University of Khartoum

Faculty of Medicine

Postgraduate Medical Studies Board

The National Burden of Selected Diseases and Injuries in Sudan in the Year 2002

By

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Dedication

To the memory of a great teacher, my father.
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Last but not least, I would like to thank my family for their continuous support, patience and encouragement and may God bless them all.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALE</td>
<td>Active Life Expectancy</td>
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<tr>
<td>CBS</td>
<td>Central Bureau of Statistics</td>
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<tr>
<td>CEYLL</td>
<td>Cohort Expected Years of Life Lost</td>
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<td>CFR</td>
<td>Case Fatality Ratio</td>
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<tr>
<td>DALE</td>
<td>Disability Adjusted Life Expectancy</td>
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<tr>
<td>DALY</td>
<td>Disability Adjusted Life Years</td>
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<td>DFLE</td>
<td>Disability Free Life Expectancy</td>
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<td>EPI</td>
<td>Expanded Program of Immunization</td>
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<td>GBD</td>
<td>Global Burden of Disease</td>
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<tr>
<td>GDP</td>
<td>Gross Development Product</td>
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<tr>
<td>GNP</td>
<td>Gross National Product</td>
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<tr>
<td>HeaLYs</td>
<td>Healthy Life Years</td>
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<tr>
<td>HIV</td>
<td>Human Immunodeficiency Virus</td>
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<tr>
<td>AIDS</td>
<td>Acquired Immunodeficiency Syndrome</td>
</tr>
<tr>
<td>ICD</td>
<td>International Classification of Disease</td>
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<tr>
<td>MICS</td>
<td>Multiple Indicator Cluster Survey</td>
</tr>
<tr>
<td>NBD</td>
<td>National Burden of Disease Study</td>
</tr>
<tr>
<td>PEYLLS</td>
<td>Period Expected Years of Life Lost</td>
</tr>
<tr>
<td>PYLLs</td>
<td>Potential Years of Life Lost</td>
</tr>
<tr>
<td>QALY</td>
<td>Quality Adjusted Life Years</td>
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<tr>
<td>SDHS</td>
<td>Sudan Demographic and Health Survey</td>
</tr>
<tr>
<td>SLE</td>
<td>Standard Life Expectancy</td>
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<tr>
<td>SMPH</td>
<td>Summary Measures of Population Health</td>
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<td>SMS</td>
<td>Safe Motherhood Survey</td>
</tr>
<tr>
<td>SPLM</td>
<td>Sudan People Liberation Movement</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>YHL</td>
<td>Years of Healthy Life</td>
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<tr>
<td>YLL</td>
<td>Years of Life Lost</td>
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<tr>
<td>YLDs</td>
<td>Years Lost due to Disability</td>
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</table>
Abstract

This case study was conducted to pretest the burden of disease methodology in Sudan settings. It aimed at measuring the burden of selected diseases and injuries in Sudan in 2002, using Disability Adjusted Life Years (DALYs). The diseases were Malaria, Measles, Protein energy malnutrition, Low birth weight, Maternal hemorrhage, Diabetes Mellitus and Road traffic accidents. It also aimed to analyze the sensitivity of the burden to changes in the weights given to different disabilities.

A search for local studies and reports providing epidemiological data on these diseases was conducted. Preliminary epidemiological estimates were developed from the data. The estimates included mortality rates, incidence rates, prevalence proportions, case fatality hazards, remission hazards, average duration and relative risk of mortality. The preliminary estimates were entered into disease modeling computer software; DISMOD. This produced internally consistent mortality and incidence rates that were used to calculate DALYs for each disease.

For both males and females, low birth weight accounted for the highest burden followed by protein energy malnutrition, malaria, measles, Diabetes Mellitus and road traffic accidents, with maternal hemorrhage preceding the latter in females. The rank order of the diseases varied in the different age groups. The change in disease burden when using a different set of disability weights was the greatest in diseases with a high disability burden and in those were the difference between the disability weights given to a condition is large. The validity of disease burden estimates was reduced by uncertainties arising from different sources. The study revealed deficiencies in epidemiological data of the diseases under study. Further revisions and improvement of the methods used, with refinement of the final estimates of incidence and mortality of the diseases under study, were recommended. It is also important to conduct a full analysis of all disease and injury burden in Sudan. More reliable epidemiological data should be provided by improving
the vital registration system, and conduction of population based longitudinal studies and national surveys.
الخلاصة

أجريت هذه الدراسة لإختبار منهجية قياس عتبة الأمراض في ظروف السودان، باستخدام مؤشر "السنوات المفقودة المعدلة للإعاقة". هدفت الدراسة لحساب هذا المؤشر في السودان للعام 2002 لمجموعة مختارة من الأمراض والإصابات تتكون من: الملاريا، الحصبة، سوء التغذية بسبب نقص الطاقة، البروتين، نقص وزن المواليد، نزيف الأمهات، السكري وآفات حوادث المرور. هدفت الدراسة أيضاً لتحليل مدى حساسية العبء المقاشي لتغير الأوزان المعتادة لأنواع الإعاقة المختلفة.

تم البحث عن الدراسات والتقارير التي تحتوي على بيانات ومعلومات وبائية تخص هذه الأمراض في السودان، ثم تم تطوير مؤشرات وبائية أولية لكل مرض والإعاقة الناتجة منه، من المعلومات التي تم الحصول عليها. ضمت هذه المؤشرات معدل الوفاة، معدل الإصابة، معدل الإنتشار، معدل الإصابة لتحمل، متوسط مرارة المرض وخطر الوفاة النسبي. عدلت هذه المؤشرات بواسطة الحاسوب وباستخدام برنامج DISMOD لتناسبه داخلياً مع بعضها البعض، ثم استخدم معدل الوفاة والإصابة الناتج في حساب السنوات المفقودة المعدلة للإعاقة لكل مرض.

أظهرت النتائج أنه عند الذكور والإناث، كانت أكثر أمراض المجموعة عبناً هو نقص وزن المواليد، نزيف سوء التغذية، ثم الملاريا، ثم الحصبة، ثم السكري، ثم الأمراض الحيوانية، مع تقدم نزيف الأمهات على الأخير عند الإناث. اختلف ترتيب الأمراض حسب اللون، بانعكاس المجموعات العمرية. عند تغيير الأوزان المعتادة لكل نوع من الإعاقة، ظهر التأثير الأكبر في عتبة الأمراض التي شكلت الإعاقة جزء كبير منه، بالإضافة إلى الأمراض التي اختلفت فيها الأوزان المستخدمة اختلافاً كبيرا.

أظهرت الدراسة وجود نقص في السودان في المعلومات الخاصة بوبانيات بعض الأمراض المدروسة، فتضمنت توصيات الدراسة توفير البيانات الوبائية ذات الجودة العالية بتحسين نظام المعلومات الجيوبية وإجراء البحوث والمسوحات القومية، مراجعة وتطوير الطرق المستخدمة في تحضير المؤشرات الأولية وتعديلها، تنفيذ المؤشرات المعدلة الناتجة من برنامج الحاسوب، وقياس عبة جميع الأمراض بالسودان باستخدام المنهجية المختبرة.
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INTRODUCTION

The burden of disease is important information that is required for assessing the health needs of the population, setting of priorities, allocation of scarce resources and monitoring and evaluation of health services, activities and programs (1). Traditionally it was expressed as rates of occurrence (incidence and prevalence rates), mortality and disability. The problem with this approach is that it hinders comparison between diseases due to the different estimates used in expressing the burden of different diseases. Large numbers of statistics are encountered when comparisons are made between populations or across time (2). Disability tends to be overlooked due to the traditional influence of mortality, so that disabling diseases are given less attention than killing diseases. Moreover, this approach describes the current burden only with no implications of future health status.

The Global burden of Disease study (GBD) (3) quantified the global burden of diseases, injuries and risk factors, using an approach that combined information on mortality and morbidity. The estimate designed and calculated was the Disability Adjusted Life Years (DALY). This summarizes mortality and morbidity estimates in one figure, facilitating comparisons and providing comprehensive information on the burden of disease. It describes both the current and future losses from the health of populations. It also provides a link to cost effectiveness analysis of health related interventions. National burden of disease studies were conducted in many countries and they were useful in guiding health sector reform and priority setting in these countries (2).

There is no previous experience with the application of burden of disease analysis in Sudan. Although guidelines for planning and conducting national burden of disease studies exist, the methods proposed are general and need local adaptation (2). In the GBD 2000 (4), country specific estimates of disease burden have been derived by
Introduction

imputation from regional estimates for some diseases, and directly from country specific
data for other diseases. Locally developed and revised methods that utilize local data and
research results were not developed. Developing local models is important because they
will provide more approximate estimates. Burden of disease methods utilize secondary
data. The availability of the data needed for burden of disease analysis has not been
explored before in Sudan. Health state valuations are incorporated into the calculation of
DALYs. Several sets have been developed and decision has to be made as to which set
should be used for Sudan. To make this decision it is important to know first how
changing health state valuations affects disease burden.

This study aims to synthesize the results of local surveys and research conducted in
a group of selected conditions into DALY estimates, using locally adapted and revised
methods. The selected conditions are: malaria, measles, protein energy malnutrition, low
birth weight, maternal hemorrhage, diabetes mellitus and road traffic accidents. This
group was selected because each disease represents a broad category of diseases as
classified in the GBD. These categories are: communicable diseases, maternal conditions,
perinatal conditions, nutritional deficiencies, non communicable diseases and injuries.

The study will provide experience with all steps involved in measuring the burden
of different types of diseases, using DALYs. The study will identify different constraints
that may be faced during all stages of burden analysis. The sensitivity of the results to the
types of health state valuations will be used by the researchers, to decide which type
should be used for disease burden measurement in Sudan. The study will also provide
initial estimates of the burden of some selected diseases regarded as public health
priorities, in a new approach that combines information on mortality and non–fatal
health outcomes. Moreover, by examining the different data sources available for these
conditions, gaps in information will be identified and future research will be directed
towards filling them.

Because Sudan is a low income country, the results are expected to show a
significant burden of mortality and disability due to communicable, perinatal, maternal
and nutritional conditions. Difficulties in obtaining data and synthesizing them into final estimates are also expected.
OBJECTIVES

GENERAL OBJECTIVE

To measure the burden of selected diseases and injuries in Sudan for the year 2002 in order to pretest burden of disease methodology in local settings.

SPECIFIC OBJECTIVES

1. To develop internally consistent estimates of national incidence and mortality rates for the following conditions:
   a. Malaria
   b. Measles
   c. Protein energy malnutrition
   d. Low birth weight
   e. Maternal haemorrhage
   f. Diabetes mellitus
   g. Road traffic accidents

2. To calculate age and sex specific Disability Adjusted Life Years for the conditions under study.

3. To analyze the sensitivity of the calculated burden to the set of disability weights used.

4. To develop experience in the application of the DALY approach in Sudan

5. To identify data gaps and constraints in conducting national burden of disease studies in Sudan.
LITERATURE REVIEW

MEASURING POPULATION HEALTH

The defining goal of health systems is to improve health. Measuring population health is therefore an important part of assessing health system performance. Population health is measured at 2 levels: The average level of health and the distribution of health inequalities in the population. Population health should reflect individual’s health throughout life and should consider non fatal health outcomes together with mortality (5). Moreover, scarcity of resources makes it difficult to meet all the health needs of the population. Effective and equitable resource allocation calls for objective measurement of the burden of disease in populations.

SUMMARY MEASURES OF POPULATION HEALTH

The burden of diseases in a population depends on the diseases frequency and severity. Incidence density, cumulative incidence and prevalence are measures of disease frequency. Severity is measured by premature mortality (death before expectation of life in the absence of the disease) and morbidity (impairments, disability and handicaps resulting from the disease) (6).

Summary measures of population health are composite health indicators that combine information on mortality and non fatal health outcomes (morbidity) in a single number and therefore summarize the average level of population health. (1). Over the past 20 years composite indicators have been developed for the main reason of enabling evidence based resource allocation and health policy formulation (6).

All summary measures use the unit of time to express disease burden. Their calculation requires information about age specific mortality, the epidemiology of non
fatal health outcomes and the values given to different health states in relation to ideal health or death. They use readily available information from different sources.

**MERITS OF SUMMARY MEASURES OF POPULATION HEALTH OVER TRADITIONAL INDICATORS**

1. They combine mortality with morbidity and therefore consider diseases that have no great mortality impact but considerable morbidity. (1)
2. They use time as a unit of measurement and this was identified as the best approach to measuring the burden of disease. (3)
3. They are easy to understand and convey to policy makers. (2)

**USES OF SUMMARY MEASURES OF POPULATION HEALTH**

1. Comparing the health of different populations. This allows focusing on populations with the poor health system performance.
2. Monitoring changes in the health of a given population.
3. Identifying and quantifying overall health inequalities between populations.
4. Providing attention to the effects of non fatal health outcomes on the health of the population.
5. Informing debates on priorities for health service delivery and planning thus enabling evidence based resource allocation.
6. Short-listing priorities for research and development.
7. Analysing the benefits of a health intervention in cost effectiveness analyses.
8. Enriching curricula for professional training in public health (1).

**TYPES OF SUMMARY MEASURES**

Summary measures are divided into health expectancies and health gaps:

**Health expectancies**

These are life expectancies that give lower weights for years lived in health states worse than full health
Examples: Active life expectancy (ALE), Disability Free Life Expectancy (DFLE), Disability adjusted life expectancy (DALE), Years of healthy life (YHL), quality adjusted life expectancy (QALY), dementia free life expectancy, health capital, and cause deleted life expectancy.

They are based on life tables and therefore are age adjusted and do not depend on any particular age structure.

Health gaps

These quantify the difference between the actual health of a population and some stated norm for population health. They are mortality gaps that take into account time lived in a state worse than ideal health. Examples include: DALYs, HeaLYs.

Health gaps are expressed in absolute terms and therefore are age dependant and are affected by the age structure of the population in which they are applied.

Figure I shows a survivorship curve of a hypothetical population.

Area A+B is the life expectancy at birth.
Health expectancy = \( \Lambda + f(B) \) where \( f \) is a function representing weights or values given to time lived in a state worse than ideal health. These weights vary from 0 to 1 with 1 being ideal health.

Health gap = \( C + g(B) \) where \( g \) is a function representing weights given to time lived in a suboptimal health state, with 1 being equivalent to death.

Summary measures also vary according to the method of health state valuation. Some like DFLE use dichotomous valuations that assign a value of 0 to a health state below an arbitrary level and a value of 1 to health states above it. Others like the DALE and DALYs use polychotomous or continuous valuations with a range of weights from 0 to 1. These vary further according to:

1. The persons assigning the values: patients, health care providers or relatives of patients.
2. Method of valuation
3. The description of the health states including the domains of health used in the description.
4. The range of health states valued at the same time.
5. The deliberative process by which the valuation is made (1).

RELATING SUMMARY MEASURES TO CAUSES OF BURDEN

For SMPH to be useful, the relative magnitude of different health problems (diseases, injuries and risk factors) should be identified. This causal attribution is usually done by 2 methods:

Categorical attribution: attribution of burden to single cause categories that are mutually exclusive. It is suitable only for health gaps and is used for diseases and injuries only.

Counterfactual analysis: this compares the current and future levels of SMPH with levels expected under a hypothetical scenario (2). It can be used for health gaps but is more useful for health expectancies and for health gaps measuring the burden of risk factors.

SMPH are useful tools that assist in decision making but they should be used with caution due to the uncertainty associated with them. They use readily available data from different source and uncertainty comes from problems of reliability and validity of these data (6). Users of these indicators should be aware of these uncertainties.

DISABILITY ADJUSTED LIFE YEARS

DALY is a health gap measure that combines mortality and morbidity. It was developed for the GBD, a study that was started by the WHO and Harvard School of Public Health to measure the burden of disease and injury in the world human population (2)

DALY is a widely used indicator that influences policy debates. Because of this its design incorporated values that might seem reasonable for most of the society. These values are:
1. The value of one year lost by death or disease at any age is the same for all populations of the world irrespective of race, socioeconomic status and other factors.

2. The only variables that should be considered in calculating the burden of disease are age and sex. According to these variables mortality and morbidity components of DALYs may be calculated differently.

3. DALYs are used to quantify proximal biomedical factors that affect health i.e. disease and injuries as well as distal factors such as environmental and socioeconomic factors (3).

**Calculation of DALYs**

DALYs are usually disaggregated by age and sex and can be calculated by geographical region. Being incidence based they are calculated for a reference year. This is usually the most recent data rich year such as a census year (2). The GBD measured the global burden of disease for the years 1990 and 2000 and ever since has been doing yearly revision and update of the estimates (4,7). GBD 1990 has also projected the burden of disease to the year 2020 (8) and quantified the burden attributable to selected risk factors (9). The study initially used 5 age groups for the burden of disease in 1990. For subsequent revisions 8 age groups were used. In 1990, the World Bank divisions of the world into 6 regions were used to report the result. These were subsequently divided to form 14 regions, based on levels of child (less than 5 years) and adult (15 - 59 years) mortality. Further subdivisions were made to form 17 subregions that were rearranged to the 14 regions used for reporting.

Five mortality strata were defined in terms of quintiles of the distribution of $5q_0$ and $45q_{15}$ (both sexes combined) as shown in Table 2. Adult mortality $45q_{15}$ was regressed on $5q_0$ and the regression line used to divide countries with high child mortality into high adult mortality (stratum D) and very high adult mortality (stratum E). Stratum E includes the countries in sub-Saharan Africa where HIV/AIDS has had a very substantial impact (7).
Table 1: Definitions of mortality strata used to define WHO subregions for the GBD 2000

<table>
<thead>
<tr>
<th>Mortality stratum</th>
<th>Child mortality</th>
<th>Definition</th>
<th>Adult mortality</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Very low child mortality (1st quintile of 5q0)</td>
<td>$s_0 &lt; 0.0122$</td>
<td>Low adult mortality</td>
</tr>
<tr>
<td>B</td>
<td>Low child mortality (2nd and 3rd quintile of 5q0)</td>
<td>$0.0122 &lt; s_0 &lt; 0.062$</td>
<td>Low adult mortality</td>
</tr>
<tr>
<td>C</td>
<td>Low child mortality (2nd and 3rd quintile of 5q0)</td>
<td>$0.0122 &lt; s_0 &lt; 0.062$</td>
<td>High adult mortality</td>
</tr>
<tr>
<td>D</td>
<td>High child mortality (4th and 5th quintile of 5q0)</td>
<td>$0.062 &lt; s_0$</td>
<td>High adult mortality</td>
</tr>
<tr>
<td>E</td>
<td>High child mortality (4th and 5th quintile of 5q0)</td>
<td>$0.062 &lt; s_0$</td>
<td>Very high adult mortality</td>
</tr>
</tbody>
</table>

Source: GBD 2000 (7).

A demographic input is required for calculation of DALYs:

1. Total midyear population by age and sex for the reference year, obtained from census and projections. This is needed for calculating numbers from rates.

2. Total mortality by age and sex for the reference year. This serves as an envelope for validating cause of death data. The sum of cause specific number of deaths for each age and sex group should equal the total mortality for that group. It can be obtained from the following sources:

   i. Vital registration: to be useful death registration completeness should ideally be not less than 95% and a minimum cut off point of 80%. Demographic techniques are used to check completeness of death registration and correct for incompleteness.

   ii. Sample registration systems: these collect vital events data for a representative sample of the population.

   iii. Household surveys: provide child and infant mortality data using direct methods and adult mortality using indirect methods (2).

   iv. Demographic techniques: these include the WHO modified Brass Logit method used for countries where vital registration is too poor to adjust and there is no survey mortality data (4). Most surveys report on child mortality. This was used to predict adult mortality and both were used in the Logit method to construct a full life table (10). This method was used in the GBD to estimate the all cause mortality rates by age and sex and construct a life table for countries with no source of mortality data (11).
DALY has 2 components:

**Mortality component:**

This is the years of life lost (YLL). It is calculated from:

1. Cause specific mortality rates by age and sex
2. Life expectancy for each age sex group.

**Cause of death data**

Cause of death data is also used to validate epidemiological estimates or calculate incidence when this is unknown.

**Sources of data**

1. Vital registration systems:

   This is the gold standard if it records at least 70% and ideally 95% of all deaths. The deaths should be cause specific with the cause medically certified (by a medical practitioner).

2. Sample registration systems: data on causes of death use medical certification as well as verbal autopsies (identifying the cause of death from history provided by individuals’ family supplemented by medical records where possible). These systems were the source of mortality data for India in the GBD.

3. Household surveys: these may include child and adult mortality modules with verbal autopsies.

4. Population surveillance systems: population laboratories that provide vital registration events for a small population.
5. Epidemiological estimates:

Incidence, remission and case fatality can be used to estimate mortality. Epidemiological estimates as well as epidemiological surveys tend to overestimate mortality because they usually concentrate on single causes without considering co-morbidity (2).

6. Cause of death models: these are statistical models that allow prediction of the mortality attributable to one cause or cause category from all cause mortality. They are based on the postulation that cause specific mortality is a linear function of all cause mortality. Compositional models were developed using compositional data and are used to predict the distribution of all cause mortality over broad cause categories (12). They are also used to control deviations of the empirical mortality distributions from the predicted pattern (2). A spreadsheet program called CODMOD uses these models to analyze deviations of observed cause of death patterns or construct them (12).

7. Hospital data: these can be used only where a high proportion of deaths occur in hospitals.

8. Cancer registries: these record cancer deaths.

In analysing the burden of disease, a comprehensive list of causes of death is prepared. When these are obtained from vital registration, it is recommended that 80% or more of all deaths are given specific ICD codes. Deaths in ill defined categories are reallocated to other specific categories using algorithms (2).

The GBD study developed a list of causes that are of public health importance globally. It has four levels of disaggregation and the revised list includes 135 diseases and injuries. It is broadly divided into:

- Group 1 causes: communicable diseases, maternal causes, perinatal conditions, nutritional conditions
Group 2: non communicable diseases

Group 3: intentional and unintentional injuries

Deaths and nonfatal outcomes are attributed to single causes according to the rules of the International Classification of Disease (ICD) (4).

For Sudan the cause of death data was developed by the GBD as follows: The pattern of deviation of the broad cause of death data of South Africa (good quality vital registration data) from the pattern predicted by cause of death models was applied to all cause mortality to calculate mortality rates in broad groups (groups 1, 2 and 3) (13). The preliminary estimates for more detailed causes were obtained by applying the pattern of cause specific mortality of Egypt (4).

Validation of cause of death data

The GBD developed preliminary estimates of mortality that were then validated and adjusted. Validity checks that can be used for this process are:

1. Demographic plausibility of the data on causes of death.
2. Specificity of some diseases to certain age and sex groups such as breast and prostate cancer.
3. Some cancer deaths follow a standard well defined age pattern and data giving different patterns should be re-examined.
4. If more than 10% of all deaths are coded to senility and ill defined causes, an investigation of a sample of these deaths should be done using verbal autopsies, death certificates, and medical records.
5. Cause of death models can be used to compare their predicted broad pattern with the one derived from the data (2).

Life expectancies

Life expectancy at a certain age is the time expected to be lived in the future by a person at that age. YLLs use life expectancies at the age of death. This is the time that has been lost by a death at that age. Different sets of life expectancies give different types of YLLs.
Type of YLLs

Potential years of life lost (PYLLs)

This uses a potential limit of life chosen arbitrarily. Duration of life lost by the death of a person at a certain age is the potential age limit minus age at death. It is easy to calculate and treats all ages equally but deaths beyond the limit do not contribute to the burden of mortality.

Period expected years of life lost (PEYLLs)

These are local life expectancies from a period life table for a population. Here deaths at all age contribute to the mortality burden. However using local numbers limits cross population comparability. They are not useful for measuring the burden for the same population at different times due to their variation over time and across populations. Moreover, poor communities with low life expectancies will paradoxically have lower burdens than rich communities with high life expectancies.

Cohort expected years of life lost (CEYLLs)

Period life expectancies assume that age specific mortality rates remain unchanged, which is not always valid. Mortality has been declining over the last decade so that life expectancy of a cohort at each age has been increasing. It is more suitable to use life expectancies from a cohort life table (ideally based on following up a cohort till the death of its last member but can also be developed by projecting mortality rates). However cohort life expectancies also limit cross population and over time comparability.
**Standard life expectancies (SLE)**

These are life expectancies from standard life tables. They were developed and used in the GBD. These are based on the highest life expectancy at birth which is that of Japanese females (82.5 yrs). The Coale and Demeny West model life table level 26 (14), with a female life expectancy at birth of 82.5 years, was used for female standard life expectancies. As for males, a difference in life expectancy was taken as 2.5 years lower than females. Since there is no model life table for male life expectancy at birth of 80 years, the Coale and Demeny West model life table level 25 with a female life expectancy at birth of 80 years was used for male standard life expectancy (14). Differences between SLE of males and females were allowed to reveal to public policy the difference in survival potential between the sexes resulting from a number of genetic and environmental factors. This will permit public policy to deal with these factors to narrow the differences in survival potential. However this remains a controversial issue. Standard life expectancies are used for all populations at all times and therefore address the shortcomings of all the other sets of life expectancies (3).

**Morbidity component**

Years lost due to disability (YLDs): This is a function of the total time lived with disability and a weight given to that time.

Total time lived by the population with disability:

This can be expressed as the prevalence times one year or the incidence times the average duration of disability. The second approach is preferred in DALYs because:

1. It is consistent with method of calculation of YLLs, mortality rates being incidence rates.
2. Incidence rate is sensitive to current epidemiological trends.
3. Using incidence or deriving it from prevalence gives a chance for checking the internal consistency of the epidemiological estimates used in calculation of YLDs.

4. The best measure for assessing intervention benefits is the volume of life years added.

The two approaches yield the same results if the incidence of disability and the population age structure are constant over time (3).

A reliable incidence rate and average duration should be consistent with other epidemiological estimates such as prevalence, mortality, case fatality rates and remission rates. The process that can be used to obtain internally consistent estimates is as follows:

1. Researching current knowledge of the disease: supplemented with expert opinion, this is useful to understand the natural history of the disease.

2. Constructing a diagram of the natural history of the disease: this shows the epidemiological dynamics of the disease and the transfer from susceptible state to disease state and complication and or death or recovery. It is also useful in clarifying the case definition, and identifying the epidemiological estimates needed.

3. Searching for epidemiological estimates in:
   a. Disease registers: such as for infectious diseases, cancer, congenital anomalies, diabetes and epilepsy. They register new cases of disease.
   b. Population surveys:
      Provide prevalence of disease and disability some of which are self reported. They are limited by representativeness, case definitions, self reporting nature of the answers, and study quality.
   c. Epidemiological studies: can provide data when there are no disease registers or good quality surveys. Especially useful are longitudinal studies of the natural history of the disease, providing information about sequelae, case fatality, remission and average duration.
   d. Health facility data: due to problems of under-coverage, under-reporting and non-representativeness, health facility data can only be useful as source of morbidity data for serious conditions. These include: maternal and perinatal conditions, meningitis, stroke, myocardial infarction, surgical conditions and serious injuries.
Checking data quality

The data available should be of the highest quality attainable. It should be plausible with the known epidemiology of the disease, adjusted for non-representativeness and examined by experts. Computer software is used to check the internal consistency of the estimates. DISMOD is a type of software that processes a certain input set of epidemiological estimates to produce an internally consistent output set.

The software is based on the following dynamic disease model:

![Diagram of disease model]

Source: National burden of disease studies: a practical guide (2)

It accepts for input at least 3 of the following epidemiological estimates:

1. Incidence rate
2. Prevalence
3. Remission rate
4. Case fatality rate
5. Mortality rate
6. Average duration
7. Relative risk of mortality.

Case fatality, remission and mortality rates should be instantaneous rates (hazards) with a person-time denominator. In the most recent version of the software (15), Incidence rate can be entered as a hazard or as a population rate with a mid-year population as denominator. Case fatality and relative risk of mortality are considered the
same and one suffices for the other. Only short average durations are accepted (less than 2 years) but the remission and/or case fatality should be high.

**DISMOD is used for the following purposes:**

1. Checking internal consistency of epidemiological estimates.
2. Calculating incidence from prevalence when the former is unavailable.
3. Calculating average duration from incidence, remission and case fatality rates.
4. Extrapolating estimates in desired age categories from estimates presented in different age categories.

**Disability weights**

These are numerical values given to time lived in non fatal health state. They quantify the society's preference for different health states and do not represent the experience of a person living in these states, nor do they quantify the value of a person living in a suboptimal health state. They range from 0 to 1. For DALYs, 0 is perfect health and 1 represents death.

The valuation is done in some form of interview of a number of respondents with space for deliberation using the following techniques:

1. Rating scale/ visual analogue
2. Standard gamble
3. Time trade-off
4. Person trade-off.

The respondents can be of 5 types: Individuals experiencing the health states to be valued, health care providers, general public and patients’ families.

The design of disability weights assumes that:

1. A series of health states can be defined using an established instrument or other descriptors.
2. Individuals’ preferences for time lived in different health states can be expressed in values.
3. These preferences can be measured using an interview or questionnaire.

4. The severity of a health state and the time spent in that state are independent.

A group of health states representing a full range of states from very mild to very severe are selected and described to the respondents. They can be described using standardized domains of health as those in existing classification systems such as the health utilities index. They may also be described ad hoc. Tools such as pictures, cartoons or multimedia presentations may be used to aid the description (2).

The GBD developed and used a protocol for disability weight measurement. 22 indicator conditions were selected to represent a wide variation of health states from very mild to very severe states, and to include many health domains: physical, mental and social. A variant of the person trade off method was used to develop disability weights for these conditions, by a group exercise involving a deliberative process. Other techniques were used to encourage respondents to examine their preferences carefully. There was a high agreement between the respondents with Spearman Correlation Coefficient more than 0.86. Eight other groups from over 25 countries did the same exercise and correlation coefficients among them were higher than 0.87. Based on this, 7 classes of disability weights from 0 to 1 were developed. Each class contained 2 or 3 indicator conditions. The rest of the diseases and injuries were then distributed among the 7 classes by the respondents using a rating scale. For some conditions, different disability weights were developed with and without treatment (16). Except for a few conditions co-disability was not considered. This means that disability weights for coexisting conditions are the simple sum of the disability weights for each condition. This sometimes leads to disability weights more than 1. Disability weights were developed for Down's syndrome with mental retardation and cerebral palsy and mental retardation. Dependant co-disability should be adjusted for while independent co-disability needs not, because correcting for the latter will lead to a bias with higher burden in low disability populations and vice versa.(3).
Dutch disability weights were also developed. They use different indicator conditions and they were developed for a restricted group of conditions. They were used in the Australian burden of disease study where adjustments for co-morbidity were made for the following conditions:

1. Common coexisting nonfatal conditions of old age such as diabetes, hearing loss and osteoarthritis.
2. Some mental health disorders.
3. Congenital malformations
4. Injuries (17).

Disability weights were also developed and used in the work of the Ghana Health Assessment Team. They were developed through expert opinion and community participation. They are referred to as disability extent or percentage disablement (expressed as percentages) (18).

**Other social values**

*Discounting*

This is applying a certain discount rate to years lost in the future. It is important in economic analysis and is used for DALYs for the following reasons:

1. To be consistent with the measurement of health outcomes in cost effectiveness analyses.
2. To prevent deaths at younger ages from having a higher weight.
3. Without discounting, research or disease eradication programs with a non-zero probability of succeeding will receive all current expenditure because its future benefits will be infinite. GBD applied a discount rate of 3%, which is less than the 3.5 recommended by economists (2).

*Age weighting*

The GBD applied lower weights to years lost at the young and older age groups than the other groups because some studies showed a wider social preference to time lived by a young adult than the same time lived by a young child or at older ages. It is argued that
this is inequitable and that the standard age weights used in the GBD do not reflect actual social values (2).

Because discounting and age weighting are controversial issues, the GBD reports results with no discounting or age weighting (2).

**Precision of the DALY estimates**

Uncertainty analysis is the process by which confidence or uncertainty intervals are made around the DALY estimates. They describe explicitly the precision of the estimates derived from limited data sources. Analytical methods can be used to quantify uncertainty for simple quantities but complex quantities require simulation methods, such as the Monte Carlo simulations used in the GBD. Uncertainty may arise from:

1. Incomplete information
2. Bias in information such as non representativeness.
3. Disagreements between information sources.
4. Model uncertainty
5. Uncertainty in preferences.
6. Uncertainty inherent to the data generation process (e.g. using event counts to infer risk) (19).

The difference between sensitivity and uncertainty analysis is that the former involves deterministic variation of the social values included in the estimation of DALYs while the latter involves varying the parameters used such as incidence rates. Uncertainty analysis can not be applied to the social values (3)

**National burden of disease studies**

The first study to quantify the burden of disease in a Least Developed Country using the combined mortality and morbidity approach was conducted in Ghana. It used the Healthy Days of Life Lost. This indicator differs from DALYs in that it uses the life expectancy at the age of onset of disease instead of life expectancy at age of death, to calculate the mortality components. It expresses burden in days and uses local disability
weights. In Ghana, communicable diseases, perinatal and maternal conditions and nutritional deficiencies were predominant (18).

Healthy days of life lost were later developed into healthy life years with the same method of calculation but burden expressed in years (20). The use of the life expectancy at age of onset of disease rather than the life expectancy at the age of death is argued to be a more appropriate approach to quantifying the consequences of disease onset and interventions. The time of onset perspective is considered by some to be useful because it is based on the natural history of disease concept. By emphasising the consequences of new disease cases, HeaLYs are more useful in thinking of disease prevention whereas DALYs being based on a current year perspective are claimed to be more useful for disease treatment interventions. The difference between DALYs and HeaLYs becomes more evident in diseases with secular trends such as HIV (21). HeaLYs were used to measure the burden of disease in Pakistan. The burden was predominantly of communicable diseases, perinatal conditions and nutritional deficiencies. However the study revealed the emergence of non communicable diseases and injuries, showing the state of epidemiological transition (22).

Mexico quantified the burden of disease in 1991 using DALYs. The study used the same methods as the GBD 1990 but with some modifications. The study analysed the burden for 32 Mexican states separately. It revealed predominance of non communicable conditions at the national level as well as regional discrepancies, with a high burden in disadvantaged states predominantly of group 1 diseases. The study provided results useful for health system reform and mobilized a large no of experts in different diseases and conditions, to discuss health priorities. It also helped in identifying health information gaps (23).

In Australia, the burden of disease was measured for 1996 using DALYs. The study differed from the GBD in that it used or derived disability weights from the GBD as well as disability weights developed in the Dutch burden of disease study. Adjustments were made for co-morbidity. The 15 leading causes of DALYs lost in 1996 in Australia were
non communicable diseases and injuries. The study initiated cost effectiveness analyses for cancer, coronary heart disease and mental disorders control (17). The state of Victoria in Australia also conducted a separate burden of disease study with similar methods and adjustments. (24).

In South Africa the national burden of disease study used DALYs and disability weights from Australian NBD and GBD. The study also projected the burden of HIV/AIDS to the year 2010, and analysed the sensitivity of the YLLs to discounting and age weighting and to changing the standard life expectancies to local life expectancies. HIV/AIDS caused the highest burden in terms of DALYs and it was the first cause of premature mortality. Other top causes of burden included injuries, perinatal conditions and non-communicable diseases (25).

**THE CONDITIONS UNDER STUDY: GLOBAL AND REGIONAL BURDEN**

In 2002 malaria was the 9th leading cause of burden accounting for 3.12% of the total burden of disease. In the Eastern Mediterranean region it was the 16th leading cause of burden (1.6%). Measles accounted for 1.44% of global burden and 1.78% of regional disease burden, ranking 19th and 13th respectively. Protein energy malnutrition was the 23rd cause of burden globally (1.13%) and the 19th regionally (1.47%). Low birth weight was the 9th leading cause of DALYs lost globally accounting for 3.11% of total disease burden and the 4th regionally (4.72%). Maternal hemorrhage ranked the lowest among this group (72nd globally and 58th regionally). Diabetes mellitus and road traffic accidents were the 26th and 11th leading causes of burden globally respectively. At the regional level they were the 33rd and 8th respectively (26).

**PRIOR ESTIMATES OF DISEASE BURDEN FOR SUDAN**

Although no local burden of disease study was conducted specifically in Sudan, the GBD developed prior estimates for all WHO member states including Sudan using
various methods. The following methods were used to calculate country specific estimates for the diseases under study:

**Malaria**: country to sub-regional mortality ratio was applied to regional prevalence estimates (4).

**Measles**: country specific data were used to develop country specific estimates of measles incidence using a model based on demographic data, vaccination coverage and vaccination efficacy. It also used case fatality ratio from several studies (27).

**Protein energy malnutrition** (28): Country specific estimates were obtained from recent national surveys in the WHO member countries.

**Maternal hemorrhage**: the GBD estimated regional incidence of postpartum hemorrhage using multi-center studies that were not based on self reporting. It was adjusted for the availability of treatment as indicated by the proportion of births attended or managed expectantly or actively by skilled birth attendants. Mortality rates were predicted from all cause maternal mortality. The regional incidence to mortality ratios for each age–sex group were applied to country specific mortality due to maternal hemorrhage to calculate the country specific incidence of maternal hemorrhage (29). The same method was used for low birth weight (4).

**Diabetes mellitus**: for Sudan the national survey conducted in northern Sudan in 1992 (30) was used as a source of the prevalence rate (31).

**Road traffic accidents**: For all types of injury, age- and sex-specific ratios of incident non-fatal events to deaths were used to estimate regional incidence rates from health facility data. Incidence to mortality ratios were applied to country specific mortality to calculate country specific incidence (32).

The estimates were developed for the year 2000 and then adjusted for 2002 using mortality projections and epidemiological trends (4).
The following table shows prior DALY estimates for Sudan for the selected diseases as reported in the GBD

Table 2: Prior DALY estimates for Sudan for the selected diseases reported in the GBD 2002 revision

<table>
<thead>
<tr>
<th>Malaria</th>
<th>Measles</th>
<th>PEM</th>
<th>Low birth weight</th>
<th>Maternal haemorrhage</th>
<th>Diabetes mellitus</th>
<th>Road traffic accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>787099</td>
<td>205608</td>
<td>190602</td>
<td>252847</td>
<td>50342</td>
<td>82849</td>
<td>362500</td>
</tr>
</tbody>
</table>

Source: Prior estimates of incidence, prevalence, mortality and average duration for Sudan in 2002 (33)
CHAPTER TWO
MATERIALS AND METHODS

STUDY DESIGN

Descriptive synthetic case study

STUDY AREA

Geographic profile

Sudan is an African country with a total area of 2,506,000 squared km (about 1 million square miles). It is divided politically into states:

Khartoum state, the capital, Nahr-Elnil state, Northern state, Red Sea, Kassala, Gadarif, Al-Gezira, Sinnar, Blue Nile and White Nile states, Northern, Southern and Western Kordofan states, Northern, Southern and Western Darfur states. The southern states include: Upper Nile state, Jonglei state, Unity state, Warab state, Lakes state, Bahr Aljabal, Northern Bahr Algazal, Western Bahr Algazal, Eastern Equatoria and Western Equatoria states (33).
Demographic and economic profile

Table 3: Some demographic and economic indicators for Sudan in 2002:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>32,769,000</td>
</tr>
<tr>
<td>Annual growth rate</td>
<td>2.63%</td>
</tr>
<tr>
<td>Sex ratio</td>
<td>98.5 males per 100 females</td>
</tr>
<tr>
<td>Crude birth rate</td>
<td>37.8 per 1000 population</td>
</tr>
<tr>
<td>Crude death rate</td>
<td>11.5 per 1000</td>
</tr>
<tr>
<td>Population under 5 yrs</td>
<td>15.89%</td>
</tr>
<tr>
<td>Population 5 – 24 yrs</td>
<td>45%</td>
</tr>
<tr>
<td>Women in reproductive age</td>
<td>15.13%</td>
</tr>
<tr>
<td>Urbanization</td>
<td>34.8%</td>
</tr>
<tr>
<td>Male life expectancy at birth</td>
<td>52.5 years</td>
</tr>
<tr>
<td>Female life expectancy at birth</td>
<td>55.5 years</td>
</tr>
<tr>
<td>Per capita GNP</td>
<td>$US 330</td>
</tr>
<tr>
<td>Per capita GDP</td>
<td>$US 570</td>
</tr>
<tr>
<td>Adult literacy rate</td>
<td>49.9%</td>
</tr>
<tr>
<td>Economically active population</td>
<td>48.5%</td>
</tr>
</tbody>
</table>

Source: Annual Statistical Report 2002 (34)

Health profile

According to the results of the multiple indicator cluster survey, the infant mortality rate in 2002 was 108 per 1000 live births for males and 99 per 1000 live births for females. 40% of the population did not have access to improved source of drinking water (35). Maternal mortality was 509 per 100,000 live births (36). Sudan is categorized by the WHO (World Health Organization) in mortality stratum D, i.e. high child mortality and high adult mortality (7).

HEALTH RELATED DATA SOURCES

A/ Vital registration system

The records of births and deaths in the population of each state are kept by the state bureau of statistics. It covers all the 16 states in the north but only 3(Upper Nile, Bahr – Elgazal and Equatoria) of the southern states. In the past years deaths were registered by all health facilities available in an area: hospitals, health centers, dispensaries, and by
community leaders and peoples committees. These might or might not issue a death certificate depending on the legal need for it. While all deaths occurring in hospitals were registered, not all deaths occurring in the community were so. In more recent years, only deaths with death certificates signed by a doctor were registered, which further reduced the death registration (personal communication, Khartoum state Statistical Bureau, 2002). In-patient hospital deaths are reported monthly to state ministries of health which report them to the Federal Ministry of Health. The causes of death are coded using the ICD – 10 (International Classification of Disease), the data summarized by age, sex, state and cause and published in a yearly report together with other health facility statistics (34).

Causes of death are not available for all registered deaths. The available data varies in quality. Only hospital in-patient deaths and those which were examined post – mortem are medically certified and therefore have information on causes of death. Cause of death data for some of the rest of the deaths is obtained by lay reporting. The GBD study estimated vital registration coverage for the region of Sub – Saharan Africa to be 1.1 % (13). Using the Brass – Growth – Balance method (2), adult (above 5 years) death registration completeness in 14 reporting states in Sudan in 2002 was 4.8%; 6.4% for males and 3.3% for females (Annex A).

**B/ Demographic censuses**

These are carried out every 10 years, the last census being in 1993. It covered all the northern states with the results for the southern states projected from the results of the 1983 census. These censuses provide total population numbers by age and sex categories for each state, in addition to number of deaths during the census year by age, sex and state. Projections of the population size by age, sex and state are available at 5 yr intervals from 1993 to 2018 (37).

**C/ Routine health service records**

Data from health facilities are reported to the statistics department of the state ministries of health where they are compiled and monthly reports sent to the National Centre for
Health Information in the Federal Ministry of Health. It includes data about disease specific outpatient number of visits, inpatient admissions and deaths, in addition to the utilization of the different services in these health facilities (34).

**D/ National population surveys**

These are surveys that use a nationally representative sample of the population. Many surveys have been conducted in Sudan in the last decade. These include:

1. Sudan demographic and health survey (SDHS): conducted in 1989/1990 and provides infant and maternal mortality and morbidity information as well as adult mortality (38).

2. Sudan maternal and child health survey (PAPCHILD): conducted in 1992/1993 for northern Sudan and 3 states in southern Sudan, and provided information about many aspects of maternal and child health including maternal, infant and child mortality rates, adult female mortality rate, and prevalence of childhood diseases and accidents (39).

3. Safe Motherhood Survey (SMS): conducted in 1999, this was a comprehensive survey of reproductive health status in Sudan. It provides maternal, infant and child mortality rates and reproductive morbidity rates. It covered only northern Sudan and 3 urban centers in southern Sudan (36).

4. Multiple Indicator Cluster Survey (MICS) in 2000. They provide information about child health, some aspects of reproductive health and other health indicators, for all of northern and part of southern Sudan (35).

**E/ Other useful data sources**

Other sources available include surveys and surveillance data of varying quality and representativeness from the different communicable disease control programmes, Directorate of Primary Health Care, studies conducted by academic institutes,
governmental and non-governmental organizations. Police and military forces records also contain data about the different types of injuries.

**STUDY POPULATION**

The study measured the burden of the selected diseases and injuries in all the population, males and females of all ages in the year 2002, at the national level.

**STUDY VARIABLES**

1. **Demographic variables:**
   - Total midyear population by age and sex for the study population in the year 2002.
   - All cause mortality rates by age and sex for the study population in the year 2002.

2. **Cause of death data:**
   Age, sex and cause specific mortality rates in the study population for the year 2002.

3. **Standard life expectancies for each age and sex category.**

4. A set of at least three morbidity estimates of disabling sequelae of diseases and injuries, for each age and sex category of the study population. The estimates included:
   - Incidence rate.
   - Prevalence proportion.
   - Remission rate.
   - Case fatality rate.
   - Relative risk of mortality.
   - Average duration of each disabling sequelae for each age and sex group.

5. **Disability weights for each disabling sequelae.**

**METHODS OF DATA COLLECTION**

A systematic review of related studies was carried out using the following search strategy:
Search of local databases at:

1. National research centre: the electronic data base was searched using the diseases names as keywords. The studies were extracted from the center’s library by photocopying or direct review and summarization.

2. Sudan library – University of Khartoum:

   The electronic database and printed catalogues were searched for all health related postgraduate theses catalogued in the library (up to 2001), and concerning the diseases under study. The keywords used in the electronic search were formed of the diseases names. The studies reviewed were registered in the library by date of review, author, name and address of reviewer for ethical purposes. Because theses submitted after 2001 were not catalogued and one catalogue was still in press, the following sources of postgraduate theses of the University of Khartoum were searched:

   a. Faculty of medicine university of Khartoum library printed catalogue of postgraduate theses from health related faculties.

   b. Hand search of the archives of the Faculty of postgraduate studies – University of Khartoum, for theses from the faculties of Medicine, Science, Pharmacy and Public and Environmental health, submitted after 2001.

3. The books of abstracts of the Department of Paediatrics and Child Health and the Department of Obstetrics and Gynaecology of the University of Khartoum. Relevant theses were obtained from the department libraries. The books also helped in identifying theses missed in the Sudan Library search.

4. National medical specialization board:

   A printed list of all submitted theses was examined and eligible theses reviewed and summarized.
**Search of international databases**

The electronic databases, Pubmed, Ovid and Embase were searched using keywords formed basically of the disease name, sequelae, area of study, and other relevant words. Annex (B) shows a list of the keywords used.

Electronic databases were searched to find research papers not listed in local databases and identify research done in Africa or internationally were no local study in a certain research area was found.

Abstracts were reviewed and eligible studies identified and obtained from open access databases (Biomed Central, Ingenta, Blackwell Synergy, Ovid, Science Direct and HINARI).

Individual contact with researchers at health research institutes:

The institutes where contacted and areas of research and key researchers in the diseases under study identified and contacted. They were informed about the study and published papers were obtained in hard or soft copy. Unpublished work was obtained in documents or interview with the researchers. The researchers were asked to identify other researchers working in the same field and these were also contacted and information obtained in the same way. Researchers were also approached for papers identified from international databases but could not be obtained in full text.

**Non governmental organizations**

These were contacted for surveys and data from surveillance conducted by them in their specific project areas.
Reference tracing

Papers and theses identified from databases search were screened for relevant references and these were searched in open access web sites, libraries and by contacting the researchers who participated in the studies.

Federal Ministry of Health data

Reports and studies from directorates and administrations of the Ministry of Health were obtained.

Annex (C) shows a list of all places contacted for data.

Data collection tools

1. Data collection checklist:

This was used by the data collectors to record information from the abstract and sometimes from the full report, to aid in selection of the eligible studies.

2. Study summary sheet:

This was used to extract relevant information from full text reports or papers. It summarized the identifying information of the study, eligibility of the study, its quality and the relevant results (Annex D).

Conduct of the search

The search was conducted by the investigator and 2 data collectors. The data collectors were trained on electronic search, extraction of full text reports from open access web sources, review of abstracts and filling data collection checklists. When the search was conducted by the data collectors, information about eligibility of the study was recorded by them in the data collection checklist. The investigator used the latter to select eligible studies, review them and summarize them in the study summary sheet. When the search
was done by the investigator, the eligibility was determined directly from the study. The study selection, review and summarization were done by the investigator only.

**Study eligibility criteria**

1. Health related population based studies. However hospital based studies were included for complications of the diseases where no population based studies could be found, for injuries and severe conditions of which most of the surviving cases are expected to be found in hospital.

2. Local published and unpublished studies. International studies and regional studies were included only where no local ones could be found or when they were considered to be more reliable.

3. Giving at least one of the following epidemiological estimates:
   a. Incidence rate or proportion with the duration.
   b. Prevalence proportion.
   c. Disease specific mortality hazard or mortality rate with the duration of follow up.
   d. Case fatality rate or the case fatality ratio with duration of follow up.
   e. Remission rate or remission ratio with duration of follow up.
   f. Average duration of the disease.
   g. Age distribution of the disease.
   h. Sex distribution of the disease.
   i. Distribution of complications.
   j. Relative risk of mortality.

There were no restrictions regarding time of the study, geographical region, age groups or sex groups.

The studies selected for use were the most recent, most representative, with the best methodological quality, and with some exceptions, applying the same case definition used for developing the disability weights of the GBD.
**SOURCES OF THE DATA OBTAINED:**

- Localized and multi-center hospital based studies
- Localized population based studies
- National surveys
- African and international studies
- Official reports of the Federal Ministry of Health, Traffic Police, and the SPLM (Sudan People Liberation Movement) health secretariat.
- NGO surveillance reports
- GBD data

**ETHICAL CONSIDERATIONS**

In the case of unpublished data, a written informed consent was obtained from the investigator or the person in charge of the data. The consent explained the purposes of the study and guaranteed protection of the data Annex (E).

**DEVELOPMENT OF DEMOGRAPHIC ESTIMATES**

**Total population in 2002 by age and sex**

Projections of the population size for the year 2002 were available by state only, without age and sex disaggregation. The 1998 – 2003 medium projections by age and sex were obtained from the CBS for Sudan (37), and the projections for the year 2002 were interpolated as follows:

The annual growth rate for each age and sex group was calculated as follows:

\[ r = \frac{\ln P_t}{P_0 / t} \]
Where $r =$ annual growth rate.

$P_t =$ population at the next projection year (2003)

$P_o =$ population at the base year (1998).

t is the time interval between the base year and the next projection year.

The population size for each age and sex group for the required year was calculated using the following formula:

$P_t = P_o \times e^{rt}$

Where

- $P_t =$ population size to be calculated.
- $P_o =$ population at the base year.
- $e =$ the natural number.
- $r =$ annual growth rate.
- $t =$ the interval between the base year and the required year.

Source: Central Bureau of Statistics (CBS)

Population size and composition for southern Sudan in 2000 were obtained from results of MICS southern Sudan (40), and projected to the year 2002 assuming an annual growth rate of northern Sudan of 2.6%. The data was provided for 3 age groups: <5, 5-17 and >17. It was used in the calculation of the burden of measles.

The calculations were made on Microsoft Excel 2002 (41).
All cause mortality rates

Death registration completeness for ages 5 years and above was assessed using the Brass – Growth Balance method (Annex A). It was found to be lower than the standard set for conduction of burden of disease studies, rendering vital registration system unsuitable for providing mortality data.

All-cause mortality rates were calculated from the mortality envelope for Sudan, used in the GBD 2002 (33). The number of death reported in each age and sex group was divided by the midyear population of that group to obtain mortality rates for 2002. Calculations were made using Microsoft Excel 2002 (41).

The total population and mortality rates were used as the demographic input for DISMOD.

METHODS OF DEVELOPMENT OF INTERNALLY CONSISTENT EPIDEMIOLOGICAL ESTIMATES

For all diseases under study, models were developed to calculate epidemiological estimates from the best and sometimes the only data available. In some instances the models were based on the GBD models. The methods used the case definitions and sequelae of the GBD. With one exception, it was assumed that there were no trends in the epidemiology of the diseases under study, due to lack of time series data. The models, assumptions, and data were revised and in some instances, modified by an expert in each disease. The experts were consulted separately. Annex F shows a list of all experts consulted at this step.
METHODS USED FOR EACH DISEASE

MALARIA

Sequelae, case definitions and disability weights:

<table>
<thead>
<tr>
<th>Sequelea</th>
<th>Case definition</th>
<th>Disability weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>Infectious disease caused by protozoa of the genus Plasmodium</td>
<td></td>
</tr>
<tr>
<td>Episodes</td>
<td>Attacks of chills, fever, and sweating due to Plasmodium infection</td>
<td>0.183</td>
</tr>
<tr>
<td>Anaemia</td>
<td>Defined using WHO criteria for mild to very severe anaemia.</td>
<td>0.012</td>
</tr>
<tr>
<td>Neurological sequelae</td>
<td>Includes hemiplegia, aphasia, ataxia and cortical blindness.</td>
<td>0.458</td>
</tr>
</tbody>
</table>

WHO criteria for mild to severe anaemia:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>Haemoglobin of 100-109 g/l in pregnant women, 110-119 g/l in children and adult women and 120-129 g/l in adult men.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Haemoglobin of 70-99 g/l in pregnant women, 80-109 g/l in children and adult women and 90-119 g/l in adult men.</td>
</tr>
<tr>
<td>Severe</td>
<td>Haemoglobin of 40-69 g/l in pregnant women, 50-79 g/l in children and adult women and 60-89 g/l in adult men.</td>
</tr>
</tbody>
</table>

Source: GBD 2002 (4).

Preliminary estimates developed:

1. Incidence of malaria cases in 2002.
2. Average duration of malaria episodes, neurological sequelae and anaemia.
3. Case fatality hazard.
4. Proportion of malaria cases developing complications: anaemia and neurological sequelae.
Assumptions

1. Under reporting of fever presumed malaria is the same for all age groups and remains constant through time.
2. Underreporting of fever presumed malaria is the same in southern Sudan as in northern Sudan.
3. The epidemiological demarcation between low endemicity and high endemicity areas follows the geographic demarcation between the northern and southern states of Sudan.

Calculations

The incidence of malaria was calculated as follows:

Incidence of fever presumed malaria:

The cases reported to the formal health system as malaria were considered as fever presumed to be malaria since some could have been diagnosed only on clinical basis. Even health facility confirmation of malaria was of variable validity (42,43). The degree of underreporting of fever presumed malaria for children below 5 was calculated as follows:

The total number of reported cases below 5 years in 2000 (44) was divided by 26 to find the average biweekly incidence of episodes. The assumption was that the number represented single episodes and not more than 1 visit for the same episode.

The biweekly incidence of fever treated as malaria in children below 5 years from the MICS 2000 for northern Sudan (45) was taken as a gold standard. It was divided by the average biweekly incidence from the reported cases to find the underreporting factor.

This factor was assumed to apply for all ages since there was no validation data for ages 5 years or more. It was also assumed to apply to the year 2002. The total number of cases reported to the formal health system of the northern states in 2002 as malaria (34) was multiplied by the underreporting factor. For southern Sudan, Sudan People Liberation Movement (SPLM) health secretariat report (46) gave the number of reported cases in
2002 and assuming the same underreporting factor, the total number of cases of fever presumed malaria was calculated for southern Sudan.

To calculate the incidence of true malaria, the calculated number of episodes was multiplied by 30% for northern Sudan. This was the median value summarizing the results of population based studies that gave the percentage of fever presumed malaria episodes diagnosed as malaria with a positive blood film (47-49). A higher percentage (50%) was used for cases of the southern Sudan, since in this high endemicity area; the positive predictive value of fever was expected to be high. The numbers of true malaria episodes for northern and southern states were added to produce the total national number of episodes expected to have occurred in 2002. The incidence rate of malaria was found by dividing the number by the total mid year population.

Disaggregation by age and sex:

The age and sex specific incidence rate was calculated using age - sex ratios developed from a longitudinal study in a hypoendemic area (50) and population based surveillance results for fever (excluding other infections) in a hyperendemic area (51). The ratios were developed by dividing each age and sex specific rate by the overall incidence of each study, standardized for age using the Sudan population age structure. The age groups used for the input incidence where: <1, 1 -5, 6 – 10, 11 – 15, 16 – 20, 21 – 30, 31 – 40, 41 – 50, >50.

Average duration:

The GBD 2000 assumption for Sudan, 0.011 years was used. Duration was an input because the remission was high and the duration was short. The duration was assumed to be the same for all age and sex groups (33)
Case fatality hazard:

Only one study gave the case fatality ratio with the duration of hospitalization of the cases. The case fatality ratio from this study (52) was converted to a hazard using the following formula:

\[
\text{Hazard} = \frac{-\ln (1 - p)}{d}
\]  

(2)

Where \(p\) is the proportion and \(d\) is the duration of follow up.

Proportion of malaria cases developing anaemia:

The proportion of malaria cases in all population groups, developing severe anaemia was reported in one study (52). The proportion of cases developing all forms of anaemia was calculated from this study by multiplying the proportion developing severe anaemia by 2.5. This factor is the median of a range of factors derived from studies that report the proportions of all types of anaemia in different population groups (53-55). The proportion was assumed to be the same for all Sudan and for all the age – sex groups.

Average duration of anaemia was assumed to be 1 year as in the GBD 2002 prior estimates for Sudan (33).

Proportion of cases developing neurological sequelae:

Due to lack of data, the proportion used was restricted to neurological sequelae from cerebral malaria. The same study used for the proportion developing severe anaemia was used for the proportion of cases developing cerebral malaria. Studies reported the proportion of cerebral malaria cases developing neurological sequelae for population group 0 – 9 only (56). A proportion reported in Nigeria was used (57). It was assumed to be the same for Sudan and for all age - sex groups.
DISMOD

DISMOD was used to produce an output set for malaria episodes using the input set of incidence, average duration and case fatality hazard. The output incidence was used to calculate incidence of neurological sequelae by applying the proportion developing neurological sequelae from cerebral malaria. DISMOD was also used to calculate the average duration of neurological sequelae using the incidence rate, assuming a case fatality rate of 0 for all groups, and using a remission hazard, calculated from the remission proportion and duration of follow up of the Nigerian study (57) and assumed to be the same for all groups.

Measles

Sequelae, case definitions and disability weights:

These are diarrhea, pneumonia and malnutrition. Burden of mortality from these sequelae was attributed to measles while burden of disability was attributed to the respective diseases.

Case definitions and disability weights used:

<table>
<thead>
<tr>
<th>Disease</th>
<th>Case definition</th>
<th>Disability weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measles episodes</td>
<td>Acute and highly contagious infection with measles virus characterised by red, blotty rash, fever, cough, coryza and conjunctivitis</td>
<td>0.152</td>
</tr>
<tr>
<td>Measles death</td>
<td>Death occurring within 1 month after onset of measles</td>
<td></td>
</tr>
</tbody>
</table>

Source: GBD 2002 (4).

Preliminary estimates developed:

1. Incidence rate.
2. Case fatality hazard.
3. Remission hazard.
**Calculations**

The model used in GBD 2000 to calculate the global burden of measles was adopted (27). The model assumed the following:

1. Universal infection: all susceptible children will ultimately contract measles (GBD assumption).
2. No sex differences in disability or mortality (GBD 2000 assumption).
3. Average duration of 2 weeks (GBD 2000 assumption).
4. The burden of measles falls only on the age group 6 months – 19 years (GBD 2000 assumption).

Choice of the model was based on the fact that vaccination coverage in Sudan was less than 80% (40,45), no mass vaccination campaigns were conducted in 2002, and surveillance was not case based in 2002 (personal communication, Expanded program of immunization (EPI), 2004).

**Incidence:**

With the universal infection assumption, incidence of measles was calculated as follows:

Total number of incident cases = susceptible birth cohort = Birth cohort in 2002 – (Birth cohort X VC X VE).

Where VC is the vaccination coverage and VE is the vaccination efficiency.

The birth cohort was calculated by multiplying the crude birth rate by the total population. Calculations were done separately for northern Sudan due to differences in the 2 factors. (34,40). Vaccination coverage for northern and southern Sudan was obtained from national surveys (40,45). Vaccination efficacy was 85% because the vaccine is given in one dose before the first year of age (27). Total incidence rate was calculated by dividing the total number of incident cases in northern and southern Sudan by the total population of Sudan. It was disaggregated into 4 age groups: <1, 1 – 4, 5 –
Materials and Methods

19, 20+ for both males and females. The age distribution of a small scale longitudinal population based study (58) was used as recommended by expert opinion. The incidence was assumed to be the same for both males and females.

Case fatality hazard:

Only 2 studies gave the case fatality ratio and duration of follow up and their case definitions of measles mortality matched that of the GBD (59,60). Two different case fatality hazards were calculated, one from each study.

Remission hazard:

A remission ratio was calculated from each case fatality ratio by subtracting it from 1. 2 remission hazards were therefore calculated.

DISMOD

Two input sets were used, with the same incidence rate and two different sets of case fatality and remission hazards. The input was processed and the output set that produced an average duration of 2 weeks (GBD assumption endorsed by expert opinion), was selected for use. The output incidence and mortality age distribution was different from that recommended by experts and only the overall incidence and mortality outputs were used. They were divided into the recommended age distribution.
**Protein energy malnutrition**

*Sequelea, case definitions and disability weights:*

<table>
<thead>
<tr>
<th>Sequela</th>
<th>Definition</th>
<th>Disability weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wasting</td>
<td>Observed weight for height at least 2 standard deviations below the mean for 0-5 year old children.</td>
<td>0.053</td>
</tr>
<tr>
<td>Stunting</td>
<td>Observed height for age at least 2 standard deviations below the mean for 0-5 year old children.</td>
<td>0.002</td>
</tr>
<tr>
<td>Developmental disability</td>
<td>Limited physical and mental ability to perform most activities in all of the following areas: recreation, education, procreation or occupation</td>
<td>0.024</td>
</tr>
</tbody>
</table>

Source: GBD 2002 (4).

*Preliminary estimates developed:*

1. Prevalence of wasting
2. Prevalence of stunting
3. Prevalence of underweight
4. Mortality hazard of wasting
5. Incidence rate of wasting

*Assumptions*

1. Relative risk of wasting when comparing northern and southern Sudan applies also to stunting and underweight.
2. Average duration of wasting is 5 years (GBD 2000 assumption) (28).
3. The proportion of children developing developmental disabilities is the proportion that was underweight (GBD 2000 assumption) (28).
4. Stunting and developmental disabilities are permanent (GBD 2000 assumption) (28).
5. Mortality results only from wasting (GBD 2000 assumption) (28).
6. No sex difference in wasting, stunting and underweight.
Calculations

Prevalence of wasting:

The prevalence data was obtained from national surveys and calculations were made separately for northern and southern Sudan.

Northern Sudan:

Trend in wasting was estimated using time series data from three national surveys (39,45,61). The prevalence reported in MICS 1995 (61) and 2000 (45) were adjusted for seasonal variation. The first was measured in the dry season and the second in the rainy season. Using a relative risk of 2 derived from a longitudinal study (62), and assuming the same average duration in the dry as rainy season, the average prevalence proportions were calculated. More data points (one for each year) were created by linear interpolation between the original data points. The data fitted a cubic model and the prevalence in 2002 was calculated using the following equation:

\[ Y = 3.11 + 12.11t - 2.56t^2 + 0.15t^3 \]

\( Y \) is the prevalence and \( t \) is time from \( t_0 \) where \( t_0 \) is 1993

Southern Sudan:

Trend was estimated from MICS 1995 (61) and MICS 2000 (40). The latter measured the prevalence of mid upper arm circumference less than 12.5cm. This was used to calculate the prevalence of wasting by adjusting it for less than perfect sensitivity and specificity, using the following formula:

\[ \text{Adjusted prevalence} = \frac{\text{Apparent prevalence} + \text{specificity} - 1}{\text{Sensitivity} + \text{specificity} - 1} \]

Source: Epidemiologic methods for health policy (63).
The sensitivity and specificity from a study in Rwandan refugees was used (64).

The prevalence of wasting in southern Sudan in 2002 was calculated by applying the estimated trend.

The overall prevalence for Sudan was calculated for one age group 0 – 4 years by an average of the prevalence in northern Sudan and the prevalence in southern Sudan weighted by the mid year population under 5 of the 2 regions.

Prevalence proportions of stunting and underweight:

Northern Sudan:

The trend was estimated from 2 surveys: the PAPCHILD (39) and MICS 2000 (45). It was applied to calculate the prevalence of stunting and wasting in 2002.

Southern Sudan:

This was estimated from the prevalence in northern Sudan by applying to it the wasting ratio of northern Sudan to southern Sudan.

The prevalence proportions for northern and southern Sudan were pooled to calculate the overall prevalence of stunting and underweight.

Mortality hazard of wasting:

The mortality rate of wasting was calculated by applying a proportionate mortality of 2.6% used in the GBD 2000 (28) to the under 5 mortality in northern and southern Sudan. A weighted average of the resulting specific mortality for the 2 regions was calculated and used as a mortality hazard, since at low rates, the population rate equals the hazard (2).
Incidence rate of wasting:

This was calculated from the prevalence by applying an average duration of 5 years as assumed by the GBD 2000 (28).

DISMOD:

The software was used to produce an internally consistent incidence and mortality rates of wasting using the 3 preliminary estimates developed. It was also used to calculate the average duration of stunting and developmental disabilities using the prevalence and assuming case fatality and remission hazards of zero for each.

**Low birth weight**

Sequelae

All developmental sequelae including cerebral palsy, mental retardation, epilepsy, hearing loss and visual loss have been grouped into one sequela (4).

Case definition

LBW: Birth weight below 2500g. It includes small-for-gestational-age infants and premature infants (4).

Disability weights

0.106 for all sequelae (4).

Preliminary estimates developed

1. Incidence hazard of low birth weight sequelae
2. Number of deaths in each sex group.

Assumptions

1. Rural and urban differences in the prevalence proportion of low birth weight in northern Sudan apply to southern Sudan.
2. No sex difference in mortality rate of low birth weight.

Calculations

The calculations were done separately for northern and southern Sudan. For northern Sudan the prevalence of low birth weight was obtained from the SMS survey (36). For southern Sudan the prevalence was calculated for rural areas from urban prevalence (35), by applying the urban to rural prevalence ratio of urban to rural prevalence in northern Sudan assuming that the same differences exist in southern Sudan. The urban and rural prevalence proportions of southern Sudan were pooled to calculate the overall prevalence proportion. The prevalence proportions for northern and southern Sudan were then pooled to calculate the overall prevalence for Sudan. The disability hazard was calculated from data of a longitudinal study (65). It was applied to the prevalence of low birth weight to calculate the incidence hazard of low birth weight disability sequel.

The number of deaths in each sex group was calculated by applying the proportionate mortality of 5.2% (GBD assumption) to the under five mortality for Sudan, calculated by pooling that for northern and southern Sudan (36). The mortality rate was assumed to be the same for males and females and the number of deaths in each group was calculated by applying the mortality rate to the mid – year population under 5 in each group in 2002.

DISMOD:

The software was used to calculate the average duration of disability from low birth weight for each age – sex category using the preliminary incidence hazard estimates and assuming a case fatality and remission hazards of zero.
Maternal haemorrhage

Sequelae, case definitions and disability weights

<table>
<thead>
<tr>
<th>Sequelae</th>
<th>Case definition</th>
<th>Disability weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe anaemia from maternal hemorrhage</td>
<td>Blood haemoglobin level &lt; 10mg/dl following postpartum haemorrhage</td>
<td>0.093</td>
</tr>
</tbody>
</table>

Source: GBD 2002 (4).

Preliminary estimates developed

1. Incidence rate
2. Remission hazard
3. Mortality hazard

Assumptions:

1. The mortality burden is due to the immediate effect of haemorrhage.
2. Severe anaemia is precipitated by haemorrhage in women with moderate anaemia at the time of delivery (GBD assumption) (29).

Calculations

Age specific incidence rate:

2 sources were used:

1. Safe motherhood survey (36)
   The incidence of PPH was calculated by multiplying the proportion of live births complicated by self reported PPH by the incidence of live births per 1000 women reported in the same survey.
   The incidence was calculated for the age group 15 – 49, divided into seven 5-year age groups, as in the data source used, to derive the incidence. The calculations were conducted separately for each age group.

2. MOMA study (66):
   This was a multi-center population based longitudinal study in Africa. The incidence of PPH reported in the study was adjusted for the differences in
proportion of births attended by skilled birth attendants between the study population and Sudan population. Since no age specific incidence rates were reported in the study, adjustment for age could not be performed. The incidence of PPH in births attended by doctors, midwives and those not attended was calculated using the proportion attended by skilled birth attendants in the study group, and the following assumptions:

a. The incidence of hemorrhage in births not attended by skilled birth attendants is twice that in births attended by skilled attendants with expectant management (29).

b. The incidence in those managed expectantly is twice those managed actively (29).

c. The proportion of births attended by midwives was managed expectantly and that attended by doctors was managed actively.

The incidence rates were applied to the proportions in Sudan to calculate the overall incidence of postpartum hemorrhage.

Mortality hazard:

Three sets of mortality hazards were calculated from 3 different sources:

1. The proportionate mortality from hemorrhage was derived from a number of hospital reports from different parts of the country (67-73). The median proportionate mortality was used to summarize the results of these studies and was similar to the value used in the GBD 1990 (74) and 2000 (29). The overall maternal mortality rate reported in the SMS (36) was assumed to be the same for all groups between 15 and 49 years. The maternal mortality per 100000 live births due to hemorrhage was calculated from the estimated proportion and the maternal mortality ratio. This was converted to maternal mortality per 1000 women for each age group using the incidence of live births per 1000 women in each age group.

2. The case fatality ratio from a local hospital based study (75) was applied to the age specific incidence to calculate mortality.

3. The case fatality ratio from the MOMA study (66) was applied to the age specific incidence.

Remission hazard:

This was calculated roughly from the case fatality ratio from the population based study assuming duration of 1 day.
Proportion developing severe anaemia:

Two methods were used:

1. The proportion was obtained from a local hospital based case study (75). The proportion was assumed to apply to all age groups between 15 and 49.

2. An indirect method was also used. This method first calculated the proportion of hemorrhage cases that were anemic, assuming that this proportion will progress to severe anaemia after a hemorrhage episode. The method assumes independence between anemia and hemorrhage. The proportion of anemic cases was calculated as follows:

   The proportion of hemorrhage cases who attended antenatal care was calculated by a weighted average for the trimester specific proportions from the SMS (36).

   The proportion of live births with hemorrhage and attending antenatal care and not taking iron or folate supplementation was calculated using the proportion of antenatal care attendants (36) and the proportion of this not taking supplementation (36).

   Proportion not attending antenatal care and having hemorrhage was then added to the proportion of live births with antenatal care attendance, no supplementation and having hemorrhage. The joint proportion was multiplied by the probability of becoming anaemic in the absence of supplementation from a health facility based study of antenatal care attendants (76).

Both methods gave very similar results.

Average duration of severe anaemia:

That of the GBD 2002 prior estimates for Sudan was used.

DISMOD:

The software was used to produce an internally consistent set by entering the input set and varying the mortality rate. The output incidence was used to calculate the incidence of severe anaemia by applying the proportion from method 1.
Diabetes mellitus:

Sequelae, case definitions and disability weights

<table>
<thead>
<tr>
<th>Sequelae</th>
<th>Case definitions</th>
<th>Disability weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>Venous plasma concentration of µ 11.1 mmol/l 12 h after a 75g oral glucose challenge</td>
<td>0.014</td>
</tr>
<tr>
<td>Diabetic foot</td>
<td>Chronic or recurring diabetic foot ulcers</td>
<td>0.134</td>
</tr>
<tr>
<td>Neuropathy</td>
<td>Loss of reflexes and of vibration; damage and dysfunction of sensory, motor or autonomic nerves attributable to diabetes</td>
<td>0.073</td>
</tr>
</tbody>
</table>
| Retinopathy – blindness | **Retinopathy**: Microaneurysms or worse lesions in at least one eye; progressive damage of the small blood vessels of the retina  
**Blindness**: Unable to distinguish the fingers of a hand at the distance of 3 meters, or, has less than 5% of remaining vision as compared to a normally sighted individual; visual acuity of less than 3/60, or corresponding visual field loss in the better eye with best possible correction | 0.555              |
| Amputation              | Surgical elimination of the lower extremity or part of it because of gangrene    | 0.120              |

Source: GBD 2002 (4)

Preliminary estimates developed

2. Remission rate.
3. Relative risk of mortality.
4. Proportions of disabling sequelae.

Assumptions

1. Burden of diabetes mellitus is attributable to Type I and type II only (GBD 2000) (31).
2. There are no differences in the burden of the 2 types (GBD 2000) (31).
3. Equal sex distribution of disability.
4. Equal age distribution of disability.
5. Amputations, neuropathy and diabetic septic foot will be assumed occur only after the age of 19 years (GBD 2000) (31).
6. Blindness due to retinopathy will be assumed to occur only after the age of 14 years (GBD 2000) (31).

Calculations

Age and sex specific prevalence of disability:

The prevalence was calculated differently for age groups: 0 – 14, 15 – 24 and 24+.

Age group 24+

The age and sex specific prevalence was obtained from a population based study representing northern Sudan (30) and reporting in 3 age groups: 25 – 44, 45 -64 and 65+. For southern Sudan, the prevalence was assumed to be 1% derived from the relatively low prevalence proportions of neighboring African countries to the south of the Sudan (77) and recommended by expert. It was assumed to be the same for all ages above 24 and for both sexes. The age and sex specific prevalence for all Sudan was calculated by first combining the overall prevalence for northern and southern Sudan through an average weighted by the population sizes. Then the new overall value was divided into 3 age groups using the age and sex distribution of the prevalence in northern Sudan assuming that it also applies for southern Sudan.

0 to 14 years:

An incidence rate was available for this group (78) and was assumed to be the same for all Sudan. Prevalence was calculated from incidence by multiplying the latter by the average duration derived from the GBD 2002 prior estimates of average duration for this age group for Sudan (33). It was assumed to be the same for males and females.
15-24 years:

There was no local data for this age group. A value was calculated by estimation from the age group 24+ using the distribution reported in the Saudi Arabia study (79) which considered the age group 15-29 years in addition to older groups. However the value estimated for males was much lower than that of females and lower than the other age groups. Because the distribution of the prevalence for males was inconsistent with local and regional GBD estimates (33), 2 more values were estimated for males as follows:

1. By linear interpolation between the below 15 years and the above 24 years age groups.
2. Assuming that the prevalence was the same as for females.

Remission rate:

This was 0 for all age and sex groups

Age and sex specific relative risk of mortality:

Relative risk of mortality for diabetes cases, used in the GBD 2000 (31) was adopted. For blindness due to retinopathy, a relative risk of mortality of 2.5 was used for both males and females (80,81).

Proportions of disabling sequelae:

Proportions from a multi-center study were used (82). No study reported the proportion developing diabetic septic foot or diabetic amputation or blindness. The proportion developing diabetic septic foot was estimated from the proportion developing angiopathy and peripheral neuropathy. The 2 latter conditions were assumed to be independent and their proportions were multiplied by each other to produce the proportion developing
both complications. 50% were assumed to develop diabetic septic foot if having both
conditions (personal communication; Gabir Abuliz Diabetes Center, 2004) and the joint
probability was therefore halved to produce the proportion developing diabetic septic
foot. Other small scale health facility based case studies reported the percentage of
diabetic septic foot patients undergoing amputations (83-85). The results of these studies
were summarized by a weighted average to provide a proportion for diabetic amputation
assumed to be resulting from diabetic septic foot only. The proportion developing
advanced retinopathy was used as a proxy to the proportion developing blindness. As for
blindness, the proportion developing advanced retinopathy was taken as a proxy to the
proportion developing blindness.

DISMOD:
The input set was entered in DISMOD, and the prevalence in males in the age group 15-
24 was varied between the 3 values calculated to produce an output with an age
distribution consistent with the GBD estimates. The software was also used to produce
the incidence and average duration of diabetes mellitus cases and to calculate the average
duration and incidence of diabetic neuropathy and diabetic amputation using the
prevalence and assuming a case fatality and remission rates of 0. Diabetic septic foot
duration was assumed to be 6 months as in the GBD. This was used together with the
prevalence and a series of remission rates to produce an internally consistent output with
the same average duration. The output for the average duration of diabetic septic foot for
some age - sex groups was more than 6 months and these were changed to 6 months.
The software was also used to calculate the incidence and average duration of blindness
using the prevalence, remission rate of 0 and the relative risk of mortality of blindness.
Road traffic accidents

Case definition

Road traffic accidents episodes include crashes and pedestrian injuries due to motor vehicles. An incident episode of non fatal injury is defined as “an episode that is severe enough for the person to be hospitalized or which requires emergency room care” (32).

Sequelae

One local hospital based study (86) reported on the injuries resulting from road traffic accidents and these were selected to be the sequelae to which the burden was attributed.

Preliminary estimates developed:

1. Incidence rate.
2. Mortality hazard
3. Case fatality hazard.
4. Incidence of disabling sequelae.
5. Relative risk of mortality.

Assumptions

1. Complete reporting of injuries from road traffic accidents.
2. Different natures of injury at each site will be assumed to occur equally since the available distributions are by site of injury rather than nature of injury.
3. Equal sex distribution across all subcategories.
4. Equal treatment proportions for short and long duration injuries.
Calculations

Incidence rate:

The incidence was calculated from the number of incident road traffic accident injuries reported by age in the traffic police annual report in 2002 (87). The number of cases in each age group was divided into male and female cases using a sex ratio of 7:3 (86). The age – sex specific incidence was calculated by dividing the number of cases in each group by the mid year population in 2002 for that group. The incidence was assumed to hold for all Sudan.

Case fatality hazard:

The case fatality rate for each age group was found by dividing the no. of deaths reported (87), by the total number of incident cases. A number of case fatality hazards were calculated assuming different durations of follow up (1yr, 0.5 year, 0.25 year). It was assumed to be the same for both males and females.

Mortality hazard:

The age and sex specific mortality rate was first calculated by dividing the no of deaths reported (87) by the total mid year population in 2002 for that group. The resulting population rate was used as hazard.

Incidence of disabling sequelae:

The proportion in each age group developing serious injuries was estimated from the annual report (87). Reported serious injuries are ones that required hospital transfer. These age specific proportions were applied to the output age specific incidence of road
traffic accidents to calculate the overall incidence of non fatal injuries for each age – sex group. The proportions were assumed to be the same for both males and females.

The incidence of each disabling injury was calculated separately for each age and sex group by whether the cases were treated or not, and by whether the disability was long term or short term, because of the variation in disability weights by treatment proportions and variation in the average duration by both factors. The distribution of sequelae was obtained from a local hospital based study (86). Division into treated and untreated cases and long term and short term disability was made using GBD 2000 proportions (32).

Average duration:

The average duration of disabling sequelae were obtained from the GBD 2000 (31), except for long term disability resulting from spine, skull and femur fractures, and from intracranial injuries.

DISMOD

The software was used to check the internal consistency of the preliminary estimates: incidence, case fatality hazard and mortality rates of road traffic accidents. The output incidence was used to calculate the incidence of disabling sequelae by applying the proportion developing serious injuries (calculated from report) to the output incidence. The software was also used to calculate the average duration of long term disability from spine, skull and femur fractures, and from intracranial injuries, using the incidence of these disabilities, remission rate of 0 and relative risk of mortality assumptions of the GBD 2000 (32).

Calculation of all preliminary estimates was done using Microsoft Excel 2002 (41).
STANDARD LIFE EXPECTANCIES

The standard life expectancies from a model life table, the Coale and Demeny West level 26 for females and level 25 for males were used (14). The standard life expectancies for the average age at death were interpolated from the life table, taking the average age at death of each age group as the midpoint for that group, except for the age groups <1yr and 1 – 4 years. For these the average age at death was taken as 0.3 years and 2.6 years respectively (2).

DISABILITY WEIGHTS

2 sets of disability weights, GBD 2000 weights and Ghana Health assessment team weights (22) were applied. The Ghana health assessment team weights were expected to be the most approximate to local preferences in Sudan.

DATA ANALYSIS METHODS

Calculation of years lost due to premature mortality (YLLs)

The mortality output of DISMOD for each disease and the standard life expectancy at the average age at death were used to calculate YLLs.

The basic formula is:

\[ YLL = N \times L \]

Where

- \( N \) = the number of deaths in each age - sex group in 2002.
- \( L \) = the standard life expectancy for the average age at death.

Total and age – sex specific YLLs were calculated.

Source: National Burden of Disease Studies: A Practical Guide (2)
Materials and Methods

Calculation of years lost due to disability (YLDs)

For each disease, the incidence of each disabling sequela, originating from DISMOD, was used with the average duration and its disability weight to calculate YLDs. The YLDs for all the sequela were added together to find the total YLDs for that disease. This operation was done for each age – sex group.

Formula used:

\[
\text{YLD for a disabling sequelae} = N \times L \times DW \ (3).
\]

Where:

- \(N\) = the number of incident cases of disabling sequelae of the disease or injury.
- \(L\) = the average duration of disability.
- \(DW\) = the disability weight for the sequelae.

Source: National Burden of Disease Studies: A Practical Guide (2)

Calculation of disability adjusted life years (DALYs)

For each disease, YLLs and YLDs for each age - sex group were added to calculate age-sex specific DALYs. These were added to calculate the total DALYs lost for that disease. DALYs per 1000 population were also calculated.

Sensitivity analysis

YLDs were calculated again using the Ghana Health Assessment Team disability weights. Since there were no disability weights in this set that were specific for severe anaemia following postpartum hemorrhage, low birth weight and road traffic accidents, the disability weights for adult female anaemia, birth diseases and injuries were used for these conditions respectively. For malaria and diabetes, the average duration of the episodes and cases respectively were used, excluding the sequelae. For measles, low birth weight and maternal hemorrhage, there was only one sequela per disease and its average duration
was used. For road traffic accidents, the disability weights were applied to each of the sequelae with its average duration because the sequelae were considered independent. For protein energy malnutrition, the sequelae were dependant and the disability weight given to malnutrition in general was high. Since only wasting was considered to be a cause of mortality and since it had the highest GBD disability weight it was selected for the application of Ghana disability weight. The resulting DALYs were compared with DALYs calculated separately for wasting.

The change in the burden of each disease for each age and sex group when using the Ghana disability weight set was calculated as a percentage of the burden when using the GBD weights.

**Data analysis tools**

Microsoft Excel 2002 spreadsheets (41) were used to calculate standard life expectancies, YLLs, YLDs and DALYS.
CHAPTER THREE
RESULTS

NATIONAL INCIDENCE AND MORTALITY ESTIMATES

The incidence and mortality rates of malaria by age and sex are shown in table 4. The incidence of malaria in males was 340.85 per 1000 and in females was 335.17 per 1000. The highest incidence for both males and females was in the age group 5 – 14 yrs. Mortality rate of malaria was 0.92 per 1000 and 0.90 per 1000 in males and females respectively. The age group 5 – 14 yrs in both males and females had the highest mortality as well.

Table 5 shows the incidence and mortality rates of measles. The overall incidence in measles was lower in males (11.4 per 1000) than in females (12.45 per 1000). The incidence was highest in the age group 0 – 4 yrs for both males and females and declined to reach zero after the age of 29 yrs. The overall mortality was also lower in males (0.48 per 1000) than in females (0.53 per 1000). As the case with the incidence, the mortality rate was highest in children less than five years for both males and females and declined to a very low rate in the age group 15 – 29 yrs after which it was zero.

As shown in table 6, the overall incidence in males of wasting, stunting and developmental disability was, 4.03, 23.88 and 21.57 per 1000 respectively. The incidence of wasting was higher in females (4.25 per 1000) but the incidence of stunting and developmental disability was lower in females (23.26 and 21.01 per 1000 respectively).

Table 7 shows the mortality rate of wasting in children less than five years which was almost equal for males and females (0.45 and 0.44 per 1000 respectively)
The incidence of disabling sequelae resulting from low birth weight in the first year of life (table 8) was the same in males as in females (0.1 per 1000) while mortality from low birth weight was higher in males than in females (1.16 versus 1.10 per 1000).

Table 9 shows the incidence of severe anaemia resulting from maternal hemorrhage. It was the lowest in the age group 5 – 14 years and the highest in the age groups 15 – 29 and 30 – 44 years after which it declined to relatively very low values. The overall incidence was 0.6 per 1000. The same table shows mortality from maternal haemorrhage. Unlike the incidence it is highest in the very old age group and the overall mortality was 0.02 per 1000.

In table 10 the overall incidence of diabetes mellitus was 0.77 per 1000 for males. It was higher for females (0.93 per 1000). The incidence was lowest in the age group 5 – 14 years in both males and females. It increased to peak at the age group 45 – 59 in males and in the group 70 - 79 years in females. It then declined in the older age groups. Mortality was similarly higher for females than males (0.42 versus 0.33 per 1000 respectively). It also followed the same age pattern as the incidence in males and females.

The incidence of road traffic accidents (table 11) was much higher in males (0.21 per 1000) than in females (0.09 per 1000). In both males and females it was highest in the age group 45 – 59 years (0.25 and 0.1 per 1000 respectively). Mortality was similarly higher in males than females (0.05 versus 0.02 per 1000 respectively) and peaked in the same age group as the incidence.

**DISABILITY ADJUSTED LIFE YEARS**

Figure II shows the DALYs lost per 1000 population due to malaria in males compared to females in each age group. The burden rose to peak in the age group 5 – 14 years and then declined to a minimum in the age group 80+. Males were affected more than females up to 14 years but then females predominated all the way to the oldest age group. However, in the group 45 – 59 years, the burden was equal for both males and females.
The age and sex distribution of the burden of measles is shown in figure III. In both males and females the burden was highest in children less than five years and declined steeply to a minimum in the age group 15 – 29 years. Afterwards it was zero. The burden was highest in female children less than five years but was almost the same for both males and females in the other age groups.

The burden of protein energy malnutrition was carried solely by children less than five years for both males and females (figure IV). In this age group, it was higher in females than in males.

Figure V displays the burden of low birth weight by age and sex. The burden affected only infants and was higher in females than males.

Figure VI shows 2 peaks in the age distribution of the burden of maternal hemorrhage. The first peak occurred in the age group 30 – 44 while the second peak occurred in the age group 60 – 69. The burden continued to be high in the next age group, to decline after the age of 79.

As depicted in figure VII the burden of diabetes varied greatly between males and females. It was the lowest in the two youngest age groups in both males and females. In males it rose to a peak in the group 45 – 59 years while in females it peaked in the group 70 – 79 yrs. The burden was higher in females up to the group 30 – 44 yrs but became lower in the group 45 – 59. In the higher age groups the burden was higher in females.

The burden of road traffic accidents was higher in males than in females for all age groups (figure VIII). For both males and females the burden increased after the youngest age group to peak at the age 15 – 29 years and declined to a minimum in the oldest age group.

Figure IX shows the rank ordering of the diseases by total DALYs for males. Low birth weight accounted for the highest burden followed by protein energy malnutrition.
Malaria ranked third while measles followed. Non communicable conditions (diabetes and road traffic accidents) had the lowest burdens.

The figure also shows the relative contribution of disability to the total disease burden. The highest contribution was observed in protein energy malnutrition where disability accounted for almost half the burden while the burden of disability in low birth weight, measles and road traffic accidents was almost negligible when compared to the burden of mortality.

Similar findings were observed in females (figure X). The same rank ordering of the diseases as in males was found. However maternal hemorrhage accounted for a higher burden than road traffic accidents. Low birth weight, measles, maternal hemorrhage and road traffic accidents also had a very low burden of disability compared to mortality.

Table 12 displays the total DALYs lost by males due to the diseases under study by age and sex. In the age group 0 – 4 years in males, the distribution of burden among the diseases under study was similar as the overall distribution except that measles preceded malaria and road traffic accidents preceded diabetes mellitus. After the age of 5 years, malaria ranked first and was followed by measles then the non communicable conditions. After 45 years, diabetes preceded malaria but the order reversed at the oldest age group.

In females (table 13), the distribution of burden among the diseases in children less than five years was the same as the overall distribution except that measles preceded malaria. The situation reversed in the age group 5 – 14 years and measles and malaria topped the list. This continued into the older age groups with the gradual emergence of maternal hemorrhage. In spite of that, diabetes mellitus always preceded maternal hemorrhage as the cause of DALYs lost. It accounted for the highest burden after the age of 45 years.

Table 14 shows a slight change in the rank order of the diseases under study when using DALYs versus YLLs only. Protein energy malnutrition moved from third position
with YLLs to second position with DALYs, displacing malaria. The rest of the diseases preserved their rank orders.

The differences between the DALY estimates of the study and the GBD prior estimates are evident in table 15. The rank order of the diseases in the study and the rank ordering of the GBD 2002 differed for all diseases except for measles and maternal hemorrhage which ranked fourth and seventh respectively in both lists.

**Sensitivity to Disability Weights**

Table 16 shows the percentage change in burden of malaria when using Ghana disability weights. Throughout all age groups the effect did not vary much between males and females. For both males and females the least effect was in the youngest age group. It rose with age to reach a maximum, with the burden almost doubling in the oldest age group. The overall effect of Ghana disability weights on malaria burden was a rise of about 11% for males and 10% for females.

An overall increase in the burden of measles of 0.73% was observed for both males and females when using Ghana disability weights (table 17). The effect was highest in the age group 5 – 14 years for both sexes.

Table 18 shows the effect on the burden of protein energy malnutrition. An increase in burden of 38.42% for males and 40.59% for females was observed.

In the burden of low birth weight, the effect was very slight with an increase of about 0.01% only (table 19).

In maternal hemorrhage, only a small increase in burden was observed (table 20).

Table 21 shows the effect on the burden of diabetes mellitus. In spite that the effect on the overall burden did not vary greatly between males and females (increase of 8.91% and 8.47% respectively); it varied widely between the age – sex groups. The largest effect
was a decrease in the burden of 71.63% in males and 44.39% in females in the age group 80+ yrs.

A generalized decline in the burden of road traffic accidents was observed (table 22). The decline in overall burden was more in females than in males (5.48% versus 2.67%). There was no wide variation in the burden between the age–sex groups.
Table 4: Age and sex specific incidence and mortality rates of malaria per 1000 population in Sudan in 2002

<table>
<thead>
<tr>
<th>Age group</th>
<th>Incidence</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Less than 4</td>
<td>317.81</td>
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<td>5-14</td>
<td>411.97</td>
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<td>15-29</td>
<td>330.53</td>
<td>338.39</td>
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<tr>
<td>30-44</td>
<td>253.70</td>
<td>271.84</td>
</tr>
<tr>
<td>45-59</td>
<td>347.56</td>
<td>318.67</td>
</tr>
<tr>
<td>60-69</td>
<td>350.88</td>
<td>398.33</td>
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<tr>
<td>70-79</td>
<td>350.88</td>
<td>398.33</td>
</tr>
<tr>
<td>80+</td>
<td>351.15</td>
<td>398.34</td>
</tr>
<tr>
<td>Overall</td>
<td>340.85</td>
<td>335.17</td>
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Table 5: Age and sex specific incidence and mortality rates of measles per 1000 population in Sudan in 2002

<table>
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<th>Age group</th>
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</tr>
</thead>
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<td>5-14</td>
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<tr>
<td>15-29</td>
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<td>5.62</td>
</tr>
<tr>
<td>30-44</td>
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<td>-</td>
</tr>
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<td>45-59</td>
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<td>60-69</td>
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<td>80+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>11.40</td>
<td>12.45</td>
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Table 6: Age and sex specific Incidence rates of wasting, stunting and developmental disability per 1000 population in Sudan in 2002

<table>
<thead>
<tr>
<th>Age group</th>
<th>Wasting</th>
<th>Stunting</th>
<th>Developmental disability</th>
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</thead>
<tbody>
<tr>
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<td>Males</td>
<td>Females</td>
<td>Males</td>
</tr>
<tr>
<td>Less than 4</td>
<td>25.03</td>
<td>27.12</td>
<td>148.18</td>
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<tr>
<td>5+</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Overall</td>
<td>4.03</td>
<td>4.25</td>
<td>23.88</td>
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Table 7: Mortality from wasting per 1000 population in Sudan in 2002 by age and sex

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<td>5+</td>
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<tr>
<td>Overall</td>
<td>0.45</td>
<td>0.44</td>
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</table>
Table 8: Age and sex specific incidence of low birth weight sequelae and mortality of low birth weight per 1000 population in Sudan in 2002

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<th>Age group</th>
<th>Incidence</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
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<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>0</td>
<td>0.59</td>
<td>0.62</td>
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<tr>
<td>1+</td>
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<tr>
<td>Overall</td>
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Table 9: Age specific incidence of severe anaemia resulting from maternal hemorrhage, and mortality from maternal hemorrhage per 1000 population in Sudan in 2002

<table>
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<tr>
<th>Age group</th>
<th>Incidence</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
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<tr>
<td>5-14</td>
<td>0.05</td>
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<td>15-29</td>
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<td>45-59</td>
<td>0.18</td>
<td>0.02</td>
</tr>
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<td>60-69</td>
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<td>70-79</td>
<td>0.05</td>
<td>0.14</td>
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<td>80+</td>
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<tr>
<td>Overall</td>
<td>0.60</td>
<td>0.02</td>
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Table 10: age and sex specific incidence and mortality rates of Diabetes Mellitus per 1000 population in Sudan in 2002 by

<table>
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<td>Females</td>
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<td>1.02</td>
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<td>80+</td>
<td>0.28</td>
<td>0.84</td>
<td>0.31</td>
<td>0.86</td>
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<tr>
<td>Overall</td>
<td>0.78</td>
<td>0.93</td>
<td>0.33</td>
<td>0.42</td>
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Table 11: Age and sex specific incidence and mortality rates of Road traffic accidents per 1000 population in Sudan in 2002

<table>
<thead>
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<th>Age group</th>
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<td>Females</td>
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<td>0.03</td>
<td>0.01</td>
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<td>0.22</td>
<td>0.10</td>
<td>0.07</td>
<td>0.03</td>
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<td>30-44</td>
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<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>45-59</td>
<td>0.47</td>
<td>0.19</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>60-69</td>
<td>0.38</td>
<td>0.17</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>70-79</td>
<td>0.33</td>
<td>0.14</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>80+</td>
<td>0.32</td>
<td>0.14</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Overall</td>
<td>0.21</td>
<td>0.09</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Figure II: DALYs lost due to malaria per 1,000 population in Sudan in 2002 by age and sex
Figure III: DALYs lost due to Measles per 1000 population in Sudan in 2002 by age and sex
Figure IV: DALYs lost due to Protein energy malnutrition per 1000 population in Sudan in 2002 by age and sex.
Figure V: DALYs lost due to Low birth weight per 1000 population in Sudan in 2002 by age
Figure VI: DALYs lost due to maternal hemorrhage per 1000 females in Sudan in 2002 by age
Figure VII: DALYs lost due to Diabetes mellitus per 1000 population in Sudan in 2002 by age and sex
Figure VIII: DALYs lost due to Road traffic accidents per 1000 population in Sudan in 2002 by age and sex
Figure IX: Rank order of the diseases under study by total DALYs in males

- Road traffic accidents
- Diabetes Mellitus
- Measles
- Malaria
- Protein energy malnutrition
- Low birth weight

Total DALYs (000)

- YLLS
- YLDS
Figure X: Rank order of the diseases under study by total DALYs in females
Table 12: Total DALYs lost by males in Sudan in 2002 due to the diseases under study, by age and sex

<table>
<thead>
<tr>
<th>Age group</th>
<th>Less than 4</th>
<th>5-14</th>
<th>15-29</th>
<th>30-44</th>
<th>45-59</th>
<th>60-69</th>
<th>70-79</th>
<th>80+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diabetes</strong></td>
<td>2126.88</td>
<td>4157.73</td>
<td>1743.80</td>
<td>27617.39</td>
<td>97790.13</td>
<td>19245.52</td>
<td>5107.49</td>
<td>674.02</td>
<td>174153.80</td>
</tr>
<tr>
<td><strong>Road traffic accidents</strong></td>
<td>3043.45</td>
<td>9572.90</td>
<td>20564.73</td>
<td>7758.91</td>
<td>3559.05</td>
<td>515.06</td>
<td>74.90</td>
<td>19.54</td>
<td>45108.53</td>
</tr>
<tr>
<td><strong>Low birth weight</strong></td>
<td>1438658.18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Maternal hemorrhage</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Measles</strong></td>
<td>442673.83</td>
<td>86726.56</td>
<td>39665.10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>571065.49</td>
</tr>
<tr>
<td><strong>Malaria</strong></td>
<td>192238.50</td>
<td>373415.81</td>
<td>283597.99</td>
<td>85896.58</td>
<td>44781.23</td>
<td>9049.11</td>
<td>1916.99</td>
<td>688.72</td>
<td>991584.93</td>
</tr>
<tr>
<td><strong>Protein energy malnutrition</strong></td>
<td>1093365.87</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1093365.87</td>
</tr>
</tbody>
</table>
Table 13: Total DALYs lost by females in Sudan in 2002 due to the diseases under study, by age and sex

<table>
<thead>
<tr>
<th>Age group</th>
<th>Less than 4</th>
<th>5-14</th>
<th>15-29</th>
<th>30-44</th>
<th>45-59</th>
<th>60-69</th>
<th>70-79</th>
<th>80+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>5769.56</td>
<td>7107.84</td>
<td>43890.12</td>
<td>81962.44</td>
<td>58595.87</td>
<td>28978.11</td>
<td>21022.54</td>
<td>1109.2</td>
<td>248435.67</td>
</tr>
<tr>
<td>Road traffic accidents</td>
<td>1281.15</td>
<td>4150.54</td>
<td>8826.70</td>
<td>3513.13</td>
<td>1536.86</td>
<td>220.83</td>
<td>24.83</td>
<td>4.15</td>
<td>19558.19</td>
</tr>
<tr>
<td>Low birth weight</td>
<td>1590709.35</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maternal hemorrhage</td>
<td>-</td>
<td>672.79</td>
<td>10434.38</td>
<td>7205.44</td>
<td>751.50</td>
<td>912.68</td>
<td>250.12</td>
<td>71.69</td>
<td>20298.60</td>
</tr>
<tr>
<td>Measles</td>
<td>447774.55</td>
<td>89748.55</td>
<td>40121.91</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>577645.00</td>
</tr>
<tr>
<td>Malaria</td>
<td>176575.18</td>
<td>356327.12</td>
<td>286812.63</td>
<td>105868.07</td>
<td>46084.61</td>
<td>11161.92</td>
<td>2341.21</td>
<td>871.72</td>
<td>986042.47</td>
</tr>
<tr>
<td>Protein energy malnutrition</td>
<td>1095783.65</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1095783.65</td>
</tr>
</tbody>
</table>
### Table 14: Rank order of the diseases under study using YLLs versus DALYs

<table>
<thead>
<tr>
<th>Using YLLs</th>
<th>Using DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low birth weight</td>
<td>Low birth weight</td>
</tr>
<tr>
<td>Malaria</td>
<td>Protein energy malnutrition</td>
</tr>
<tr>
<td>Protein energy malnutrition</td>
<td>Malaria</td>
</tr>
<tr>
<td>Measles</td>
<td>Measles</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>Diabetes Mellitus</td>
</tr>
<tr>
<td>Road traffic accidents</td>
<td>Road traffic accidents</td>
</tr>
<tr>
<td>Maternal hemorrhage</td>
<td>Maternal hemorrhage</td>
</tr>
</tbody>
</table>
Table 15: Rank order of the GBD 2002 compared to that of the study using total DALYs:

<table>
<thead>
<tr>
<th>Study</th>
<th>GBD 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low birth weight</td>
<td>1. Malaria</td>
</tr>
<tr>
<td>2. Protein energy malnutrition</td>
<td>2. Road traffic accidents</td>
</tr>
<tr>
<td>3. Malaria</td>
<td>3. Low birth weight</td>
</tr>
<tr>
<td>5. Diabetes Mellitus</td>
<td>5. Protein energy malnutrition</td>
</tr>
<tr>
<td>6. Road traffic accidents</td>
<td>6. Diabetes Mellitus</td>
</tr>
</tbody>
</table>
Table 16: Percentage change in burden of malaria in Sudan in 2002 when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 4</td>
<td>7.71</td>
<td>7.16</td>
</tr>
<tr>
<td>5-14</td>
<td>9.62</td>
<td>9.10</td>
</tr>
<tr>
<td>15-29</td>
<td>10.55</td>
<td>10.18</td>
</tr>
<tr>
<td>30-44</td>
<td>12.80</td>
<td>12.27</td>
</tr>
<tr>
<td>45-59</td>
<td>23.08</td>
<td>20.51</td>
</tr>
<tr>
<td>60-69</td>
<td>39.07</td>
<td>35.26</td>
</tr>
<tr>
<td>70-79</td>
<td>61.99</td>
<td>54.70</td>
</tr>
<tr>
<td>80+</td>
<td>108.35</td>
<td>103.70</td>
</tr>
<tr>
<td>Overall</td>
<td>10.84</td>
<td>10.43</td>
</tr>
</tbody>
</table>
Table 17: Percentage change in burden of measles in Sudan in 2002 when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 4</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>5-14</td>
<td>2.19</td>
<td>2.21</td>
</tr>
<tr>
<td>15-29</td>
<td>1.37</td>
<td>1.35</td>
</tr>
<tr>
<td>30-44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>45-59</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>60-69</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>70-79</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>80+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>0.73</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Table 18: Percentage change in burden of wasting in Sudan in 2002, when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 4</td>
<td>38.42</td>
<td>40.59</td>
</tr>
<tr>
<td>5+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>38.42</td>
<td>40.59</td>
</tr>
</tbody>
</table>
Table 19: Percentage change in burden of low birth weight in Sudan in 2002, when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 4</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>5+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Table 20: Percentage change in burden of maternal hemorrhage in Sudan in 2002, when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 4</td>
<td>-</td>
</tr>
<tr>
<td>5 – 14</td>
<td>0.83</td>
</tr>
<tr>
<td>15 – 29</td>
<td>1.29</td>
</tr>
<tr>
<td>30 – 44</td>
<td>1.41</td>
</tr>
<tr>
<td>45 – 59</td>
<td>0.90</td>
</tr>
<tr>
<td>60 – 69</td>
<td>0.05</td>
</tr>
<tr>
<td>70 – 79</td>
<td>0.06</td>
</tr>
<tr>
<td>80+</td>
<td>0.17</td>
</tr>
<tr>
<td>Overall</td>
<td>1.23</td>
</tr>
</tbody>
</table>
Table 21: Percentage change in burden of Diabetes Mellitus in Sudan in 2002, when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 4</td>
<td>11.81</td>
<td>10.84</td>
</tr>
<tr>
<td>5-14</td>
<td>-49.13</td>
<td>-27.66</td>
</tr>
<tr>
<td>15-29</td>
<td>-1.57</td>
<td>24.10</td>
</tr>
<tr>
<td>30-44</td>
<td>8.53</td>
<td>3.36</td>
</tr>
<tr>
<td>45-59</td>
<td>16.69</td>
<td>13.48</td>
</tr>
<tr>
<td>60-69</td>
<td>-1.65</td>
<td>6.32</td>
</tr>
<tr>
<td>70-79</td>
<td>-1.65</td>
<td>2.35</td>
</tr>
<tr>
<td>80+</td>
<td>-71.63</td>
<td>-44.39</td>
</tr>
<tr>
<td>Overall</td>
<td>8.91</td>
<td>8.47</td>
</tr>
</tbody>
</table>
Table 22: Percentage change in burden of road traffic accidents in Sudan in 2002, when using Ghana disability weights, by age and sex:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 4</td>
<td>-3.88</td>
<td>-4.38</td>
</tr>
<tr>
<td>5-14</td>
<td>-2.77</td>
<td>-3.10</td>
</tr>
<tr>
<td>15-29</td>
<td>-2.26</td>
<td>-2.72</td>
</tr>
<tr>
<td>30-44</td>
<td>-2.88</td>
<td>-4.32</td>
</tr>
<tr>
<td>45-59</td>
<td>-3.15</td>
<td>-3.42</td>
</tr>
<tr>
<td>60-69</td>
<td>-3.74</td>
<td>-3.76</td>
</tr>
<tr>
<td>70-79</td>
<td>-3.17</td>
<td>-1.13</td>
</tr>
<tr>
<td>80+</td>
<td>-0.79</td>
<td>-1.01</td>
</tr>
<tr>
<td>Overall</td>
<td>-2.6702</td>
<td>-5.47943</td>
</tr>
</tbody>
</table>
CHAPTER FOUR
DISCUSSION

NATIONAL INCIDENCE AND MORTALITY ESTIMATES

Malaria

The incidence and mortality calculated in this study exceeded that reported from health facilities (34) because under-reporting was taken into account using a method derived from that used to quantify malaria burden in two districts in southern Ghana (88). The under-reporting fraction calculated was in agreement with the finding that less than 20% of presumed malaria cases in sub-Saharan Africa are reported to the formal health system (89). It was also close to the underreporting factor found in southern Ghana (88). The number of cases and deaths also exceeded the prior estimates reported in the GBD 2002 (33). This could be due to the different methods of calculation. The age distribution was also different with most cases and deaths occurring in 5 – 14 yrs age group, rather than the 0 – 4 yrs group in the prior estimates. This was most probably the result of the computer modeling process because the preliminary estimates reported most of the cases in the 0 – 4 group. However the age group 0 – 14 yrs in both sources of estimates still carried the highest incidence and mortality.

Measles

The incidence and mortality rates were higher than those of the GBD estimates in spite that both studies used the same method. The birth cohort used in the study was probably increased by the high crude birth rate used for southern Sudan. Mortality was
higher because the case fatality ratio used in this study exceeded the maximum CFR reported in measuring the global burden of measles (27).

Another set of estimates have been developed using dynamic models (89). These are claimed to be more reliable since they account for age specific attack rates and population immunity. However the models are complex and require more data than the static model used in this study.

**Protein energy malnutrition**

The calculation and the application of the trend in protein energy malnutrition were main steps in the analysis of its burden. The trend calculation for underweight was similar to that conducted for Sudan in a previous study (90), but in this study, the prevalence was adjusted for seasonal variation. That is why unlike the other study, the prevalence showed a declining trend.

The total number of incident cases compared well with the GBD prior estimates (33), probably due to the use of similar data sources. Even after calculation and application of trend, the prevalence in 2002 was very close to the 2000 prevalence reported in the MICS (28) and used in the GBD 2000 (34). However mortality differed not only in numbers but also in age distribution. This was probably an effect of the computer modeling process.

**Low birth weight**

The prior estimates of the number of incident cases of disabling sequelae (33) exceeded that of the study while the opposite occurred regarding the number of deaths. This was most probably due to the different calculation methods and the different data sources used.
Maternal hemorrhage

The prior estimates for the number of incident cases and deaths (33) also exceeded those of the study probably due to the different calculation methods. Occurrence of cases and deaths of maternal hemorrhage beyond the reproductive age group of 15 – 49 years is an effect of computer modeling. The estimates can be corrected using expert opinion to limit the results to the reproductive age group.

Diabetes mellitus

The incidence followed the age and sex distribution of the preliminary prevalence estimates. When the number of cases and deaths are compared to the prior GBD estimates (33), they are found to be lower than the latter. The GBD use the same source of data used in this study for northern Sudan. However in this analysis, the overall prevalence was lower than that for northern Sudan because of the relatively low prevalence assumed for southern Sudan. On the other hand, the number of deaths calculated in this analysis was higher than that of the GBD probably due to the different calculation methods.

Road traffic accidents

Road traffic accidents had the lowest incidence and mortality of all the diseases. The rates were probably underestimated due to the complete dependence on officially reported cases. However no population based studies were found. As expected the numbers of cases and deaths reported in the GBD prior estimates for Sudan far exceeded those of the study.

The role of computer modeling

In spite that DISMOD ensured that the estimates produced were internally consistent and therefore more valid, unexpected results were obtained in the case of malaria and
maternal hemorrhage. This was also pointed out in a validation study that compared the results of DISMOD and another software with measurements from a high quality empirical data set. Large discrepancies and unrealistic results were obtained. These were attributed to data inaccuracies or past disease trends. The validation study acknowledged the importance of judgement and expert knowledge in the revision of estimates from the disease modeling software (91).

**DISABILITY ADJUSTED LIFE YEARS**

The age and sex distribution of DALYs per 1000 population in most diseases followed the age and sex distribution in the final incidence and mortality estimates. However in the case of road traffic accidents, the burden shifted to earlier age groups probably due to the loss of more YLLs per one death in the younger age groups than in older ones. In the case of maternal haemorrhage, in spite that most of the incidence and mortality were in the reproductive age group, the second peak in burden per 1000 population after the age of 59 years was observed and was due to the relatively small denominator after 59 years.

Effective comparison between the total DALYs lost due to each disease as calculated in this study and the total DALYs reported in the GBD prior estimates (33) was hindered by the application of age weighting and discounting to the latter. The prior estimates were lower than the study estimates for malaria, measles, protein energy malnutrition and low birth weight because the epidemiological estimates had the same difference. For diabetes mellitus the differences in mortality and the effect of age weighting and discounting led to the fact that the prior estimates (33) were also lower than the study estimates. However in the case of road traffic accidents and maternal hemorrhage, the wide difference in epidemiological estimates made the prior estimates higher than the study estimates in spite of age weighting and discounting.

The rank order of the diseases did not differ much between males and females. This was because in most of the diseases under study, absence of sex difference was assumed,
while in others the estimates were almost equal for both sexes. In road traffic accidents the burden was much higher in males than in females, but it was still very low compared to the other diseases. The domination of the burden by childhood conditions may partially be due to the absence of age weighting and discounting. That was why the application of age weighting and discounting has been recommended (2). As expected in a developing country, the burden of non-communicable diseases and injuries was less than that of communicable diseases and childhood illnesses included in the study. However the relative importance of non-communicable diseases and injuries could not be concluded from this study because the rest of the conditions have not been assessed yet. No generalization could be made beyond this list of diseases. If a full analysis had been conducted it might have appeared that non-communicable diseases and injuries rank higher than other communicable conditions or maternal and perinatal and nutritional conditions. Moreover, road traffic accidents burden is expected to be an underestimate because of the use of official reports.

In females, the fact that maternal haemorrhage accounted for a low burden could be due to the limited age range affected by the condition. Although low birth weight and protein energy malnutrition also affect a limited age range, their action early in life leads to loss of more YLLs than would occur in maternal hemorrhage.

The rank order of the diseases in this way should be interpreted with caution. This is because the disease categories are mutually exclusive. The sequelae of malaria do not include low birth weight or protein energy malnutrition and the sequelae of measles do not include protein energy malnutrition. However, since malaria is a risk factor for low birth weight (92), the burden of low birth weight necessarily includes low birth weight resulting from malaria. Therefore the burden of malaria extends beyond the reported burden to include part of the burden of low birth weight. In fact the overall burden of malaria might exceed that of low birth weight. This argument is supported by the finding that malaria more than doubled all cause mortality in children less than five years (93). The same argument applies to measles as a risk factor for protein energy malnutrition.
The choice of a disease as a priority for action should therefore account for the mutually exclusive nature of the diseases categories and the part of the disease burden attributable to other diseases in the list.

The difference in the rank order of diseases using the prior estimates of the GBD (33) was expected since different calculation methods, different data sources and the use of age weighting and discounting led to large differences between the DALY estimates for the study and prior DALY estimates of the GBD (33).

The difference in the rank order between different age groups was also expected because some diseases are most frequent in certain age groups. It also differed between males and females partly due to the interference of maternal hemorrhage as a condition exclusive to females and partly due to the sex difference in the burden of road traffic accidents.

The slight change in the rank order when using DALYs compared to YLLs only was due to the fact that for most of the diseases selected for the study, the burden of mortality was predominant. Therefore the addition of disability burden did not make a significant change. However it cannot be concluded that the burden of mortality alone is enough to assess disease burden because this is a limited diseases list and different results may be obtained if a full analysis is conducted. In studies with a full disease burden analysis (17,18,22-25), more significant changes in the rank order of the diseases were observed.

Comparison of the results with the results of other countries was hindered by the use of other summary measures of population health in measurement of the disease burden in some countries, the use of discounting and age weighting for DALYs used by the other countries, the different years of assessment and the different methods of categorization of the diseases. In general, group I diseases predominated the burden as in developing countries (18,22). The results contrasted with those of developed countries.
Discussion

(17,24,25) where most of the burden was attributed to non communicable diseases and injuries. The regional estimates of DALYs for the same diseases showed similar results except for road traffic accidents which ranked second in the group and protein energy malnutrition ranking fifth (26).

**SENSITIVITY ANALYSIS**

The decision about which set of disability weights is to be used is important because the disability weights are the most subjective part of the burden of disease analysis. Their being most approximate to local societal preferences encourages decision makers to use the results. Ghana disability weights were used in this analysis because they were developed in a neighboring African country with similar conditions. As expected their effect was largest on the disease with a large disability burden; Protein Energy Malnutrition. The effect was the least for the diseases with predominant mortality burden except for malaria and diabetes mellitus. In these diseases, the difference in the disability weights of the GBD and of Ghana for these diseases was large.

For each disease, the effect of using Ghana disability weights varied between males and females and between the different age groups. This variation between the age groups is the widest in the case of malaria probably because of the high disability weight given to malaria in the Ghana set. This is expected to affect the rank order of malaria and diseases with a similar characteristic within the different age groups.

In spite that the Ghana disability weights were expected to be the most approximate to Sudanese societal preferences, their use was constrained by the different disease categorization and case definitions used in their development.

Age weighting and discounting reduce the disease burden. The amount of reduction varies between the diseases and depends on the age group most affected by the disease. Sensitivity to age weighting and discounting is better examined by the difference in the rank order of the disease categories with and without them. This is more informative if a full analysis is made. A small number of diseases that do not represent the full disease list
regarding age group most affected would not give valid information to decide whether to apply them or not. That was why sensitivity analysis to age weighting and discounting was not attempted in this study.

LIMITATIONS OF THE STUDY

This study was based on collection and processing of secondary data, which created uncertainty in the estimates. This problem was common to all national burden of disease studies but in varying degrees (17, 18, 22-25). The uncertainty in this study came from the following sources:

The data sources

Bias

Bias resulting from methodological issues in the studies used was carried on to the calculated estimates. In some studies such flaws could not have been evident because some aspects of the methodology were not reported. Where bias was evident the studies were resorted to only where no other sources could be found. The bias in the studies cannot be quantified and therefore cannot be expressed as uncertainty limits.

Bias from non representativeness was the most evident type. The data used ranged from health facility based case studies to nationally representative population based studies. Health facility based case studies are not representative of the population concerned even if sample sizes are adequate. Some population based studies and NGO surveillance systems were localized and did not represent all the country. Even some national surveys failed to cover the whole country due to inaccessibility of some areas. Some estimates were borrowed from studies in neighboring African countries, and one of the studies used was in Finland. However non representative and non local studies were resorted to only where no local estimates could be found or were too unreliable to use.
Time of study

Not all the studies used related to 2002. This could have affected the validity of the results because their use was based on the assumption of a stable epidemiological and demographic status. Except for protein energy malnutrition, no reliable time series data could be found to estimate trends in the diseases epidemiology. However in the case of road traffic accidents, a study showed that the incidence of serious injury was stable (95). Using old data may lead to overestimation or underestimation of the burden of disease with declining or rising trends respectively.

Case definitions

Although studies collected for use essentially had to have the same case definitions as those used developing the disability weights, this rule was violated in four situations:

1. Case definitions were not matched with those of the Ghana disability weights because the study used disease categories and sequelae of the GBD. These were different from those used by the Ghana health assessment team.

2. In estimating the proportion of severe anaemia from malaria, all the studies found used the same case definition for severe anaemia for all population groups. The GBD defined severe anaemia differently for pregnant women, children and non-pregnant adults.

3. In estimating the incidence of maternal hemorrhage, the proportion reported in the SMS was based on subjective assessment of the occurrence of heavy bleeding. Self-reporting of hemorrhage experience was found to overestimate the incidence of these diseases (29). However, this survey was resorted to because it was nationally representative and population-based, and because other studies were case studies that reported maternal hemorrhage as a hospital proportion. The lack of an objective method to measure the amount of blood lost and the different case definitions used in different studies has been a continuous limitation in measuring the burden of maternal hemorrhage (29).

4. Studies reporting the proportions of diabetes mellitus sequelae did not report case definitions. They were used because they were the only sources of such information.
The consequences of using a data source with a non matching case definition is that false positive cases (with the GBD definitions as gold standard) will be included or false negative cases excluded, leading to over or underestimation of the disease burden respectively.

Different study populations

Some estimates were found for only certain age groups such as neurological sequelae from malaria and prevalence of diabetes mellitus. The estimates were generalized from these groups with little or no supporting evidence. This was resorted to because of the lack of studies on the other age groups. Findings from northern Sudan were generalized to southern Sudan in the same way.

Uncertainty from indirect methods

Simple indirect methods were used to calculate the case fatality rate of road traffic accidents, prevalence of diabetes in the age group 0 – 14 years and 15 – 24 years and incidence of wasting. More complicated indirect methods were used to calculate the incidence of malaria, measles, severe anaemia resulting from maternal hemorrhage and incidence of stunting and developmental disability from malnutrition. These methods combined information from different sources and therefore combined multiple uncertainties. They also used assumptions to fill information gaps and this added to the uncertainty.

Uncertainty from assumptions

The methods designed or adopted from the GBD involve assumptions where no direct evidence or no information was available. The assumptions therefore carry their own uncertainty. However these assumptions were revised and endorsed by experts.
Discussion

Uncertainty from disability weights

Disability weights reflect societal preferences. In spite of the extensive analysis done in the GBD to ensure that the disability weights developed were highly reliable, their method of development was subjective and therefore they carry an unquantifiable level of uncertainty. Ghana disability weights are expected to be closer to the local social preferences than the GBD disability weights.

Uncertainty analysis

An uncertainty analysis was not conducted in this study due to difficulties in obtaining necessary input and technical difficulties associated with the analysis.

DATA GAPS REVEALED

There were no reliable sources of all cause mortality and cause specific mortality.

No nationally representative reliable source of malaria or measles incidence exists. Except for measles, longitudinal population based studies of the natural history of the diseases could not be identified. They are the most reliable source of case fatality and remission rates as well as disability proportions and the average duration of the diseases (2). National maternal hemorrhage morbidity data was derived from self reported morbidity over a long recall period. There were no local population based studies of incidence and case fatality of maternal hemorrhage with ascertainment of the morbid conditions using a standard case definition as in the MOMA study. There was no wider scale research on the sequelae of road traffic accidents.

NEW ADDITIONS IN THIS STUDY

This study is the first local assessment of the burden of the selected diseases in Sudan. As part of the GBD revisions for the year 2002, country specific estimates were developed (4). Except for measles, protein energy malnutrition and diabetes mellitus, these estimates were developed by indirect methods from regional estimates. For diseases
where country specific data was used in the GBD assessment, more local studies were used by this assessment. For measles, more recent population estimates for southern Sudan, and estimates from more recent studies on case fatality were used. The age distribution of cases was adopted from a local study rather than from the GBD methods. In the case of protein energy malnutrition trend was estimated after adjusting some of the estimates, and was used to calculate prevalence proportions in 2002. As for diabetes mellitus, a more valid national prevalence was calculated when the prevalence obtained for northern Sudan was combined with the prevalence expected to apply to southern Sudan. Local studies that included postgraduate theses and unpublished studies were used to calculate the proportions of disabling sequelae. Local expert opinion was also used.

The study coupled mortality and morbidity in a single estimate for each disease, allowing easy comparison between the different diseases. It developed national internally consistent epidemiological estimates for the selected diseases, making the maximum use of the available data. However the estimates should be considered as initial estimates and the methods used should not final; they form a basis for further revisions and modifications based on new evidence and further studies. Moreover, even the best developed indirect methods should be considered as temporary alternatives for information provision. They should not cancel the need to develop high quality health information system with high quality data and low under-reporting fractions.

CONSTRAINTS IN THE STUDY

The local databases were uncoordinated and some lacked recent research. Some of the papers identified through their abstracts were not available in full text and could not be reviewed or used. With the lack of resources, experts were consulted separately with no consensus process. Technical difficulties with the computer disease modeling and uncertainty analysis were faced.
CONCLUSIONS

1. The incidence and mortality rates of each condition were found to vary by age and sex in a pattern that reflects that of the original data used to generate them. In the case of malaria the computer modeling process altered the pattern observed in the original data.

2. Wide variations were found between the incidence and mortality estimates calculated in this study and those calculated by the GBD for Sudan, probably due to different calculation methods, different data sources and the application of age weighting and discounting in the latter.

3. For both males and females, low birth weight accounted for the highest burden followed by protein energy malnutrition, malaria, measles, Diabetes Mellitus and road traffic accidents, with maternal hemorrhage preceding the latter in females.

4. The age and sex distribution of DALYs per 1000 population followed that of the epidemiological estimates in most of the diseases.

5. The rank order of the diseases varied in the different age groups.

6. Addition of the burden of disability to the burden of mortality made a slight change to the rank order of the diseases under study.

7. The change in disease burden when using the Ghana disability weights was the greatest in diseases with a high disability burden and in those where the difference between the Ghana disability weights and the GBD disability weights was large.
8. The validity of disease burden estimates was reduced by uncertainties arising from bias in the data sources used, steady state assumption, case definitions, different study populations, indirect methods, assumptions and disability weights.

9. The study revealed deficiencies in mortality data, nationally representative data on frequency of malaria and measles, valid data on the incidence of maternal hemorrhage, and longitudinal population based studies that provide case fatality and remission rates as well as disability proportions and the average duration of the diseases.

10. Difficulty in obtaining the data needed, obtaining expert consensus, the use of computer modeling and technical difficulties with uncertainty analysis were faced during the course of the study.

11. In-spite of the data deficiencies and constraints faced, it is possible to conduct a full burden of disease analysis.
Chapter 8

RECOMMENDATIONS

1. Further revisions and improvement of the data sources used in development of the preliminary epidemiological estimates for the diseases studied.

2. Conduction of a full analysis of the burden of other important of diseases in Sudan.

3. Conduction of verbal autopsy studies or longitudinal studies as a temporary resort to provide more reliable mortality data for the diseases studied.

4. The vital registration system should be improved to provide the most reliable mortality data.

5. Part of the research efforts should be directed towards population based longitudinal studies and national surveys to provide representative incidence of measles and malaria and road traffic accidents injures as well as reliable estimates of average duration, remission, case fatality and disability proportions for all the conditions studied.

6. More valid estimates of maternal morbidity should be made available in the short term by longitudinal population based studies and in the long term by population based or health facility based surveillance with minimal under-reporting.

7. Research should be conducted to update old national estimates of diabetes prevalence in Sudan.

8. Databases in the country should be updated with the most recent research and the different data bases available should be coordinated and act with the different research institutes to facilitate the obtaining of research results.
9. Proper training of researchers in Sudan on measuring the burden of disease using the DALY approach including the proper use of the different software available.

10. Revision and modification of DISMOD output for the diseases under study by experts.
REFERENCES


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46. Malaria situation and the progress made in RBM implementation in southern Sudan. 2004[25]. Available at:
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ANNEX A: METHOD USED IN CALCULATING THE COMPLETENESS OF DEATH REGISTRATION IN MALES AND FEMALES AGED FIVE YEARS AND ABOVE

Brass Growth – Balance method:

\[ N_x = \text{population at exact age} \ x \]

\[ N_{x+} = \text{population aged} \ x \ \text{and over.} \]

\[ D_{x+} = \text{deaths at age} \ x \ \text{and over.} \]

\[ \frac{D_{x+}}{N_{x+}} = \text{Partial death rate.} \]

\[ \frac{N_x}{N_{x+}} = \text{Partial birth rate.} \]

\[ X_1 = \text{average } \frac{D_{x+}}{N_{x+}} \ \text{for} \ x = 5,10,15,20 \]

\[ X_2 = \text{average } \frac{D_{x+}}{N_x} \ \text{for} \ x = 25,30,35,40. \]

\[ Y_1 = \text{average } \frac{N_x}{N_{x+}} \ \text{for} \ x = 5,10,15,20. \]

\[ Y_2 = \text{average } \frac{N_x}{N_{x+}} \ \text{for} \ x = 25,30,35,40. \]

\[ K = \frac{Y_2 - Y_1}{X_2 - X_1} \]

Completeness of death registration = \( \frac{1}{K} \)

The calculated numbers are shown in the following tables:
Table 23: Calculation of parameters needed for calculating overall completeness of registration of deaths aged more than 4 years in Sudan in 2002

<table>
<thead>
<tr>
<th>Age</th>
<th>Registered deaths</th>
<th>Reported population</th>
<th>Age X</th>
<th>Nx</th>
<th>Nx+</th>
<th>Dx+</th>
<th>Dx+/Nx+</th>
<th>Nx/Nx+</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5267</td>
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<td>5</td>
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<td>9790</td>
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<td>0.018897</td>
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<td>10</td>
<td>457122.4</td>
<td>22987274</td>
<td>9337.5</td>
<td>0.000406</td>
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<td>8885</td>
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<td>0.021931</td>
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<td>0.000545</td>
<td>0.025094</td>
</tr>
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<td>25</td>
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<td>7552</td>
<td>0.000635</td>
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<td>2071787.231</td>
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<td>207178.7</td>
<td>7266493</td>
<td>5952.5</td>
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<td>0.028512</td>
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<td>35</td>
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<td>1723692.658</td>
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<td>172369.3</td>
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<td>40</td>
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</tr>
<tr>
<td>45+</td>
<td>4353</td>
<td>4103768.588</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td></td>
<td></td>
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<td></td>
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</table>

Table 24: Parameters used to calculate death registration completeness in Sudan in 2002

<table>
<thead>
<tr>
<th>X1</th>
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<tbody>
<tr>
<td>X2</td>
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<tr>
<td>Y1</td>
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<tr>
<td>Y2</td>
<td>0.028422</td>
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<tr>
<td>K</td>
<td>20.97508</td>
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</table>

Death registration completeness in the reporting states of Sudan 2002: 0.047676
annex A: Method used in calculating the completeness of death registration in males and females aged five years and above

Table 25: Calculation of parameters needed for calculating the completeness of registration of male deaths aged more than 4 years in Sudan in 2002

<table>
<thead>
<tr>
<th>Age</th>
<th>Registered deaths</th>
<th>Reported population</th>
<th>Age X</th>
<th>Nx</th>
<th>Nx+</th>
<th>Dx+</th>
<th>Dx+/Nx+</th>
<th>Nx/Nx+</th>
</tr>
</thead>
<tbody>
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<td>265970.7</td>
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<td>232642.9</td>
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<td>20</td>
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<td>4191</td>
<td>0.000719</td>
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</table>

Table 26: Parameters used to calculate male death registration completeness in Sudan in 2002

| X1   | 0.000482 |
| X2   | 0.000908 |
| Y1   | 0.021925 |
| Y2   | 0.028607 |
| K    | 15.68267 |

Death registration completeness in the reporting states of Sudan 2002 0.063765
annex A: Method used in calculating the completeness of death registration in males and females aged five years and above

Table 27: Calculation of parameters needed for calculating the completeness of registration of female deaths aged more than 4 years in Sudan in 2002

<table>
<thead>
<tr>
<th>Age</th>
<th>Registered deaths</th>
<th>Reported population</th>
<th>Age X</th>
<th>Nx</th>
<th>Nx+</th>
<th>Dx+</th>
<th>Dx+/Nx+</th>
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Table 28: Parameters used to calculate female death registration completeness in Sudan in 2002.

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<tr>
<td>X2</td>
<td>0.000651</td>
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<td>Y2</td>
<td>0.028248</td>
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<tr>
<td>K</td>
<td>29.85162</td>
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</table>

Death registration completeness in the reporting states of Sudan 2002: 0.033499
ANNEX B: KEYWORDS USED IN THE SEARCH OF ELECTRONIC DATABASES

1. Malaria +
   a. Sudan (ep)
   b. Pregnant + mortality + Africa
   c. Pregnant + mortality + Sudan
   d. Sudan
2. Anaemia + malaria + Sudan
3. Anaemia + malaria + Africa
4. Cerebral malaria + Sudan.
5. Cerebral malaria.
6. Severe malaria + Sudan.
7. Measles +
   a. Epidemiology + Sudan
   b. Epidemiology + Africa
8. Diabetes mellitus +
   a. Africa
   b. Africa + age distribution.
   c. Complications
   d. Prevalence Africa
   e. Prevalence Saudi Arabia.
   f. Neuropathy.
   g. Neuropathy frequency.
   h. Diabetic foot and peripheral vascular disease.
9. Low birth weight +
   a. Sudan
b. Traditional birth attendants.
c. Unskilled birth attendants.
d. Perinatal mortality + traditional birth attendants + Sudan.
e. Cerebral palsy + low birth weight.

10. Anaemia + hemorrhage + Sudan
11. Anaemia + hemorrhage + Africa.
12. Anaemia + pregnancy + Sudan
13. Antepartum + postpartum + hemorrhage
15. Complications + maternal hemorrhage.
17. Incidence + Postpartum hemorrhage
18. Maternal hemorrhage + Sudan
19. Maternal mortality + causes + Sudan
21. Maternal age + mortality
22. Age + maternal mortality + Africa
23. Severe postpartum anaemia + Africa
ANNEX C: LIST OF LOCATIONS OF DATA SEARCH

1. **Health research institutes:**
   a. National health laboratory.
   b. Tropical medicine research institutes
   c. Institute of endemic diseases.
   d. Blue Nile research institute
   e. Diabetes and endocrine diseases research centre.

2. **Ministry of Health directorates and programs:**
   a. Expanded programme of immunization
   b. Malaria control directorate.
   c. Epidemiology directorate.
   d. Non communicable diseases administration, PHC directorate.
   e. Reproductive health directorate.
   f. National health information center.
   g. Planning directorate, research unit.

3. **Non-governmental organizations:**
   a. Plan sudan
   b. Okenden International.
   c. UNICEF (United Nations Children Fund)
   d. Care
   e. Goal
   f. MSF (Medecin Sans Frontieres France)
   g. SCF (S) UK
   h. MEDAIR
   i. IRC (International Rescue Committee)
   j. ACF (Action Contre la Faim)
   k. Accord
   l. Islamic Relief Worldwide

4. **Faculty of Medicine – University of Khartoum:**
   a. Department of Obstetrics and Gynaecology
   b. Department of Paediatrics and Child health
ANNEX D: TOOLS OF DATA COLLECTION

STUDY SUMMARY SHEET

Identification:
1) Disease: ................................................
2) Study number: ........................................
3) Title: ...................................................
4) Author: ................................................
5) Source: ............................................... 

Study eligibility:
1) Study design: a. Community based b. Not community based
2) Study area: .................................................................................................................
3) Year of study: .............................................
4) Epidemiological estimates provided:
   a. Incidence rate
   b. Prevalence rate
   c. Remission proportion
   d. Case fatality ratio
   e. Average duration
   f. Mortality rate
   g. age distribution of cases or deaths
   h. sex distribution of cases or deaths
   i. disability proportions
   j. Others.................................

Case definition:
................................................................................................................................................
................................................................................................................................................
................................................................................................................................................

Study population description:
................................................................................................................................................
................................................................................................................................................
Quality:

1) Study design:
   a. case study
   b. cross-sectional
   c. cohort
   d. case–control
   e. experimental

2) Sample size: ....................
   a. adequate
   b. inadequate
   c. unspecified

3) Sampling technique:
   a. representative
   b. not representative
   c. unspecified

4) Data quality assurance:
   a. adequate
   b. Inadequate
   c. unspecified

5) Missing data and dropouts: .................................................................

6) Statistical analysis
   a. adequate
   b. inadequate
   c. unspecified
Results:

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<th>Age groups</th>
<th>Incidence</th>
<th>Prevalence</th>
<th>Remission</th>
<th>Case fatality</th>
<th>Duration</th>
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</table>

Other estimates:
DATA COLLECTION CHECKLIST

Disease ..................................................................................................................................................

Study eligibility:

1. Study design:  
   a. Population based  
   b. Not Population based

2. Study area ........................................................................................................................................

3. Year of study .....................................................................................................................................

4. Epidemiological estimates provided (at least one):
   a. incidence rate  
   b. prevalence
   c. remission proportion  
   d. case fatality ratio
   e. average duration  
   f. mortality rate
   g. age distribution of cases or deaths
   h. sex distribution of cases or deaths
   i. disability proportions  
   j. others

Publication status:

   a. Published  
   b. In process for publication
   c. Unpublished

If unpublished or in process for publication, consent obtained:

   a. Yes  
   b. No
ANNEX E: CONSENT

Federal Ministry of Health
In collaboration with the Department of Community Medicine
Faculty of Medicine
University of Khartoum
The Burden of Diseases and Injuries in Sudan in 2002

Principal investigator for Phase 1: Dr. Safa Ibrahim Abdelaziz
Department of Community Medicine
Faculty of medicine
University of Khartoum

The purpose of this study is to measure the burden in terms of Disability Adjusted Life Years of a comprehensive list of diseases and injuries in Sudan in 2002. This is a new approach that summarizes information on mortality and morbidity caused by these conditions. The study will provide summarized and comprehensive information needed for planning and priority setting, and thus facilitate evidence based health policy.

The study will be conducted in the form of a project of two phases. Phase 1 is a pilot study to pretest the approach in Sudan’s data settings. It will assess the burden of 14 selected conditions: Malaria, Shistosomiasis, Meningitis, Measles, Tuberculosis, HIV/AIDS, maternal haemorrhage, protein energy malnutrition, diarrhoeal diseases, Acute respirator tract infections, low birth weight, Diabetes mellitus, Hypertension and road traffic accidents.

Phase 2 will use information provided in Phase 1 to assess the burden of the remaining conditions consisting of communicable and non-communicable diseases and injuries.

The study will rely on secondary data from published and unpublished reports, studies, and raw data related to the conditions under study.
We shall be very thankful if you provide us with the unpublished data and information available to you. In our part we guarantee the following:

- The data/information will be used for the stated purpose only.
- The data/information will not be used for any other purpose. Should this become necessary, a separate consent will be requested.
- No further processing of the data/information will be done after the end of the study. Should this become necessary, a new separate consent will be obtained.
- The data/information will not be shared with any third party without the knowledge and consent of the owner.
- Access to the data/information will be restricted to the researchers.

Principal investigator

Burden of Disease Project
Consent

- I have been approached to provide unpublished data/information for the purpose of studying the burden of diseases and injuries in Sudan in 2002.
- I have been informed and fully understand the purposes and nature of the study.
- I understand that the researchers guarantee the following:
  - The data/information will be used for the stated purpose only.
  - The data/information will not be used for any other purpose. Should this become necessary, a separate consent will be requested.
  - No further processing of the data/information will be done after the end of the study. Should this become necessary, a new separate consent will be obtained.
  - The data/information will not be shared with any third party without the knowledge and consent of the owner.
  - Access to the data/information will be restricted to the researchers.

I therefore agree to provide the data/information about:

......................................................................................................................................
......................................................................................................................................

In hard form / soft form

......................................................................................................................................

Name.........................................................................................................................
Status ...........................................................................................................................
Signature .................................................................................................................... Date: .............................
ANNEX F: EXPERT PANEL MEMBERS

1. Professor Salah Ahmed Ibrahim
   Department of Paediatrics and Child Health – Faculty of Medicine – University of Khartoum.

2. Professor Zein Alabideen Mohammed Ahmed
   Department of Paediatrics and Child Health – Faculty of Medicine – University of Khartoum.

3. Professor Abdel Salam Gereis
   Department of Obstetrics and Gynaecology – Faculty of Medicine – University of Khartoum.

4. Professor Almahdi Mohamed Ali
   Department of Internal Medicine – Faculty of Medicine – University of Khartoum.

5. Dr. Alfatih Malik

6. Dr. Abdelrahim Mohamed Ahmed
   Senior orthopaedic surgeon