartoum or other regions). Regression was done for two separate groups to determine whether there was a difference in HRQoL for people with diabetes and control individuals (Table 12). For the participants with diabetes, being 40 years of age or older negatively impacted on the HUI3 index, while being a housewife had a positive impact. Being 60 years of age or older, as well as being retired, had a negative impact on the HUI3 index for the control participants. According to sex, regression revealed that men with diabetes who were 40 years of age and older had their HUI3 negatively impacted, while this happened later in women at age 60 years and older (data not shown).

Table 11 Frequency distribution (percentages) of HUI3 attribute levels and single level attributes, comparing people with diabetes (D) and people without diabetes (C)

Attribute levels	Attribute (HUI3)															
	Vision*		**Hearing***		**Speech**		**Mobility***		**Hands***		**Emotion***		**Cognition**		**Pain***	
	D	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**
1	42	60	90	94	99	99	87	92	88	95	28	44	59	62	39	54
2	40	38	6.7	5.1	0.8	0.8	10	7.7	3.5	2.7	38	40	7.7	8.0	14	19
3	4.0	1.1	0.5	0.5	-	-	1.6	-	0.5	-	22	10	19	20	27	22
4	9.3	1.6	1.1	0.3	0.3	-	0.3	-	4.5	1.6	12	5.6	12	8.8	9.6	3.2
5	2.1	-	-	-	-	-	1.1	-	3.2	0.5	-	-	-	0.3	10	2.1
6	2.7	0.3	2.4	-	*NA*	*NA*	-	0.3	-	-	*NA*	*NA*	2.1	0.8	*NA*	*NA*
Index (SD)	0.96 (0.08)	0.99 (0.03)	0.98 (0.06)	1.00 (0.02)	1.00 (0.01)	1.00 (0.005)	0.99 (0.04)	0.99 (0.02)	0.98 (0.08)	0.99 (0.04)	0.91 (0.11)	0.94 (0.09)	0.95 (0.10)	0.96 (0.07)	0.90 (0.14)	0.95 (0.08)

*Pearson chi-square – significant differences between people with diabetes compared to people without diabetes.
NA, not applicable (i.e., level not defined for HUI3 attribute)

Table 12 Multiple regression analyses on the HUI3 multi-attribute index for people with and without diabetes

	All individuals		People with diabetes		Control individuals	
Dependent variable:	**Full model**		**Full model**		**Full model**	
	ß	***p***	***ß***	***p***	***ß***	***p***
Intercept	0.86	<0.001	0.70	<0.001	0.90	<0.001
Sex						
Men	ref.		ref.		ref.	
Women	-0.05	0.02	-0.07	0.06	-0.05	0.06
Age groups						
20-39 years	ref.		ref.		ref.	
40-60 years	-0.09	0.001	-0.17	<0.001	-0.01	0.63
60 years and above	-0.22	<0.001	-0.34	<0.001	-0.10	0.002
Diabetes diagnosis						
Control individuals	ref.		*NA*		*NA*	
Patients with diabetes	-0.16	<0.001	*NA*		*NA*	
Level of education						
Unfinished primary school	ref.		ref.		ref.	
Finished primary school	0.01	0.70	0.04	0.27	-0.04	0.13
Finished secondary school	0.00	0.99	0.005	0.91	-0.03	0.38
University students	0.09	0.08	0.14	0.09	0.05	0.38
Finished university	-0.01	0.88	0.02	0.80	-0.03	0.40
Marital status						
Single	ref.		ref.		ref.	
Married	0.05	0.08	0.07	0.13	0.03	0.39
Widowed	0.08	0.02	0.06	0.30	0.08	0.09
Separated or divorced	0.05	0.36	0.03	0.76	0.04	0.50
Cohabiting	0.09	0.53	0.02	0.91	0.09	0.67
Employment status						
Unemployed/Not working[1]	ref.		ref.		ref.	
Employed	0.00	0.97	0.05	0.20	-0.06	0.05
Retired or pensioner	-0.04	0.23	0.04	0.48	-1.14	<0.001
Housewife	0.07	0.02	0.17	<0.001	-0.04	0.24
Student	0.07	0.18	0.18	0.06	-0.01	0.87
Region						
Khartoum	ref.		ref.		ref.	
Other states	-0.02	0.20	-0.01	0.92	-0.03	0.13
R-Square	0.08		0.17		0.11	
Adjusted R-Square	0.08		0.14		0.07	
Number of observations	750		375		375	

[1]Not working due to health problems

6 DISCUSSION

The current climate of diminished health spending and increased demand for health services is forcing policy makers to either further cut back already inadequate health services, or to identify additional funding sources. This study has mainly focused on the economic and social burden of disease encountered by Sudanese patients with diabetes and their families. Several studies conducted in Sudan have investigated the clinical and epidemiological aspects of diabetes mellitus, but none of them has addressed the economic and social burden of the disease [28,76-79]. Unlike cost estimates derived from the data of individuals with diabetes identified from the general population or diabetes registers, this study design has the advantage of interviewing individuals face-to-face, thus obtaining relatively precise estimates of the cost of diabetes. This means that information about individuals' costs and utilization patterns is collected directly, rather than estimated from aggregated data [24,80]. In this research, the burden of diabetes was explored in terms of the resources used by patients with diabetes, while the benefit was reflected by the degree of diabetes control, compared with healthcare costs of individuals without diabetes, and in relation to their health related-quality of life. A low benefit in terms of poor metabolic control would be anticipated to associate with a high burden of diabetes in terms of years, and with a lower quality of life.

6.1 Expenditure on patients and their families

Our study assessing the healthcare costs associated with diabetes treatment and management showed that a four-fold increase in the cost of controlling diabetes occurred between 2005 and 2013. This is probably due to increased utilization of health services and the use of newer expensive medications and interventions, while standards of living have also increased due to slight improvements in the economy. Paying for healthcare can be unfair in two different ways. It can expose families to large unexpected expenses which could not be foreseen and which have to be paid out-of-pocket at the moment of utilization of services, rather than being covered by some kind of prepayment. Additionally, healthcare payment imposes a regression phenomenon in which those least able to contribute pay proportionately more than those that are better off.

The findings in our report demonstrate that the direct cost of diabetes care required 65% of the health expenditure of the whole family. Insulin constituted about one third of total diabetes care expenditure. Under such circumstances, people buy care even if it costs them their long-term livelihood, because medical expenses are often forced payments. In traditional economic analyses, poorer groups´ payment for healthcare is typically used as evidence of a willingness to pay, and this was proved in a previous study in a Sudanese household, such that they were willing to pay a reasonable fee for public health services with the assumption that the public health service provides good quality care [81]. However, this considerable contribution by the family was not reciprocated with optimal healthcare of the patients, as reflected by sub-optimal glycaemic control in patients in both public and private practices. More detailed cost-benefit analyses need to be addressed. Few studies have been performed to assess the costs of diabetes in LIC countries[82]. A common experience for individuals with diabetes in low-income countries is the challenge of catastrophic medical

costs and a frequent lack of appropriate medications, despite possessing medical insurance. Similar to results reported elsewhere, out-of-pocket expenses of medications was found unaffordable for most households [83]. In other low-and middle-income countries, individuals with diabetes are more likely to experience catastrophic medical spending and often do not possess appropriate medications to treat diabetes [83,84].

Our analyses showed that health care costs were four times higher in people with diabetes, compared with those without diabetes. These findings are consistent with results from other studies, in which similar data have been reported for cohorts of individuals with diabetes in Italy [85], the US [86], China [87], and Saudi Arabia, where this parameter was found to be up to ten times higher [88]. Other investigators have found that the presence of household members with chronic illnesses (such as diabetes) leads to increased health care expenditure and even impoverishment; for example, in Uganda, such households were found to be three times more likely to incur health care costs than other households. People living in LICs pay a larger share of total health expenditure, because they often lack access to health insurance and publicly-available medical services [21]. The study indicates that the human and economic impact of diabetes may be far greater in low-income countries than in the industrialized world, where a diagnosis of diabetes is made much earlier, and where effective treatments are readily prescribed. For a low-income country such as Sudan, the economic costs of diabetes are huge, and the increasing prevalence of this disease poses a substantial threat to the country's health care system and economy.

Furthermore, a financial report from the Federal Ministry of Health in Sudan also supports our results by showing that the source of finance of health care expenditure for 84% of people is normal household expenditure, while, health insurance is the source for 6% of people; friends and relatives the source for 3% of people; the sale of belongings and assets the source for another 3% of people; and loans are the funding source for 3% of people. Almost 50% of respondents said that healthcare expenditure had had an impact on household income. To finance healthcare, 28% of respondents opted not to receive full treatment, 21% reduced their non-health expenditure in favour of healthcare, and 16% borrowed money [89]. These data should be considered from the viewpoint that Sudan, as a low income country, spends almost 6.5% of its GDP on health care, with an out-of-pocket share to cover health costs of about 70%, or 84 USD per capita, and 22% through GGHE, translating to 27 USD per capita, or 8.2% of general government expenditure (GGE).

6.2 Impact on patients and their families

Various socioeconomic and educational characteristics influence the prognosis of individuals with diabetes. Economic variables include direct non-healthcare costs, such as a family's expenditure on special food, physical activities undertaken because of the child's diabetes, and informal care provided by the primary and other caregivers. The latter has been defined as the performance of tasks that help maintain or enhance the patient's health, and which are carried out by non-professional caregivers [90]. A high rate of illiteracy amongst mothers may contribute to impaired care of a child with diabetes. In addition, the illiteracy of fathers could hamper good financial support to a child with diabetes and may keep patients away from hospitals until their condition is much more severe. Another study conducted in Egypt highlights the fact that low levels of educational attainment can limit the extent to which

patients can manage their problems associated with diabetes [91]. The poor metabolic control exhibited in this study was associated with a negative impact on educational attainment and school performance of the child with diabetes. Because of inadequate and intermittent treatment, most children with diabetes were in poor health, and frequent hospital admissions prevented them from attending school. Another study has reported a negative correlation between education and level of metabolic control of type 1 diabetes [92]. Of the newly diagnosed children with diabetes in Sudan, 81% presented to hospitals with diabetic ketoacidosis [93].

A crucial observation from our study was that diabetes had a profound effect on the social and economic circumstances of both patients and their families. Compared to families that had no members with diabetes, the presence of diabetes in families had effects on schooling, training, and employment. These findings are consistent with observations of the effects of diabetes in a cohort in the United States [94], and are in agreement with studies demonstrating the negative effects of hypoglycaemic episodes on economic productivity [95]. Other recent studies have reported similar findings [96-98]. Results from a systematic review reported that diabetes had a significant negative impact on the ability-to-work outcomes considered [36]. Since our results show the impact of diabetes on economically important activities such as farming, this is potentially of great importance to Sudan, firstly because a significant proportion of the population relies on subsistence farming, and secondly because agriculture contributes a significant amount to the country's total exports. Clearly improvements in the clinical management of diabetes at the local level will not only lead to improved quality of life for individuals with diabetes and their families, but will also lead to socioeconomic improvements at both the community and local levels.

6.3 Quality of diabetes care

The results from this study, and also those of others [33,99,100], indicate that a good quality of diabetes care has yet to be achieved in Sudan. In our studies of both type 1 diabetes in children, and of adults with type 2 diabetes, we found that more than two thirds of the patients were not optimally controlled, regardless of whether they were attending private or public health clinics. This economic burden has generally not translated into optimum diabetes care in either private or public practices, and can be considered as a depletion of family resources and an inefficient healthcare delivery system.

To maintain a healthy quality of life, patients with diabetes must have access to appropriate medication, quality care and good medical advice. A study by Gilmer *et al*. reported a relationship between improved glycaemic control and decreasing healthcare costs [101]. The American Diabetes Association (ADA), for example, recommends achieving HbA1c levels of <7.0% [102], whereas the American Association of Clinical Endocrinologists (AACE) recommends levels of <6.5%. Maintenance of such glycaemic levels will significantly reduce complications in both type 1 and type 2 diabetes. Results from the United Kingdom prospective diabetes study (UKPDS) demonstrated that there is no HbA1c threshold at which further lowering does not reduce the risk of complications until the normal range (<6.0%) is reached [103]. Glycaemic control can be viewed as an intermediary outcome indicator of effectiveness of treatment, as it is known to be related to the long-term prognosis of the disease. Additionally, it is likely that poor glycaemic control is a consequence of failure to address other risk factors,

such as insufficient awareness of lifestyle risks. A low benefit in terms of poor metabolic control would be anticipated to associate with a high burden of diabetes in terms of years, and with a lower quality of life, expressed as Disability-Adjusted Life Years (DALYs) [104]. Improved glycaemic control is also associated with substantial quality-of-life and health economic benefits [105]. Favourable health economic outcomes include higher retained employment rates, greater productive capacity, less absenteeism and fewer restricted activity days [106].

While intensive diabetes therapy is more expensive, the cost of treating diabetes-related complications is substantially reduced, and the amount of time free from complications is increased. For example, using outcome data from the UKPDS trial, it has been shown for 1997 that intensive therapy costs rose by USD 1 138 per patient, while complication costs were diminished by USD 1597 [107].

As indicated previously, more than 75% of patients with either type 1 or type 2 diabetes never self-monitor their blood glucose levels [99]. In diabetes care, the regularity of blood glucose control may indicate the quality of the process of care. In our study, Home Blood Glucose Monitoring (HBGM) was only performed by one out of ten adult patients. HbA1c is the ideal way to monitor blood glucose when the facilities and resources are available, one practical consideration in Africa being maintaining the correct ambient air temperature [108]. However, for most people with diabetes in Africa, this option is infeasible. Even when available, HbA1c is measured in less than 5% of patients [109-112]. Fasting blood glucose is probably the most affordable means of monitoring people with diabetes, although even this might not be available [110]. Random blood glucose is the most common means of monitoring [110,111], which can be helpful in people with type 2 diabetes if the time of the last meal is also recorded. Urine glucose measurements can be useful in identifying people with blood glucose levels that require immediate attention. The current poor availability and lack of use of methods for monitoring blood glucose means that very few people with diabetes in Africa are likely to achieve normal levels of glycosylated haemoglobin.

One of the main factors that encouraged the private provision of health services was the perceived deterioration of the quality of services provided by public healthcare facilities [81]. In addition, the introduction of user fees in the public domain providing health services made the ratio of quality/cost more favourable for the private sector, as the higher user charges in the private sector were accompanied by its higher quality. No studies of the negative impacts of the user charge policy on equity have been performed in Sudan, despite long- standing concerns and renewed debate about its effects.

6.4 Impact on health–related quality of life

A variety of developments in the Sudanese society, including economic, political and ideological changes, have profoundly influenced health care in Sudan. Furthermore, social phenomena such as immigration of refugee populations, and altering dietary habits in various parts of the population, have also impacted upon the prevalence and treatment of diabetes, a disease which is directly related to nutrition. Our study confirmed the negative impact of diabetes on HRQoL in people with diabetes. Other findings from a case control study are in line with our results showing that Bangladeshi patients with diabetes were more likely to report

problems in all dimensions than controls, with the largest effect observed in the dimensions 'self-care' and 'mobility' [113]. Our study is in line with results from population-based studies from Korea and Germany [114,115].

In our report, pain was the most affected attribute, since people with diabetes reported having moderate to severe pain which affected performance significantly more often than control individuals. This is consistent with results showing that diabetic neuropathy in adults with type 1 or type 2 diabetes is both associated with a significantly reduced quality of life, and also a substantial economic burden both for society and for health insurance [115,116]. Pain has profound consequences for the quality of life of patients, their families, and their social and professional environment. Only a holistic clinical approach will successfully improve the patient's condition [117].

Additionally, diabetes leads to a range of impairments in vision, with blindness in a few patients [118]. While the prevalence and incidence of sight-threatening diabetic retinopathy and other sight defects in developed countries is well documented [119,116], there is little published data concerning this situation in sub-Saharan Africa [120].

Emotions constituted another source of heterogeneity in respondents with diabetes, with significant levels of 'unhappiness' more common amongst people with diabetes. Depression is a well-documented feature in these patients [51,74,121], and it is of importance to assess emotional attributes when determining disease progression outcomes in people with diabetes.

Our findings also showed differences amongst respondents for the attribute hands. Although most respondents reported no problems in using their hands, some experienced limitations in the use of hands and fingers, and were unable to perform certain tasks without help. Several studies have shown that various musculoskeletal disorders and hand lesions occur more frequently among people with diabetes [122-124].

In the age group 40 years of age or above, the HUI3 multi-attribute index was significantly different in people with diabetes. Such differences have been shown previously [125-128]. It appears that rural populations show lower levels of HRQoL compared with urban areas. However, we found no difference in HRQOL between Khartoum and other regions. Estimates of rural differentiation have shown variable results, even in studies using HUI3 [129].

6.5 Methodological considerations

Data were collected by a study team which was trained by the principle investigator (HE), one research assistant, and three data collectors. This team was hired from the Ministry of health and their selection was based on their experience with interview procedures. They underwent a four-week training, during which they were taught about the study protocol and research ethics, and trained to perform the interviews. The interviewers and interviewees were from the same socioeconomic category, which facilitated a common understanding of the questions.

One limitation of this study is the possibility of under-reporting of family income which would have caused an overestimation of the percentage of income spent on healthcare. This was most likely to have occurred in the high-income group. Secondly, we did not have data from a comparable population to indicate general family healthcare expenses. The major objective of

the study was to assess the direct cost of treating a chronic disease without reporting complications, which would be higher than that of the cost of general healthcare. Data for 26 percent of the children in study I were missing with regards to blood glucose monitoring at home, which makes the data less valid for the whole population of children in the study. In relation to our findings, it can be assumed that it is more likely that those not reporting any monitoring of blood glucose levels are those with diabetes that is not well-controlled. If such is the case, our findings would overestimate the already low level of diabetic control.

There is a potential for recall bias about costs associated with diabetes care and hospitalization, as well as a possible underestimation of the costs of inpatient visits and medication in the study population, because subjects were recruited from those receiving ambulatory care. Patients with chronic complications of diabetes are usually seen in tertiary care. Moreover, some patients' recall of cost for treatments may not be adequate because of illiteracy or because the medications were bought by others in their household. Because the recruitment of control subjects was based on recommendations by diabetes patients, there is a possibility that this sample is biased. A more careful selection strategy would have included participants either from the community or individuals without diabetes from the rolls of a hospital. However, this was not done in the present study. A strength of the present study is that the protocol used for the selection of matched control subjects ensured that a suitable control group was selected based on demographic factors. Another strength of the study was the survey instrument used, which was developed by the IDF, and this strengthens the applicability of the findings to other settings. Furthermore, the guidelines from the IDF contain instructions for coding alongside each of the questions.

The research protocol and sampling process employed in our study I and II were designed to avoid any bias in the results, although some limitations should be recognized. We included only households belonging to one metropolitan area, and so it may not be possible to apply the results to the whole country. However, due to the representative nature of the sample, the results may be applicable to other urban areas, and thus it is anticipated that the study reflects actual health service participation for a significant proportion of the Sudanese population. Since inpatient service use is infrequent, a much larger sample would be needed to explore hospitalization and its costs. A separate study in a high-income country employed data from a large retrospective, population-based cohort of Swedish patients with type 2 diabetes to assess the extent of medical resource usage, and reported that the greatest economic burden was the elevated rate of hospitalization (12–16%) in this patient population [130]. For study III and IV samples were recruited from outpatient diabetes clinics in four separate states from different parts of Sudan. These studies demonstrated that no differences were observed between Khartoum and these other regions with respect to HRQoL. Since the attributes examined in studies III & IV appeared to be consistent between Khartoum and the other four states, this suggests that it may be possible to extend the results obtained for urban areas described in study I and II to these other non-urban regions of the country.

In addition, economic assessment studies should be based on standard research methods and reliable data to ensure validity and comparability of results. Finally, areas of economic research should be broadened, such as studying issues related to the prevention of diabetes. Patients and their families need to be involved and made aware of the advantages of controlling the disease to avoid the consequences of its complications.

7 CONCLUSIONS AND RECOMMENDATIONS

Diabetes is a costly disease in Sudan, with childhood diabetes consuming a major part of the total income of a family that has a child with diabetes. People with diabetes were found to have much higher total annual costs for medical services, and also described a higher proportion of adverse social effects on themselves and on other family members, and confirms the negative impact of diabetes on HRQoL compare to those without diabetes.

The economic burden on Sudanese people with type 1 and type 2 diabetes, and on their families, is increasing. Sources of medical expenditure include the individual with the disease, which may be chronic, but also inpatient care and the reduced economic status and education level of the head of the household. Diabetes care involves long-term routine clinical visits to the clinic, regular testing and medications, while households have limited flexibility to respond to the cost of unexpected hospitalization or other illness episodes. Meanwhile, the Sudanese health care system is ill-equipped to meet this burden and its complications.

We found that over two thirds of patients attending private or public health clinics were not optimally controlled. This indicates that high quality diabetes care has yet to be achieved, despite the fact that patient OOP health care expenditure is far higher than government expenditure, which provides only one fifth of total health expenditure. However, this amount is still too small to purchase adequate quality services.

The prevalence of diabetes in Sudan is increasing, and this study has addressed the economic and social magnitude of this disease. It has revealed the ineffectiveness in the care and management of type 1 and type 2 diabetes that results in poor glycaemic control, and consequent increased morbidity and reduced quality of life. A number of measures therefore need to be urgently implemented, including making diabetes care available and accessible to those who need it, particularly in public healthcare facilities. In order to encourage vulnerable families in the control of diabetes and its complications, alternative funds should be created to finance quality diabetes care in public healthcare facilities. This would seem reasonable, since there are user charges for health services in public utilities, including those for diabetes. Those involved in diabetes care should be aware of what drives costs, and economic research is needed to assess both the impact of the growing number of available interventions, as well as how economic factors such as income level, education, lifestyle selection, and awareness of the importance of control are associated with diabetes and its complications.

The proper treatment of diabetes is not costly, but not treating diabetes properly is very costly, and economic studies demonstrate that interventions used to prevent and control diabetes may differ greatly in terms of costs per health outcome gained. Health providers and policymakers should use this information in making clinical and policy decisions in order to use resources efficiently. Efforts are needed to improve the quality of economic studies and to expand economic research to new areas in the future.

Our findings show that additional public resources need to be mobilized to deliver universal health and health insurance coverage. While the population's enrolment into the National Health Insurance System (NHIS) is critical in this respect, an effective health delivery system is fundamental for the population to benefit from the promised entitlement. These two systems should go hand-in-hand to achieve better health outcomes. While the NHIS is in its early stages,

reforms are needed to improve coverage and the program's effectiveness. Sudan has come a long way and has embarked on an ambitious goal that many larger countries have yet to establish.

From the findings in this study, I propose some possible actions to curb the burden of diabetes in LMICs:

- Initiate or strengthen a visible and viable operation policy and strategy for diabetes in the National NCDs plan. The strategic framework is to guide the funding, planning organization, provision, and monitoring and evaluation of services of people with or at risk of diabetes.

- Integrate essential standards of managing diabetes into primary health care.

- Provision of the necessary socio-economic, medical and social support for families with a child with diabetes, and for families of patients with diabetes with chronic complications.

- Continuous educational diabetes programs for patients with diabetes and their families, to promote diabetes self-management education and support.

- Provision of insulin and other anti-diabetic drugs, as well as blood glucose monitoring equipment, should be encouraged at a low cost.

- Improve primary care services for people with diabetes to reduce the cost of diabetes care at higher levels, such as control of blood pressure and blood lipids.

Implementation of inexpensive and easy to use interventions can reduce the huge economic burden of diabetes. Many of these interventions are cost-effective, and in some cases cost-saving, in LICs.

This thesis illustrates the fact that diabetes care in Sudan needs to be urgently improved. An important feature of this should be the way that various aspects of diabetes care are funded. In addition, any changes should also be supported by further research in the following areas: improvements in the quality of life of diabetes patients, both with and without complications, should be assessed by cost-analysis studies; improved mechanisms of service delivery should be identified by studies evaluating health care provision for diabetes in relation to cost; finally, coping behaviours exhibited by parents of children with diabetes, and by people with diabetes, should be studied, together with promoting the awareness of patients' and families' roles in controlling the disease and its complications, in order to gain a greater insight into how the impact of this disease might be reduced.

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Appendix: IDF Questionnaire (study III and IV)