NUTRITIONAL STATUS, INFANT AND YOUNG CHILD FEEDING AMONG CHILDREN AGED 6-59 MONTHS IN WINDHOEK AND SURROUNDING AREAS, NAMIBIA

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ABSTRACT

Malnutrition is a global health concern in children under five years, and often presents as stunting, underweight, overweight and wasting. Measurement errors in taking anthropometry limits their validity in defining childhood malnutrition, resulting in need for alternative techniques. This study aimed to determine the nutritional status of Namibian children under five years, and to correlate these findings with their dietary practices, as well as test new digital technologies in child anthropometric measurements. A cross-sectional, descriptive study was conducted on Namibian children between the age of 6 to 59 months, using anthropometric measurements of weight, height and mid-upper arm circumference. Height was collected using three different instruments, an analog height board, a digi-board and a 3D scanning mobile phone app called Child Growth Monitor (CGM). The reliability of the digi-board was assessed using technical error of measurement (TEM), percentage technical error of measurement (%TEM), intra class correlation (ICC) and statistical tests on absolute differences. Accuracy of the CGM 3D imaging to diagnose stunting was assessed by sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). In all these assessments, the analog height board was considered as the gold standard and used for comparison. A dietary survey was conducted using a 24-hour food recall questionnaire. The study recruited 612 children, of which 425 children yielded data using the digital board and analog height board and 187 children yielded data using the CGM 3D imaging and analog height board. The prevalence of malnutrition was determined to be 29.6% stunting, 4.5% wasting, 16.7% underweight and 2.4% overweight, based on the traditional analog height board. The digi-board indicated superiority to the analog height board in terms of reliability (analog TEM = 0.22, digi-board TEM=0.16), while the CGM 3D imaging underestimated children for wasting (analog and CGM 3D imaging = 7% and 1.1%). Underweight and stunting estimated similarly (analog and CGM 3D imaging = 15% and 13.3% for underweight, and 26.9% and 27% for stunting, respectively). There was a low positive correlation between malnutrition and dietary diversity of children, and food diversity was found to improve child health. In this study, the prevalence of stunting is moderate according to the World Health Organisation cut-offs, confirming that stunted growth is still a health problem in Namibian children under five years, and proper interventions such

as food donations and educational programmes to mothers on breast- and young child feeding practices are required to address these issues.

Keywords: Anthropometry, malnutrition, children, 3D imaging, reliability, dietary diversity

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DEDICATION

I dedicate this project to my Lord Almighty, who has been my source of strength and guidance throughout this process. He has answered my prayers which gave me hope and courage all the way until I completed. I would like to dedicate this thesis to my parents, the late Mr Andreas Namene and late Mrs Monika Namene, who have and still mean so much to me. Although they are both no longer in this world, their presence and support is felt until this day and I will continue to work hard to make them proud from heaven. They taught me the values of education and hard work, and I will continue to cherish and honour them forever.

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DECLARATIONS

I, Johanna Namene, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

Johanna Namene		October 2022
Name of Student	Signature	Date

LIST OF ABBREVIATIONS AND/OR ACRONYMS

3D Imaging	Three-Dimensional Imaging
BMI	Body Mass Index
CGM	Child Growth Monitor
ENA	Emergency Nutrition Assessment
FFQ	Food Frequency Questionnaire
FN	False Negative
FP	False Positive
HAZ	Height-for-age
HC	Head Circumference
HREC	Human Research Ethics Committee
HPP	Harambee Prosperity Plan
ICC	Intra Class Correlation
IYCF	Infant and Young Child Feeding
MAM	Moderate Acute Malnutrition
MBE215	Molecular-Beam Epitaxy 215
MDG	Millennium Development Goals
MICS	Multiple Indicator Cluster Surveys
MoHSS	Ministry of Health and Social Services
MUAC	Mid Upper Arm Circumference
NACS	Nutrition Assessment Counselling and Support
NAFIN	Namibia Alliance for Improved Nutrition
NAFSAN	Nutrition and Food Security Alliance of Namibia
NCD	Non-Communicable Disease
NDHS	Namibia Demographic and Health Survey

NDP 5	Fifth National Development Plan
NFNP	National Food and Nutrition Policy
NHNES	National Health and Nutrition Examination Survey
NPV	Negative Predictive Value
NSA	Namibia Statistics Agency
NSFP	Namibia School Feeding Program
OTP	Outpatient Therapeutic Program
PAHO	Pan American Health Organisation
PI	Principal Investigator
PII	Personally Identifiable Information
PPV	Positive Predictive Value
ProPAN	Process for the Promotion of Child Feeding
RGB image	Red Green Blue image
SAM	Severe Acute Malnutrition
SD	Standard Deviation
SMART	Standardised Monitoring and Assessment of Relief and Transitions
SSA	Sub-Saharan Africa
SPN	Strategic Plan Nutrition
SPSS	Statistical Package for the Social Sciences
SUN	Scaling Up Nutrition
TEM	Technical Error of Measurement
TN	True Negative
TP	True Positive
UNAM	University of Namibia

UNICEF	United Nations Children's Fund
WAZ	Weight-for-age
WFP	World Food Programme
WHO	World Health Organisation
WHZ	Weight-for-height
ZHSR	Zero Hunger Strategic Review

1. INTRODUCTION

1.1 Background of the study

Malnutrition is a global health concern in children under five years, and often presents as stunting, underweight, overweight and wasting (1). Malnutrition refers to the deficiencies, imbalance or excesses in nutrient or energy intake in an individual's body (1). It is associated with reduced childhood development (impaired cognitive function, learning and language capabilities), increased risk of child mortality, as well as poor reproductive outcomes and compromised immune system issues at later stages in life (2). One of the WHO's nutrition goals is to reduce malnutrition by 40% by the year 2025 (3). Globally, there has been a reduction in the prevalence of stunting over the past 20 years from 33.1% in 2000 to 22% in 2020 (4), yet in sub-Saharan Africa (SSA) the prevalence has increased by 4% between 2000 and 2015 (5). Childhood malnutrition is multifactorial; it is associated with diet, maternal age and education, diarrhoeal illness, place of residence (rural vs urban), low birth weight, source of drinking water, poor access to health facilities and food insecurity (6).

Malnutrition in children under five years of age is a common health problem in Namibia. According to the 2013 Namibia Demographic Health Survey (NDHS), 24% of children under the age of five years were stunted, 6% are wasted, 13% are underweight, 3% are obese/overweight and 13% were born with low birth weight (7). In 2019, some sources in the Namibian newspaper reported that only 13% of Namibian children receive their minimum acceptable diet (8). Reports indicated that a number of Namibian children suffered from severe malnutrition, and some were fed traditional beer due to a lack of food (9).

Collecting and analysing anthropometric data is a first step to determine nutritional status at both individual and national level. It is important in obtaining information about the prevalence of malnutrition within a community or a specific population group population, to identify high-risk groups and assess the role of different epidemiological factors in nutritional deficiencies (10).

Nutritional status assessments rely on a combination of methods including anthropometric, laboratory, dietary and clinical examinations to provide information about the individual (11). The word anthropometry is derived from *anthro* meaning 'human' and *metry* meaning 'measurement", describing measurements of the human body. The different measurements that are used for growth assessment in children include height/length, weight, mid-upper arm circumference (MUAC) and head circumference. The consumption of adequate amounts of food both in terms of quantity and quality is one of the key determinants of children's nutritional status (12). Children's eating pattern and food consumption is a crucial factor associated with their health and well-being (13). The consequences of inadequate food intake in children include poor immunity, delayed growth and development, and increased morbidity and mortality (13).

In an effort to obtain up to date data on nutritional status of Namibian children under five years of age, the purpose of this study was to assess the nutritional status of Namibian children under the age of five years and to correlate it to their dietary practices.

1.2 Statement of the Problem

According to the 2013 NDHS report (7), the prevalence of stunting in Namibian children under five years was 24%, wasting 6% and underweight 13%, which is a high burden. Manual anthropometric measurement are considered unreliable. In Namibia, the Namibia Household Income and Expenditure Survey (NHIES) (14) of 2015/16 and 2013 NDHS (7) produced biologically implausible measurements. WHO cut-offs flagged 12% of children for biologically implausible measurements for 2013 NDHS and 8.7% for the 2015/16 NHIES data (15). According to the WHO Expert Committee, surveys with biologically implausible measurements of 1.0% or higher indicate data quality problems and such a survey is likely to be of poor quality (16).

1.3 Objectives of the study

The broad objective of the study was to assess the nutritional status of Namibian children under the age of five years in correlation with dietary practices.

Specific objectives:

1. To assess nutritional status of children under five years old (stunting, wasting, underweight);
2. To assess the reliability of anthropometric measurements using the digital height board in comparison to the analog height board in children under five years old;
3. To assess the accuracy of 3D imaging for anthropometric measurements in children under five years old;
4. To determine the association between dietary diversity and nutritional status of children under five years old.

1.4 Significance of the study

The study provides contemporary cross-sectional data on the current state of child nutrition in Namibia and their diet. The data that is available in the literature on the nutritional status of children in Namibia is outdated, and there is lack of data available in literature on the dietary diversity among children under five years of age. The current study will fill the gaps in literature.

Manual anthropometric tools can easily be manipulated by the person doing the measurement, they are bulky and heavy, and place a burden on anthropometrists. In addition, young children often do not stand still, making it difficult to measure them accurately (17). Given that child growth has broad effects on health, nutrition and development, it is crucial that the anthropometric measurements are of high quality (18). The study evaluates a potentially faster and more accurate way of screening children for malnutrition, which is more practical, particularly for mass testing. This study is the first in Namibia to have access to both the digital height boards and the CGM 3D imaging phones, and is a pilot study to provide statistical estimates on the nutritional status of children, as well as planning strategies for a larger study. Equally important, the data from this study provides insights into the nutritional status and degree of malnutrition of the measured children in a particular area, and presents data on underweight, stunting and wasting in relation to dietary surveys.

1.5 Limitations of the study

This study was limited to using a 24-hour diet recall questionnaire and no other methods of dietary assessment such as food frequency questionnaire and food records. This is because, other dietary assessment methods take days and weeks to complete, which was not feasible and practical in our study setting.

1.6 Delimitation of the study

The target population of this study was Namibian children from Windhoek and surrounding areas; Brakwater, Dordabis and Okahandja. Hence the results of this study cannot be generalised for all Namibian children.

2. LITERATURE REVIEW

This section provides the introduction and background to understand the concept of malnutrition and presents information available in the literature on child malnutrition worldwide, in sub-Saharan Africa and in Namibia. A specific focus is on the prevalence of malnutrition in children under five years, the feeding practices employed and the diversity of food consumed. The section also examines the different forms of malnutrition that exists, the nutritional indicators used to categorise forms of malnutrition and the methods used to assess the nutritional status of under-five children including digital anthropometry. In addition, methods of assessing nutritional status in children under five years, and using 3D imaging to improve anthropometric measurements is presented. A summary of the common factors associated with malnutrition in the under-fives is also presented.

2.1 An overview of malnutrition in children under five years old

Malnutrition in children has been defined and described in various ways. To summarise, child malnutrition is a pathological state caused by insufficient nutrition, which includes undernutrition (protein-energy malnutrition) caused by insufficient intake of energy and other nutrients, overnutrition (overweight and obesity) caused by excessive consumption of energy and other nutrients, and deficiency diseases caused by insufficient intake of one or more specific nutrients such as minerals and vitamins (19, 20). Mehta and others (21) define child malnutrition based on five domains namely, anthropometric parameters, growth, chronicity of malnutrition, aetiology and pathogenesis, and developmental/functional outcomes. Malnutrition affects all groups of a population but young children are particularly at high risk because of high nutritional requirements for growth and development. Malnutrition is further classified

based on its indicators and includes: stunting (low height-for-age), wasting (low weight-for-height), underweight (low weight-for-age) and overweight (high weight-for-height). Children who eat well are more likely to survive, flourish, grow, develop, learn, play, participate, and contribute, whereas malnutrition robs children of their full potential, with consequences for children, nations, and the world at large (22).

Malnutrition has been associated with a substantial increase in the rate of child mortality and morbidity, decreased intellectual development and future productivity, and this could all be preventable. Poor nutrition in the first 1000 days (0-23 months) of a child's life can lead to stunted growth which if not treated can be irreversible, leading to risk of child morbidity and mortality (23). UNICEF reported that, nearly half of all deaths in children under five years are related to malnutrition, specifically undernutrition (24).

2.2 Global burden of malnutrition

Table 1 indicates the global trends of child malnutrition for the past three years as indicated by UNICEF, WHO and World Bank Group (22, 24, 25). Between 2000 and 2019, the prevalence of malnutrition in children under five years have declined worldwide with stunting reported to decline from 32.4% to 21.3% and the number of children affected from 199.5 million to 144.0 million (24). However, from 2018 to 2020 there was an increase in the number of stunted children worldwide and a slight decrease in the number of children who are wasted, suggesting that we are still far from a world free of child malnutrition. In addition, due to restrictions in accessing nutritious meals and necessary nutrition services during the COVID-19 epidemic, these numbers may rise significantly, with the entire impact on stunting taking years to show (22). More effort needs to be employed, in order to reach the World Health

Assembly targets (3) and Sustainable Development Goals (26) of reducing stunted children to 104 million by 2025 and to 87 million by 2030.

Table 1: Trends in global burden of malnutrition between 2018-2020

Indicators of malnutrition	Years		
	2018	2019	2020
Stunting (millions)	149	144	149.2
Wasting (millions)	49	47	45.4

Although there have been slight improvements in malnutrition worldwide, this decline has not been observed within the poor communities in low- and middle-income countries. Asia and sub-Saharan Africa contribute approximately 90% to the total malnutrition population of children under five years world-wide, and Africa alone reports 40% of children stunted and 27% wasted (27, 28). The rate of stunting is reported to be more than double among the poorest children in comparison to the richest children. Poor infrastructure, limited resources and poor access to health services are among the factors contributing to malnutrition and food insecurities (29). According to a WHO report, Africa is the only region where the number of children stunted has increased, from 49.7 million children in 2000 to 57.5 million children in 2019. According to the 2015 Millennium Development Goals (MDG) report, one-third of all undernourished children live in sub-Saharan Africa (SSA), indicating that malnutrition remains a serious health concern for children under the age of five in the sub-region (23). Similarly, around 45% (nearly half) of deaths among children under 5 years of age are linked to undernutrition. Undernutrition raises the chance of common diseases killing children, increases the frequency and severity of infections, and delays recovery from illness.

2.3 Malnutrition in Namibia

2.3.1 Trends of nutritional status of Namibian children

The Namibia Demographic and Health Survey (NDHS), has been the main source of data used to estimate countrywide prevalence of child malnutrition for the past 30 years, since its independence in 1990. Four surveys have been conducted so far, occurring every after four to five years, and the surveys are named according to the year the survey is conducted: NDHS 1992, 2000, 2006/7 and 2013. NDHS provides information on children's nutritional status by measuring the height and weight of all children under the age of five. The prevalence of stunting was found to be 23.6%, according to findings from the 2000 NDHS (6), 29.1% as recorded in the 2006/7 MOHSS, 2008 (30) and 24% in 2013 reported by NDHS, 2013 (31). Stunting (low height-for-age) has decreased from 29 to 24%, wasting (low weight-for-height) has decreased from 8 to 6%, and underweight (low weight-for-age) has decreased from 17 to 13% between 2006 and 2013, according to the Namibia Demographic and Health Survey (NDHS) , as indicated in Figure 1-3 (31, 32).

The Namibian Statistics Agency (NSA) also provides information on child malnutrition collected through the Namibia Household Income Expenditure Survey (NHIES), which is conducted approximately every four to five years. The latest NHIES anthropometric information on weight and height of children under five years was collected in 2015/16. According to their analysis, it was reported that 30.3% of all children measured were stunted, 11.2% were wasted and 19.6% were underweight, showing an increase in the prevalence of child malnutrition between 2013 and 2016. Stunting increased from 24 to 30.3%, wasting increased from 6 to 11.2% and underweight increased from 13 to 19.6%. Figure 1-3 below shows the trends in child

malnutrition from 1992-2016. However, there are known data quality problems with anthropometry from both NDHS and NHIES and this may affect these trends (32).

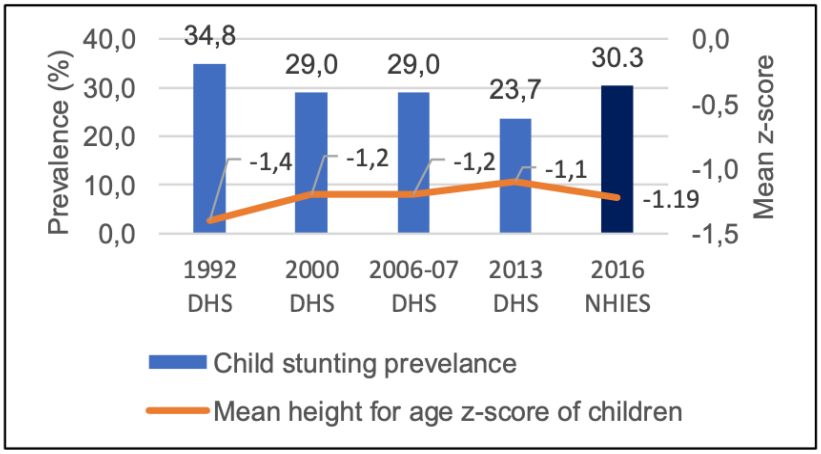


Figure 1: Stunting prevalence of children under five years from 1992-2013 (32)

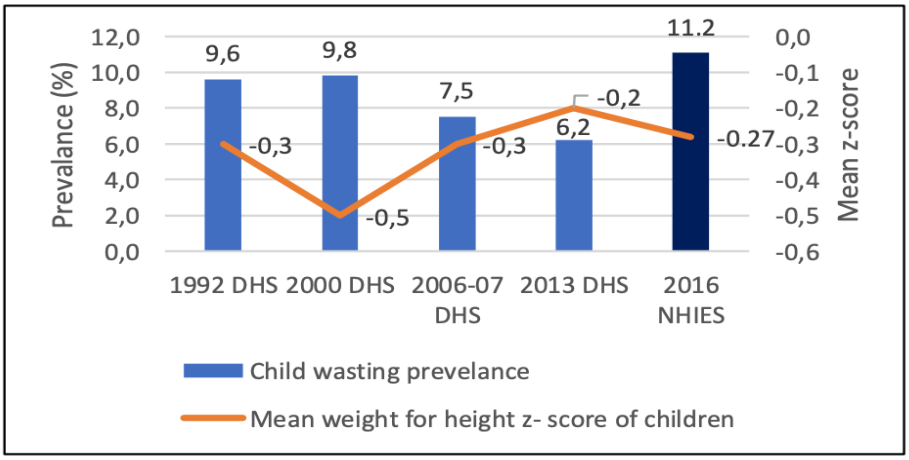


Figure 2: Wasting prevalence of children under five years from 1992-2013 (32)

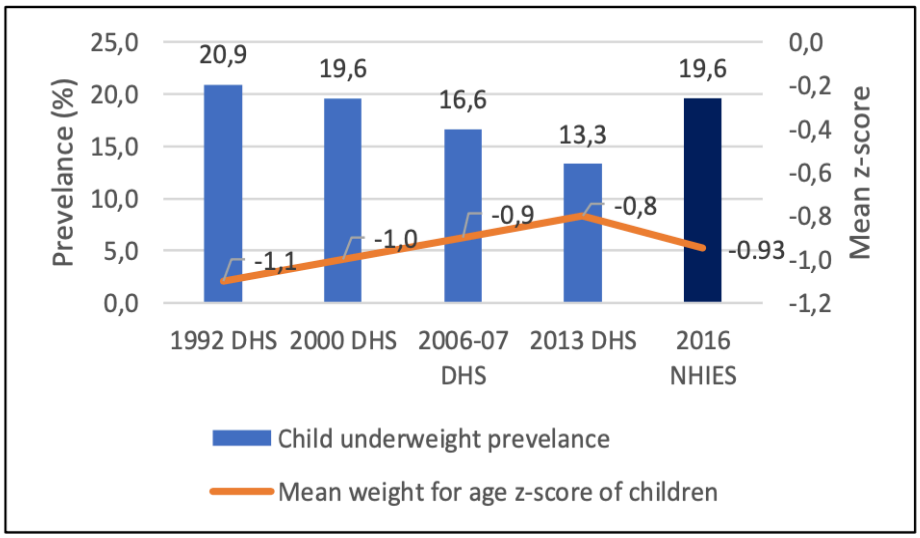


Figure 3: Underweight prevalence of children under five years from 1992-2013 (32)

2.3.2 Namibia country profile

Namibia lies along the southwestern coast of Africa, and is bordered by Angola in the north, Zambia and Zimbabwe in the northeast, Botswana to the east, South Africa in the south, and the Atlantic Ocean to the west as indicated in Figure 4 (33). It occupies an area of 824 290 km^2 and its population is currently at 2,582,402 people, where about 70% is mostly in rural areas (34). Figure 5 (32) shows the density of people across the country, indicating that more people are situated in the northern part of the country. According to the World Bank's classification, Namibia is categorised as an upper middle-income country and over the past decades, political stability and well-grounded economic policy have facilitated poverty reduction. However, its colonisation by South Africa until 1990 and the inheritance of the Apartheid system have resulted in persisting socio-economic inequalities. Namibia is therefore the world's second most unequal country following South Africa, with the highest level of income inequality in the world (35). Despite the economic growth and its upper-middle-income country status, this has not benefited all Namibians, nor has it translated into major

improvements to reduce the level of poverty across the country (27). Namibia therefore continues to experience economic challenges including worrying levels of food insecurity.

Figure 4 Map of Namibia (33)

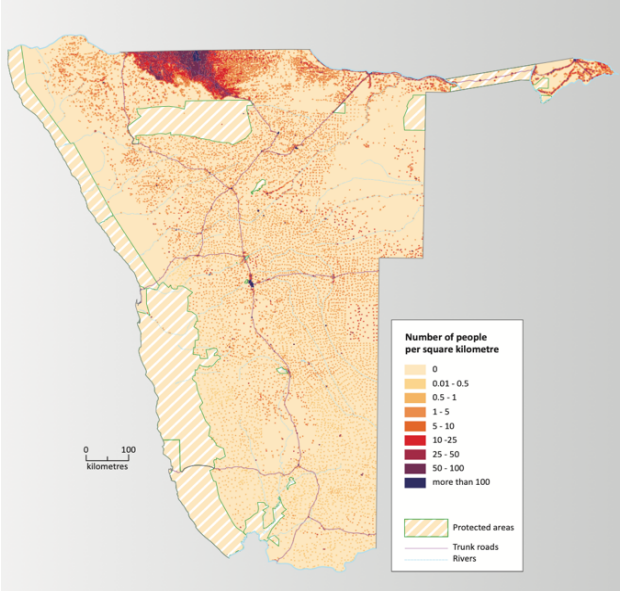


Figure 5**:** Distribution of people in Namibia (32)

2.3.3 Rainfall and food production

Namibia's climate is characterised as arid to semi-arid, with an average annual rainfall of <50 mm along the coastal area, and > 700 mm in the north-eastern corner (Caprivi strip) (36). Rainfall in Namibia occurs mainly during the summer months from December to March, although it may vary as a result of climate change. The country has experienced a shortage of water and poor soils, drought and flood in the previous years, and as a result, the majority of the population have suffered severe food insecurities (37). Food production in Namibia is dependent on the rainfall, as agricultural activities and production are influenced by the amount of rainfall received (38). Additionally, Namibia is highly dependent on its food imports as it only produces 40% of what it consumes. Price fluctuations are therefore particularly affecting families that are dependent on the market for their consumption needs (39). Smallholder farmers also had uncertain access to food as they are affected by recurrent droughts and floods due to climate change as well as limited access to land. Furthermore, the lack of modern farming techniques causes smallholder farmers living in communal areas to have low production and be more prone to food insecurity (39). The main crops grown in Namibia are pearl millet, sorghum, maize, wheat, beans, ground nuts and some fruits and vegetables such as cabbage, spinach, *mutete*, tomatoes and water melon. Maize or pearl millet makes up the foundation and staple food of most diets in Namibia (40). It is eaten with either gravy or milk, or made as a soft porridge. Dietary patterns in Namibia have however shown diversity due to the different tribes of the country. It also differs during different seasons depending on the harvest of seasonal foods.

2.3.4 Fighting against malnutrition in Namibia

Namibia has demonstrated tangible efforts and commitments to scaling up nutrition among children and pregnant women. The government of Namibia has made a pledge to make all efforts to reduce or eliminate malnutrition especially among children. The country has adopted policies in the area of nutrition such as infant and young child feeding (IYCF), elimination of micronutrient deficiency; improving maternal nutrition; and prevention of non-communicable diseases, among others. The WHO/UNICEF recommended that, all women breastfeed their children exclusively from birth until six months and thereafter, the mother should continue breastfeeding with additional appropriate and adequate complementary food for up to two years or beyond (41). Namibia adopted this policy since its recommendation in 1990 to date and awareness as well as support has been given to mothers so that they can breastfeed as recommended.

There are several developmental plans, policies and guidelines that have been put in place in the fight against malnutrition. These include: (a) The National Food and Nutrition Policy (NFNP) 1995 (42); (b) The Food Security and Nutrition Policy for Namibia and Food Security and Nutrition Action plan 2000; (c) The National Infant and Young Child Feeding policy 2003 (43); (d) Namibian Alliance for Improved Nutrition (NAFIN) 2009, which was changed to Nutrition and Food Security Alliance of Namibia (NAFSAN) in 2019; (e) Scaling Up Nutrition (SUN) 2010; and (f) The National Strategic plan for Nutrition (SPN) 2011-2015 (44).

Currently, an existing government school-feeding programme provides children with 125g of maize meal, equivalent to roughly N$1 per child/per day (45). However, the lack of data on childhood nutrition makes it difficult to assess the efficacy of these programmes and whether there are regional variations that need to be addressed.

The Vision 2030 initiative, the Fifth National Development Plan, the Zero Hunger Strategic Review, and the recent Harambee Prosperity Plan, all of which recognise the importance of food and nutrition security and support the Zero Hunger initiative in contributing to Namibia's drive to achieve Sustainable Development Goals 2 and 17 (35).

Some of the above-mentioned policies and guidelines have been employed since the country's independence and mark strong commitments towards improving nutrition and food security in Namibia, however, they are now outdated and need to be revised.

2.4 Forms of malnutrition

Malnutrition refers to three different groups of conditions: undernutrition, micronutrient-related malnutrition and overweight, obesity & diet-related noncommunicable diseases (46). Undernutrition is defined by four sub-forms namely, wasting, stunting, underweight, and deficiencies in vitamins and minerals, which are described in detail in section 2.5. Micronutrient deficiency is referred to as the inadequate intake of vitamins and minerals. In terms of global public health, iodine, vitamin A, and iron are the most important and their shortage poses a serious threat to the health and development of populations all over the world, particularly children and pregnant women in low-income countries (46). Obesity and overweight are characterised by an abnormal or excessive fat accumulation that can be harmful to one's health. Cardiovascular disorders (such as heart attacks and strokes, which are typically connected to high blood pressure), some malignancies, and diabetes are examples of diet-related noncommunicable diseases (NCDs). Poor nutrition and unhealthy diets are among the leading causes of chronic diseases around the world (46).

2.5 Nutrition Indices and Indicators for use in anthropometric measurements

Anthropometric indices are a combination of measurements, used for the interpretation of data in nutritional assessment (47). A value for a single body measurement has less meaning unless linked to an individual's age or height. Anthropometric indices, namely weight-for-age, weight-for-height and height-for-age are derived from a combination of measurements which are useful for the interpretation of anthropometric measurements as indicated below in Table 2, through the use of reference growth standards, established by WHO in 1995 (16), and updated in 2006 (20). These indices are expressed in terms of standard deviations (SD) or Z-scores (16).

Z-scores are used to determine how far an individual's anthropometric measures differ from the median measurements of a healthy population of the same age and gender (48). A z-score of zero SD indicates the median value of the reference population, any score lower than the median have a minus sign (e.g -2), indicating the lower end of the range, and any score higher than zero has a plus or no sign (e.g +2) indicating the upper end of the range. The further the score is away from zero, the greater is the risk of morbidity and mortality associated with malnutrition (49). It is crucial that all the anthropometric measurements are accurate because inaccuracies can lead to erroneous nutritional status classification and improper care and treatment.

Table 2: Z-score and their classification of malnutrition

Indicator of malnutrition	Classification	
Underweight (Weight-for-age)	Moderate malnutrition	Severe malnutrition
	SD-score <-2	SD-score < -3 (severe underweight)

Wasting (below) & overweight (above) (Weight-for-height)	SD-score <-2	SD-score < -3 (severe wasting) SD-score < 3 (severe overweight)
Stunting (Height/height-for-age)	SD-score <-2	SD-score < -3 (severe stunting)

WHO classifies the severity of malnutrition by comparison with a reference population, as low, medium, high and very high (Table 3)(50).

Table 3: WHO percentage classification assessment for severity of malnutrition

Classifications	Low (%)	Medium (%)	High (%)	Very high (%)
Stunting	<20	20-29	30-39	≥ 40
Underweight	<20	10-19	20-29	≥ 30
Wasting	<5	5-9	10-14	≥ 15

2.5.1 Low height-for-age (HAZ): Stunting

Height-for-age is an indicator for linear growth retardation and cumulative growth deficits (31). Stunting is caused by chronic or recurring malnutrition, which is frequently linked to poor socioeconomic situations, poor maternal health and nutrition, frequent illness, and/or unsuitable baby and young child feeding and care in early life (46). Children with a Z-score below minus two standard deviations (<-2 SD) are interpreted as stunted (short for their age) and chronically malnourished, while those below -3 SD are severely stunted. Stunting is a long-term impact of malnutrition; therefore, stunted children suggest a lack of adequate nourishment over an extended period. These children suffer severe irreversible both physical and cognitive damage which can last a lifetime (24, 25).

2.5.2 Low weight-for-height (WHZ): Wasting and overweight (high weight-for-height)

Weight is routinely used as the first step in nutritional assessment (49). Weight is significantly linked to one's health and shows a child's current nutritional state. The weight-for-height (WHZ) index takes into account the body mass in relation to height, and it is used to measure acute malnutrition (49). Children with a Z-score of less than -2 SD are considered wasted (thin) and thus acutely malnourished, while those with a Z-score below -3 SD are considered severely wasted (31). Wasting in children indicates that they did not have enough food in the days leading up to the survey, or that they had a recent sickness such as diarrhoea, causing them to lose weight (46). While a low WHZ index indicates wasting, the opposite indicates being overweight, that is gaining excess weight in relation to height; it implies obesity (16).

2.5.3 Low weight-for-age (WAZ): Underweight

According to NDHS (31) weight-for-age is an index for both height-for-age and weight-for-height, which reflects acute and chronic malnutrition. Children are considered underweight if their Z-score is below -2 SD, and severely underweight if it is below -3 SD. Underweight children might be stunted, wasted, or both (46).

2.5.4 Mid-Upper Arm Circumference (MUAC)

MUAC is an anthropometric measurement that is used to quickly determine the nutritional status of an individual and is commonly used to identify children with acute or severe wasting in the community. It is a circumference of the left upper arm measured using a MUAC tape at the mid-point between the tip of the shoulder and the tip of the elbow (49). MUAC has long been used as a proxy for low weight-for-height ratios which is calculated using a predetermined cut-off number (wasting) (51, 52). The following are some of the benefits of using MUAC as a screening measure for

determining undernutrition: uses basic equipment, is easy to transport to field settings, and requires little training (53). Below are the MUAC cut-offs used to classify nutritional status in children from 6 months to 59 months (Table 4). MUAC is not recommended in infants that are under 6 months (49).

Table 4: Recommended MUAC cut-offs standards for children under five years

Age (mo)	Severe acute malnutrition (SAM)	Moderate acute malnutrition (MAM)	Normal nutritional status
6-59	< 115 mm	≥ 115 < 125 mm	≥ 125 mm

While weight-for-height (WHZ) has long been the preferred indicator for diagnosing severe acute malnutrition (SAM) in primary care settings, its application by community health workers in the field has technical and practical constraints (54). To make community-level operations easier, a two-stage referral and admission system was created (55). The mid-upper arm circumference is used by community health professionals to identify and refer SAM children, while the WHZ is used by program personnel to admit SAM children to the Outpatient Therapeutic Program (OTP) (55).

2.5.5 Head circumference

Head circumference (HC) is a measurement of the head around its largest area, the occipitofrontal circumference, typically measured on infants and children until the age of five years (56). This measurement is used to offer information about a child's health, development, and nutritional status as part of a growth assessment. It is also used to monitor brain growth (may detect any abnormal growth of the brain or skull such as hydrocephalus, microcephaly, macrocephaly) and identify infants who might have neuro developmental disorders (57). Because brain development is most rapid in the

first three years of life, children in this age group should have their head circumference measured while assessing their growth and nutritional status (57).

2.5.6 Skinfold

A skinfold thickness is the double layer of skin and subcutaneous fat (panniculus adiposus) lifted as a fold and measured with standardised callipers and methodology at specific sites on the body (58). Skinfold thicknesses have long been employed as a measure of subcutaneous fat, and they are usually more accurate at predicting body fat than body mass index (BMI) (59). The measurements are based on the assumption that body fat is evenly distributed throughout the body and that skinfold thickness is a measure of subcutaneous fat (58). A skin fold calliper is used to estimate body fat by taking measurements from biceps skinfold, triceps skinfold, subscapular skinfold, and supra-iliac skinfold (60).

2.5.7 Body mass Index (BMI)

BMI is a commonly used measure of standardised weight relative to height and is often used to discriminate between underweight, normal weight, overweight and obesity (49). However, it does not provide accurate body fat measurement, especially in children and adolescents because they are still growing and developing, and their age and sex should be taken into account when assessing their nutritional status (49, 59).

2.6 Methods of assessing nutritional status

Nutritional assessment includes taking anthropometric measurements of an individual or a population, and gathering data about their medical history, measurements of the human body, dietary practices and food security setting (61).

2.6.1 Biochemical assessment

Biochemical assessments include checking the quantities of nutrients in an individual's blood, urine, or faeces (49). Laboratory approaches for assessing nutritional status are reported to be more objective and accurate than community evaluation, dietary methodology, or clinical assessment methods (61). The findings of laboratory tests can provide qualified medical practitioners with valuable information about medical issues that may affect appetite or nutritional status (49). The common laboratory tests to determine deficiency are: serum albumin level, blood-forming nutrients such as iron, folate, vitamin B6 & B12, water soluble vitamins and fat soluble vitamins level, haemoglobin concentration, minerals, cholesterol, blood glucose and various enzymes (62). Various surveys (48, 62-65) have reported that there is a lack of many of these nutrients in undernourished children. Low nutritional intake is frequently linked to a reduction in biochemical status, and some of the causes is a lack of appetite and inadequate food intake (64).

Although biochemical assessments provide accurate information, the interpretation and reporting of laboratory data is typically difficult and does not always correlate with clinical or dietary findings (66). Additionally, these tests are expensive to perform and require well trained personnel to perform them.

2.6.2 Clinical assessment

Clinical assessments are used to discover indicators of malnutrition or factors that contribute to it through medical history and a physical examination (67). Checking for apparent symptoms of nutritional deficiencies such as bilateral pitting oedema, emaciation (muscle and fat tissue loss as a result of poor energy intake and/or nutrient loss via illness), hair loss, and changes in hair colour are all part of the clinical

assessment (49). Information such as the individual's past and current illnesses, hospitalisations, and medication usage, may be found in the medical records (67).

2.6.3 Dietary assessment

In nutritional epidemiology, dietary assessment techniques are essentially used for determining dietary patterns in both children and adults (68). Dietary assessment involves evaluating food and fluid intake of an individual, which provides information about the quantity and quality of food eaten, appetite variations, food allergies and intolerance, and causes for insufficient food intake during or after an illness (49, 68). In clinical practice and research, dietary assessment techniques such as food diaries, food frequency questionnaires (FFQs), 24-hour recall, and food group questionnaires have been used to evaluate children's diets and food selectivity (68). In the 24-hour food recall method, an individual is asked to recall what they ate or drank in detail, in the 24 hours prior to taking the survey (69). Although this method is vulnerable to recall bias, prompting questions are intentionally used to help the individual remember. Sometimes, a food model/portion size measurement aid is used to estimate the food or drink portions consumed.

A food frequency questionnaire (FFQ) is another dietary assessment tool used in children's food record surveys. In this method, data is collected on the overall dietary quality rather than nutrient content and consumption, over a period of time (68). The food frequency questionnaire looks at how often people eat certain meals and, in some cases, how big their servings are. Although this procedure is quick and low-cost, underreporting is widespread. The questionnaire has a list of food where respondents are required to choose the food consumed over a designated period. However, one of the FFQ's major flaws is the lack of information about the types and quantities of food

consumed; also, completing the questionnaire necessitates a certain level of literacy (69).

Another dietary assessment tool used in children is a food record survey. This is a prospective method in which the respondent records the food and beverages consumed over a specific period of time (varying from 3-7 days) (68). Scales, measuring cups, food models, and images are used to assure accuracy when measuring the amount of food consumed. However, this method requires knowledge and skills in food portion estimation (69).

Dietary assessment is challenging especially in children. A parent or caregiver completes the questionnaire for the child, posing additional inaccuracies in nutrient intake, if foods taken outside the presence of the respondent are not accounted for. As a result, it is important that researchers and clinicians choose the right technique when examining nutritional consumption in children.

2.7 Improving anthropometric measurement using 3D imaging

Providing accurate and reliable estimates of anthropometric indicators such as the prevalence of stunting, wasting, and underweight among children is of utmost importance in monitoring progress towards eradicating hunger, improving food security and nutrition, reducing health inequalities, and assessing the progress of short- and long-term nutrition and health interventions (70). Anthropometric measurements currently rely on the use of manual tools such as the wooden height boards, measuring tapes and skin-fold thickness callipers. However, these instruments are not only prone to human error, but they are also big, heavy, and inconvenient for younger children to use, as well as a burden for anthropometrists to carry around, especially during field surveys (71). The existing traditional device also requires the enumerator to place a

large amount of focus on reading off the correct numerical value, while also counting off lines, and simultaneously working to hold the child in the correct position (18). These difficulties created by the current board can detract focus away from ensuring the proper positioning of the child. Due to these reasons, it is most likely that they produce data that is of poor quality which may not be a true representative of the population/individual's nutrition status. This could be improved with the use of an alternate device which would allow full focus to be placed on child positioning.

In a study by Assaf and others (72), they evaluated the quality of anthropometric data of various DHS surveys carried out between 2005-2014, which were done using manual anthropometric tools. The analysis included height, weight and age measurements in which measurement errors were observed in some surveys. Similarly, in another analysis on child anthropometry data quality surveys from DHS, Multiple Indicator Cluster Surveys and National Nutrition Surveys in central Africa region, found many biologically implausible measurements and over-dispersion of length/height-for age z score (73). This variability or over dispersion of data is a result of poor reliability of the equipment used and causes overestimation of prevalence (71).

Anthropometric data quality varies between countries and between surveys in the same country; making it difficult to meaningfully compare countries, analyse trends over time, or target public health interventions (18). At the individual level, poor quality data limits the ability to monitor growth and leads to misclassification of nutritional status. The usefulness of anthropometry is undermined by poor measurement quality, which has led to calls from the global nutrition community for new technology to improve the quality of child anthropometry (72).

Three-dimensional (3D) imaging is not new in anthropometric measurements. It has been used in the past in garment design, ergonomics and in the health sector for research and specialised purposes such as diagnosis and treatments (17). These devices included a television camera and a projector with a 360°-rotating table at which an individual stood while measurements were taken (74). A body scanner is an optical 3D measuring system that generates a digital copy of the surface geometry of the human body (75). Different types of body scanning technologies exist, but the most common ones in use utilise laser and light to create a full body image (75).

In a study by Conkle et al., (18), 3D imaging was done to evaluate its ability to measure length or height, head and arm circumference, by using an AutoAnthro System designed for children under five years. The study results were found to be reliable, but not entirely accurate compared to the current gold standard (18). Anthropometrists found the 3D imaging to be more feasible, indicating superiority over manual equipment (18). To our knowledge, there is little information about 3D imaging for use in anthropometric measurements in low- and middle-income countries; and few studies that used 3D scanners for child anthropometry anywhere, hence a need for this study to fill information gaps and improve anthropometric measurement for children in the health sector. Currently, there is no 3D imaging software that is recommended for use in health sector or surveys for anthropometry. This study evaluated the accuracy of a new 3D (CGM) imaging software that could potentially be used for screening malnutrition in children under five years. The CGM imaging is an open-source, while AutoAnthro uses proprietary software.

In addition to 3D imaging, improving anthropometry may be achieved with another device, the digi-board (digital height board) where the reading of the value does not

require adjustment of the measurers position or counting of lines on the measuring scale. This would prevent errors related to improper positioning of the child. This is important because it may take a long time before 3D imaging is accurate and reliable enough to be recommended for use in surveys and clinical settings. The digi-board enables height measurements to be made with just the click of a button, and the height of the child will be displayed on a screen (71). The digi-board (MBE215) is an infant, child and adult height/length electronic measurement device, which is used to measure the height of children and adults (vertical position) and the length of infants (horizontal position). The process of measuring, processing and transferring data is electronic and digital. This will give the enumerator more opportunity to concentrate on positioning the child. The hope is that the tool is able to produce data that is reliable and accurate in a short time. Analog height boards are known to be challenging especially in children under five years of age and the digi-boards will hopefully improve the reliability in data capturing.

2.8 Child feeding practices

Figure 6**:** Namibian children living in the rural area (32)

Figure 6 (32) shows an image of how Namibian children in rural areas typically eat together from one plate of food. Sufficient nutrition is crucial to child development for optimal growth, health and development. It includes feeding children food in the right amount, proportion and variety to ensure that all the essential nutrients are met. It is recommended that fruits and vegetables, and meat, poultry, fish or eggs be eaten daily or as often as possible (76). Collecting data on the types of food and liquids consumed by children is necessary in assessing the diversity of children's diets, the type of nutrients their diet is composed of, and to find any correlation between their diet and nutritional status. Young children in low- and middle-income countries such as Namibia are at risk of micronutrient deficiencies, however nearly all previous national surveys have omitted such measurements in their studies. To the best of our knowledge, the only information on national micronutrient deficiency comes from a 1992 MoHSS survey on iron, vitamin A and iodine; and a 1999 study on iodine (77). Data on the children food dietary diversity is limited and outdated, thus there is a need for data regarding the feeding practices among children under five years in the country. Poor diet and unsuitable feeding practices are some of the challenges that contribute to the development of undernutrition in children (29). According to the NDHS, as reported by MOHSS (41), only half of all Namibian babies are exclusively breastfed in the first two months of life, 24% are breastfed for six months and only 28% of children were breastfed up to two years. This is an indication that the feeding practices followed by many caregivers does not meet the standards recommended by the Infant and Young Child Feeding (IYCF) policy (43). It is recommended that all children should only be fed breastmilk from birth until they reach six months (43). However, infants are being fed water and other milks from as early as two to three months (78).

Optimal feeding is essential for child growth and development, both physically and cognitively.

Information about the child's feeding can be obtained from questionnaires that are administered to the caregivers of the children. One of the most commonly used questionnaires is the 24-hour dietary recall, food frequency questionnaire, food records, which provides information about the quantity and quality of food being fed to the children.

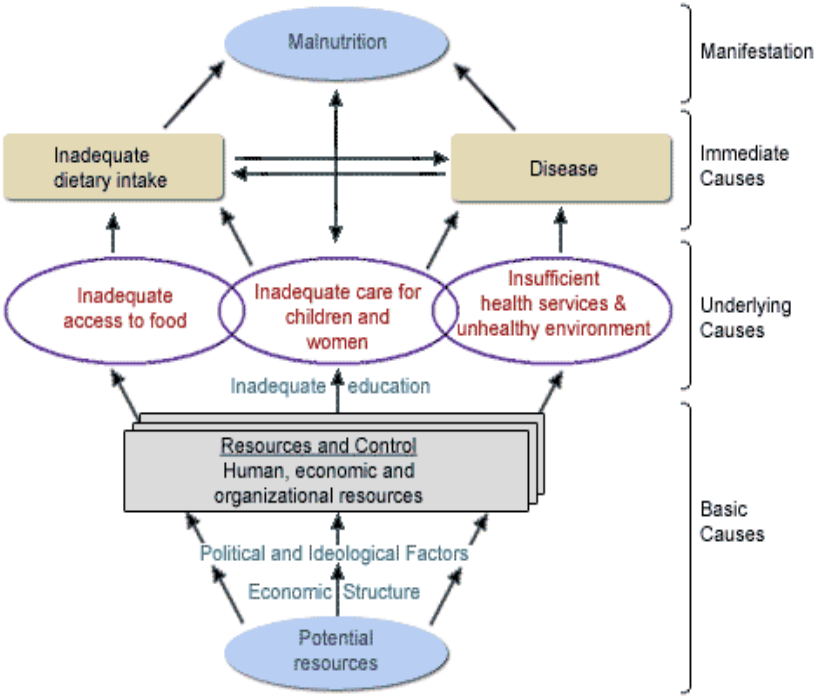
2.9 Factors associated with malnutrition among children under five years

It is essential for a child to have adequate nutrition at a young age for their development both mentally, and physically (79). The most common factors associated with child malnutrition is lack of access to nutritious food and a balanced diet, and this includes poor feeding practices such as inadequate breastfeeding and early introduction of complementary feeding, feeding the child the wrong food and lack of a variety of nutritious food (80). The most common documented factors associated with child malnutrition are: inadequate dietary intake, unsatisfactory health, infectious diseases,

absence of proper care and the mother's age & educational level (79, 81). Additional factors are summarised in Figure 7 (82).

Figure 7**:** Conceptual framework of malnutrition by UNICEF, 2016 (81).

2.9.1 Poverty and food insecurity



Children from poor households that have limited access to food are likely to be stunted, wasted and underweight (83, 84). Households experiencing food insecurity may be too far from the market to buy products or the production of food is limited (83). In addition, food security is determined by several factors including food prices, agricultural practices, climate change and market forces among others (85).

2.9.2 Mother's age and educational background

Young mothers tend to have limited information on child feeding and less experience in child care (84, 86). Moreover, younger mothers tend to have a lower educational

background which leads to a lower occupational status and these may contribute to child malnutrition (84, 86). In addition, children whose mothers have a low or no educational background are more likely to be malnourished than mothers with a higher education, and educated mothers tend to be knowledgeable and exposed to information related to child care (79, 83, 84, 87).

2.9.3 Maternal health and nutritional status

It is documented that children who are born to mothers with a poor nutritional status are more likely to be malnourished compared to children born to mothers who have a normal nutritional status (27, 87). A low birth weight is also observed mostly in children born by mothers who have underlying diseases such as HIV/AIDS and malaria (27).

2.9.4 Children's age

Malnutrition tends to be associated with older (24-59 months old) children compared to the younger ones (79, 87, 88). This could be because older children had changed their diet from exclusive breastfeeding to complementary feeding and bottle feeding and sometimes there is not enough food to feed the children, nor are they able to attain the necessary dietary diversity.

2.9.5 Hygiene and care

Poor sanitation, hygiene (e.g. washing of hands prior to food preparation) and not having access to clean water are among the factors associated with child malnutrition, causing children to be more prone to infectious diseases such as diarrhoea and pneumonia (27, 87). Diarrhoea in particular is known to cause wasting and underweight and can affect both the dietary intake and utilisation, thus affecting child nutrition (83, 86, 87). Water obtained from contaminated wells, rivers, lakes and other

unimproved sources may contain underground microbes and may not be safe for drinking (79).

2.9.6 Feeding practices

On average, babies that are not breastfed tend to be two to five times more malnourished than breastfed infants in the first two months of life, and most likely to suffer from infectious diseases within their first half year of life (27, 87). Breastfeeding is reported to be protective of the child from various infections and it is rich in nutrients needed for the child's proper growth, development and a healthy nutritional status (27, 86, 87).

2.10 Importance and need for nutritional assessment

Nutritional status is assessed for a number of reasons, as described by the Nutrition Assessment, Counselling and Support (NACS) approach (89). It is important to identify individuals that are at risk of malnutrition in order to make interventions at an early stage, before they become malnourished. In addition, the hospitalisation period is longer for individuals with malnutrition when it is not treated at an early stage, and the recovery is also slower. Such individuals are more prone to infections and complications and the rate of morbidity and mortality is higher, thus it is better for such to be avoided at an early stage through nutritional assessment. Furthermore, nutritional assessment is crucial in tracking the child's growth, informing and educating communities and parents about nutrition and the proper feeding practices, and establishing suitable nutrition action care plans. Weight loss has been associated with other severe illnesses such as HIV/AIDS, tuberculosis, cancer, liver diseases etc. Assessment of nutritional status thus allows for further analysis such as biochemical analysis to determine the underlying diseases (49).

3. METHODOLOGY

3.1 Research design and data collection procedure

This was a cross sectional descriptive study of the nutritional status of Namibian children between the age of 6 months to 59 months. The study methods are summarised in Figure 8. The research involved three parts, namely manual anthropometric measurements (using both the analog height board and the digi-board), the Child Growth Monitor (CGM) 3D imaging and the dietary survey. The methods of each part were separately discussed for the sake of clarity.

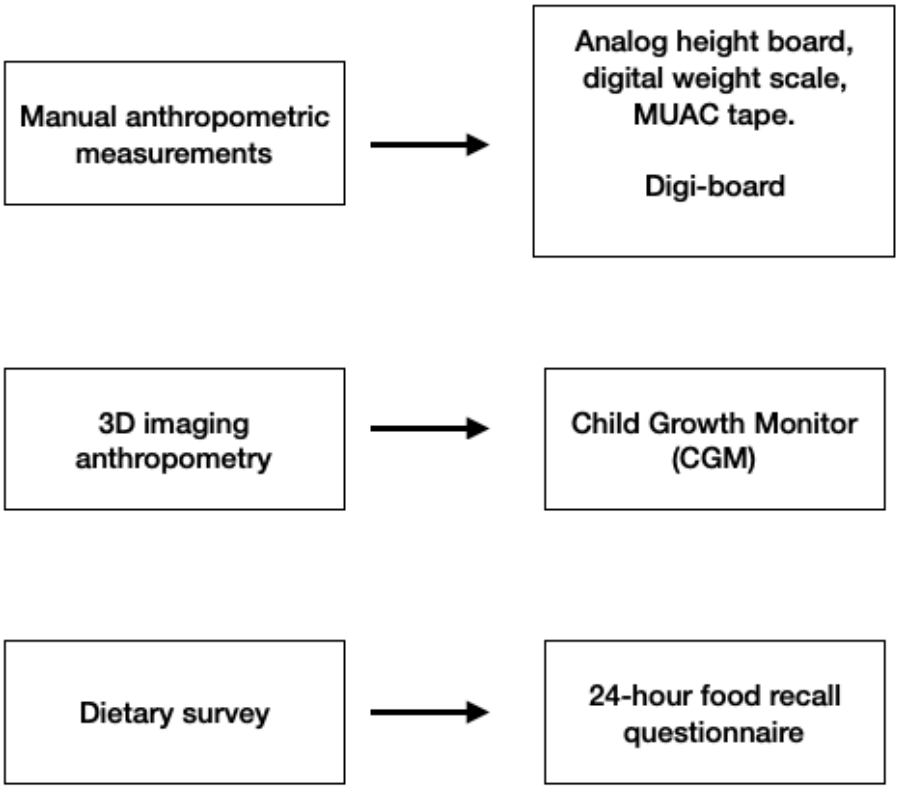


Figure 8**:** Study components

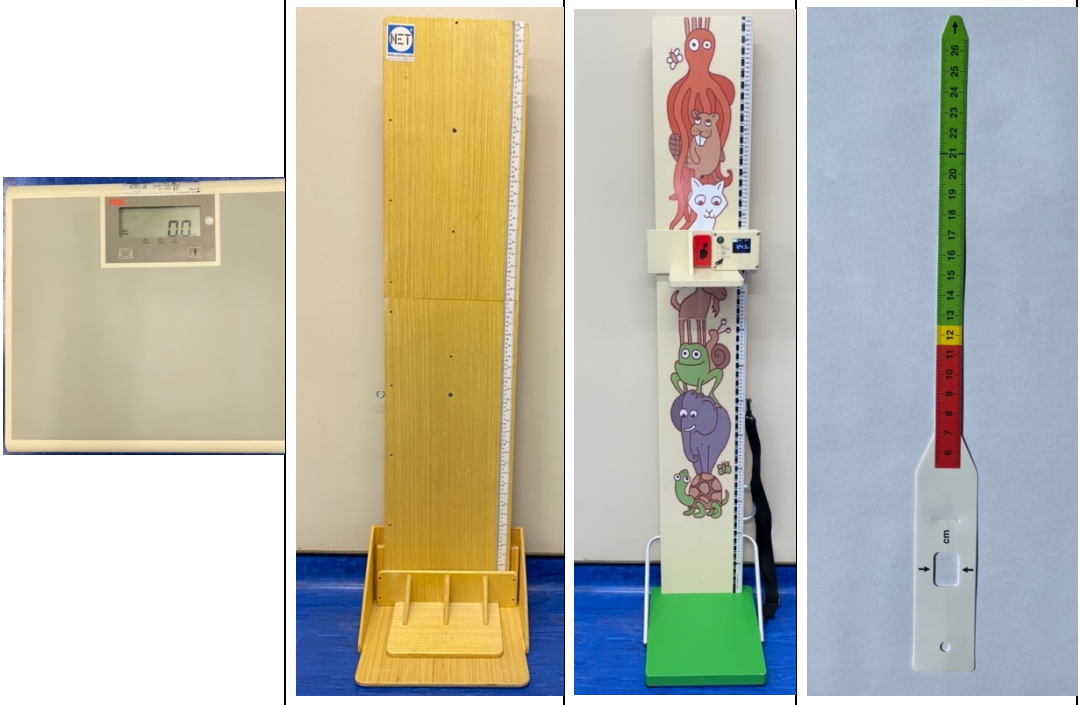
3.1.1 Part one: Manual anthropometric measurements

The aim of this part was to determine the nutritional status of children using both height boards as well as test the reliability of a digi-board in comparison to a manual height board.

Research design: A cross-sectional descriptive study

Research instrument: Anthropometric equipment, i.e. a weighing scale (Figure 9A, analog height board (Figure 9B), digi-board (Figure 9C) and MUAC tape (Figure 9D) were used to measure weight, height and MUAC, respectively, according t

o the WHO standards (16).



A-Digital weight scale	B-Analog Height Board	C-Digi-board	D-MUAC Tape

Figure 9: (A-D)**:** Equipment used for manual anthropometry manual anthropometry

Procedure: All measurements were taken and recorded by two trained enumerators (the principal investigator (PI) and an assistant). The procedures followed the WHO standard protocols (16). Length/height was measured with two height boards, an analog height board (Figure 9-B) and a digi-board (Figure 9-C).

Child height and length measurement procedure: Height was measured for children who were two years or above and able to stand on their own, while length was measured for children below two years and those that could not stand on their own. The child was prepared for measurement by removing the child's shoes, socks, any heavy garment, hair accessory and un-braid/un-tie any interfering hair. The measurement was taken after ensuring that the child's heel, knee, buttocks, shoulder blade and back of the head are against the back of the board. The first and the second measurements between each enumerator were compared to ensure that they were both within the maximum allowed difference (Table 6). Any measurement that was falling outside the maximum allowed difference was repeated. Height was recorded to the nearest 0.1cm. Both height boards were calibrated regularly on a daily basis using metal rods of known height. The detailed protocol is given in annex (f).

Intra- and inter-observer assessment for height: Each enumerator took four measurements of each child, two measurements were taken using the analog height board, and two measurements were taken using the digi-board. This was done to test for reliability of measurements within (intra-observer) and between (inter-observer) measures for both types of height boards.

Weight: Weight measurements were done according to the WHO standards (16) (Annex f) using a portable digital scale (Figure 9-A). Children were measured with minimal clothes. Weight was recorded to the nearest to 0.1 kg.

MUAC: WHO standard procedures (16) were followed when measuring MUAC using a MUAC tape (Figure 9-D). A standard MUAC tape (S0145620 MUAC) was used in this study, which is colour coded with red, yellow and green, indicating the nutritional status of the child (Table 5). Measurements were taken by wrapping the tape around the child's arm (annex f). All measurements were repeated twice and recorded to the nearest 0.1 cm.

Table 5: Standard MUAC tape

Colour	MUAC (cm)	Nutritional status
Red	0-11.5 cm	Severe wasting
Yellow	11.5 – 12.5 cm	Moderate wasting
Green	From 12.5 cm	Healthy

Maximum allowed difference: A third measurement was taken when the difference of the two repeated measurements was more than the values indicated in Table 6 (90).

Table 6: Maximum allowable difference for weight, length and MUAC measurements

Measurement	Maximum allowable difference
Weight	0.1 kg
Length/height	0.7 cm
MUAC	0.5 cm

Statistical analysis: Data was imported into both SPSS version 27 (IBM Corp., Armonk, NY, USA) and GraphPad Prism 9.3.1 (San Diego, California, USA) for quantitative and descriptive analysis. Descriptive statistics of sample size, mean,

median, standard deviation, sum of measurements were obtained. To determine the children's nutritional status, measurements of height, weight and MUAC were entered into ENA software (SMART Methodology, Toronto, Canada) and the anthropometric z-scores of each child were derived. The z-scores gave an indication of the nutritional status of a child based on the nutritional indicators as shown in Table 2.

To measure reliability, Technical Error of Measurement (TEM) and Relative TEM (%TEM) and Intra Class Correlation (ICC) were calculated using SPSS version 27. In order to calculate TEM, at least two measurements of the same child should be taken by the same observer (intra-observer reliability), or by at least two observers taking the same measurement on the same child (inter-observer reliability). Calculations of TEM for both intra- and inter observer reliability are the same when only two observers are involved or when two measurements are taken. The equation is: $\mathrm{TEM} = \sqrt{(\Sigma\, \mathrm{D}^2)/2\mathrm{N}}$, where D is the difference between measurements and N is the number of participants measured (91, 92).

In order to compare TEM collected from different measurements, absolute TEM was converted to relative TEM (%TEM) using the following equation: %TEM = (TEM/mean) × 100 (91, 92).

ICC is another measure of reliability with values ranging from 0 to 1 where values close to 1 indicate little error (91). ICC was obtained using Intra class correlation analysis on SPSS.

Mean absolute difference of two measurements was used to calculate the p-value using the Wilcoxon statistical test in SPSS. A p-value of <0.05 was considered significant for the differences between two height boards.

3.1.2 Part two: 3D Imaging

This part was done to address the objective of assessment of the accuracy of a Child Growth Monitor (CGM) 3D imaging (Welthungerhilfe, Germany) for anthropometric measurements. CGM is an artificial intelligence enabled digital solution tool which can be uploaded on to a mobile phone, which provides measurements to determine different types of malnutrition in children between the age of six months to five years of age. This uses 3D imaging for anthropometry, and has the potential to be used in mass screening to capture mid upper arm circumference and length/height in a matter of seconds (93).

Research design: A cross-sectional descriptive study

Research instrument: Scanning smart phones with a CGM 3D imaging, Figure 10.

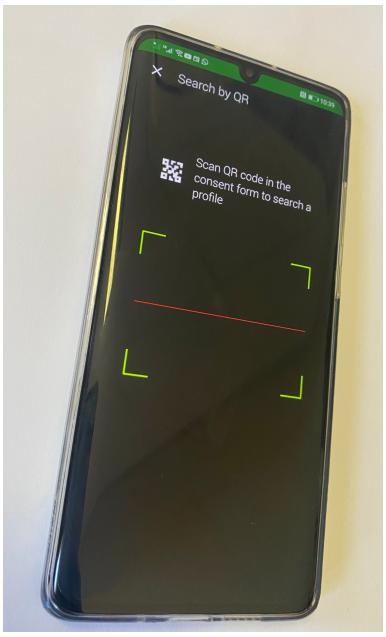


Figure 10: CGM 3D imaging phone

Procedure: Before the scan of a child was taken, a calibration image was scanned to calibrate the application. After calibration was done, both red greed blue (RGB) camera and time-of-flight (ToF) sensor should have passed the calibration, which was

indicated with an ‘OK” before continuing with taking a scan as indicated in Figure 11-A. The battery of the phone, storage, GPS and internet connection were also checked (Figure 11-B). Consent to scan the child was obtained from the parents, and if agreed, the photo of the consent form was first taken and a unique QR code available on the consent form was scanned to create a unique profile for each child (Figure 11-C). Data entry of the name of the guardian, name of the child, date of birth and gender were captured (Figure 11-D). The child’s manual measurements of height, weight and MUAC, and the presence or absence of oedema were taken and considered as gold standard and recorded on the phone (Figure 11-E). To take the scan, the child was measured with minimal clothing, such that the knees and elbow are visible. With the help and permission of the parent, the child was undressed to the diaper or shorts. If the pants, dress or skirt were long, they were folded until the knees were exposed. The child’s shoes were also removed, and the child was asked to step on a flat surface, with a clean background (such as a wall). Data was captured from a total of three scans (front, back and 360-degree scans) of children in the form of an image by using the CGM 3D imaging. For the front and back scan, the child was asked to stand straight and still for about 10 seconds, until the scan was complete. For the 360 scans, the child was asked to rotate at 360 degrees for about 10 seconds while taking the scan with the phone, and the scan measurements were displayed on the phone (Figure 11-F). Using the manual measurements earlier recorded, the application automatically generated the nutritional growth of the child (Figure 11 G-I). This was used to inform the parent of the nutritional status of the child at that specific moment. After the scan was taken and all information about the child was captured, each data set was anonymised and stored over a cloud. The application was calibrated on a daily basis.

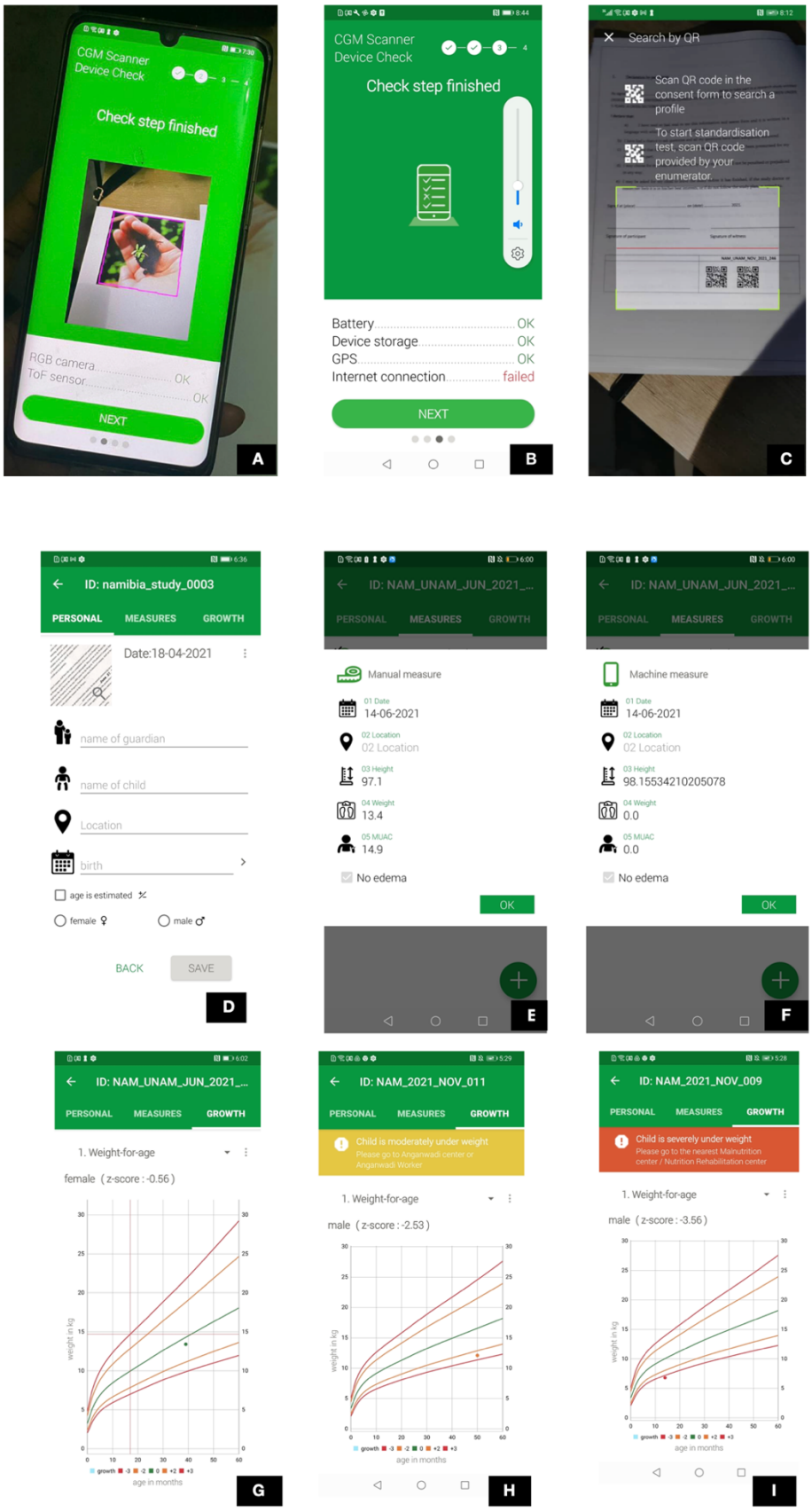


Figure 11: Procedure of data collection using CGM 3D imaging

Data processing and analysis: Data from the scans was uploaded to the Azure Cloud storage in the form of red green blue (RGB) images. After the data was uploaded successfully it was used to generate results by sending it to the end point (a system that helps to secure, monitor and analyse data). The results generated were then sent back to the application (user). Prism 9 was used for descriptive statistics of the study population and the Emergency Nutrition Assessment (ENA) for Standardised Monitoring and Assessment of Relief Transitions (SMART) software was used to determine the nutritional status of children. Accuracy of the CGM 3D imaging to detect malnutrition was assessed by sensitivity, positive predictive values (PPVs), specificity and negative predictive values (NPVs). Sensitivity is the ability of the application to detect true positives and is calculated as: Sensitivity = (True Positives)/(True Positives + False Negatives) (94). Specificity is the percentage of true negatives among all subjects who do not have a disease or condition, which is calculated as: Specificity = (True Negatives)/(True Negatives + False Positives) (94). Positive predictive value was calculated as: PPV = (True Positives)/(True Positives + False Positives), which predicts whether the people who test positive actually have the condition or not (95). Negative predictive value is the prediction of correctly identifying those among people who might or might not have the condition, as people who indeed do not have that condition, which was calculated as: NPV = (True Negatives)/(True Negatives + False Negatives) (95).

Scans of children were stored in the form of RGB images as indicated in Figure 12, in which the face of the child was blurred to assure that no child was identifiable on the uploaded images. In addition, the names and surnames of the child were replaced with unique QR codes and each participant was given a PII (personally identifiable information) that could identify a specific individual.

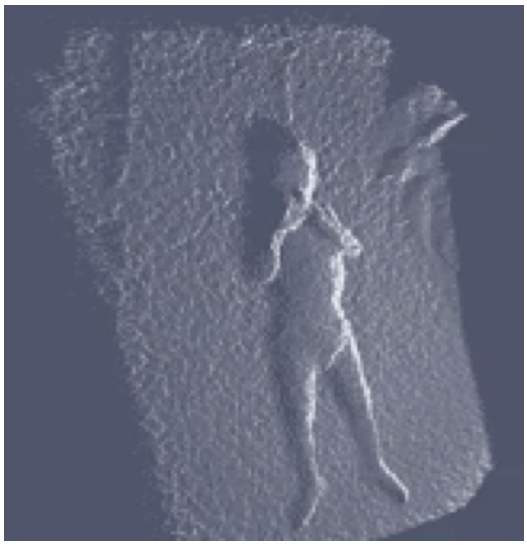


Figure 12: RGB image

3.1.3 Part three: Dietary Survey

This assessment tool was used to achieve the objective to determine the dietary patterns of the children, and to correlate this with their growth parameters. The questionnaire (Appendix d) was written in English. For parents/caregivers who did not understand English or Oshiwambo, a translator was used to translate into the local language (six main different local languages, namely; Oshiwambo, Herero, Damara, Afrikaans, Rukwangari and Silozi).

Research design: Descriptive, quantitative study

Research instrument: A 24-hour food recall dietary questionnaire (Appendix d) was used, which was deployed and approved by Multiple Indicator Cluster Surveys (MICS) and NDHS. The questionnaire recorded the children's demographic information such as their date of birth, age, sex, tribe and location. Breastfeeding background information, vitamins and mineral supplements intake were recorded, and for the most part, the foods and drinks consumed in the previous 24 hours.

Procedure: A structured questionnaire (Appendix d) was given to the children's care givers to gather information about their demographics and socio-economic data, and children's diet. The enumerator interviewed each parent/caregiver focusing on what they ate or drank.

Data analysis: Questionnaire responses for each child were recorded in Microsoft Excel, version 16.61.1 (Microsoft, Washington, USA) and then imported into SPSS for quantitative analysis. The analysis used syntax from MICS, to determine children's dietary diversity score.

3.2 Study population

The target population was Namibian children under the age of five years, with the following inclusion, exclusion and discontinuation criteria:

The inclusion criteria of the current study were children between the age of 6 months and 59 months (male and female) and whose parents had agreed to participate in the study.

Exclusion criteria - Children under 6 months and over 59 months, those with parents who did not consent, between the ages of 6 months to 59 months but were ill during the time of data collection and children, and those who were non-Namibian. Lastly,

the discontinuation criteria included children whose parents wished to withdraw their consent and required to erase their children's data collected under the project.

3.3 Sampling technique and sample size

A convenient sampling method was used in which children under the age of five years were recruited from centres that were available to participate in and around Windhoek. These centers (Havana U-Save, Goreagab community hall, Brakwater, Okahandja and Dordabis community hall) are those that the Omnicare clinic usually operate to render its services to the community. The principal investigator made the first introductory visit to the community leaders, community health workers and other local health facility staff and the public of interest to engage and explain the importance of the survey as well as inquire about their willingness to participate. A centre was then selected according to their availability and a date was set up on when the parents could bring their children for screening, should they agree to participate. For school going children, a letter of permission (Appendix e) and consent form were sent to the school principals, directed to the parents prior to data collection, and only children whose parents/guardian had signed were measured. Data collection took place in the informal settlements in and around the areas of Windhoek, by travelling with the "Mister Sister" mobile health team. The mobile clinic that takes its services to the community, and sampling was done where the clinic was set up. A convenience sampling method was used, such that children that were enrolled into this study were those that happened to be at the sampling site at the time of data collection. Six locations were sampled, namely Brakwater, Dordabis, Goreagab, Havana, Otjomuise and Okahandja.

Data collection consisted of two enumerators, the principal investigator (PI) and an assistant. Both the manual measurements and the scans required an assistant except for the dietary questionnaire. For the anthropometric measurements, the assistant prepared children for measurements and assist the PI with children during measurements if the parent/caregiver was not around to hold the child in position. Each child was first measured for weight, height and MUAC followed by taking the scans. After the child was measured (both manual and scans) the PI interviwed the parent about the child's diet and feeding practices, at the same time filling out the questionnaire. Finally, each caregiver received counselling from the enumerator on the health nutrition practises to improve the health of the child. If any child was found to be severely malnourished, they were referred to the nearest health centre for further treatment.

Sample size

The calculation of sample size was based on the information gathered from previous national surveys regarding the nutritional status of Namibian child. This study aimed to assess the nutritional status of Namibian children, and previous literature reported that the prevalence of children that were malnourished was approximately 40% (77). The sample size required was calculated according to the following formula as described by Magnani (96): $n = (t^2 \times p)/m^{2,}$, where n = required sample size, t = confidence level at 95% (standard value of 1.96), p = estimated prevalence of malnutrition in the project area and m = margin of error at 5% (standard value of 0.05). The sample size was calculated as follow: $n = (t^2 \times p)/m^2$, $n= (1.96^2 \times 0.4 (1-0.4)) / 0.052$, $n = (3.8416 \times 0.24) = 0.9219$, $n = 0.9219/0.0025$, $n = 368.7 \tilde{} 369$. Therefore, the sample size for this study was estimated at 369 children under five years old. However, a total of 612 was sampled constituting 425 children for digi-board vs analog

height board analysis and 187 children for the CGM 3D imaging vs analog height board.

3.4 Training and standardisation test

Prior to the field work, the enumerator and research assistant received training on the use of all manual equipment (analog height board, digi-board and MUAC tape) by watching the WHO anthropometry training course videos. After watching the videos, an in-person training was provided by the expert anthropometrist (child nutrition specialist, UNICEF). Training took a day, in which a total of nine children under the age of five years were each measured twice by the enumerator and research assistant and passed the standardisation test for manual anthropometry. Manual measurements followed the protocol used to develop the 2006 WHO Child Growth Standards (97). Training in using the CGM 3D imaging was provided virtually by the Child Growth Monitor (CGM) staffs from India and Germany. Demonstration videos were also provided by the CGM team on the use of the CGM 3D imaging system. The trained enumerators then informally used the CGM 3D imaging as practice and would reach out to the CGM staffs for any assistance until they were comfortable to use the software.

The PI and research assistant were both educated on the topic of growth monitoring (malnutrition and how to identify it physically) and taking consent from parents before involving their children in the project (data protection and storage of data)

3.5 Ethical considerations

In order to ensure that the survey followed principles to prevent unethical practice to participants, the study was submitted to the Human Research Ethics Committee (HREC)

(Appendix a) and approved, on the basis of less than minimal risk to any participants. The study was submitted to the Ministry of Health and Social Services (MoHSS) (Appendix b) for approval and registration. All potential participants were informed orally and in writing to ensure that participants fully understand the study and its benefits as well as any possible harm. Assent (Appendix c) for minors was obtained from a competent adult parent or caregiver. The parents/caregivers of the participating children signed the assent form as the children are minors. Every procedure was explained adequately to the respondents, and participants were informed that participation is voluntary and they could stop participating at any time. Parents were informed of the usage of data and images and the further publication of results. Confidentiality was strictly maintained through the use of unique identifiers for each participant and anonymisation of data. The images were face blurred so that no child was identifiable by the image uploaded. Once the survey was completed, the data was transferred to a password protected computer and the hard copies were saved in a locked cabinet in the Physiology division. All paper forms will be stored for up to five years and will be destroyed after this period or on request at any time. Each participant was given a toiletries pack and snacks to a value of N$ 100.00. Parents/caregivers who brought their children for the purpose of this research received N$ 30.00 to cover their transportation to and from the centres.

4. RESULTS

Section four presents the results of this study, which was conducted to determine the nutritional status of Namibian children under five years, and correlate this with their dietary patterns. The study also compared two height boards, a digi-board and the traditional analog height board for reliability. In the first part of the results, descriptive statistics of the age groups, the study site, and the ethno-linguistics groups was presented. The second part presented results on the nutritional assessment and status of children, the third part looked at the dietary patterns of the children and the final part presented the reliability and CGM 3D imaging results.

4.1 Descriptive statistics

4.1.1 Sample characteristics of children under five years

Table 7 represent the sample characteristics of the study population. The age of children was calculated in months, from the date of birth to the date the questionnaire was completed and measurement was taken.

The children's ages were divided into two groups according to their age, under two years (6-23 months) and over two years (24-59 months). Of all the 425 children recruited in this study, 40.9% were under the age of two years, and 59.1% were above two years of age. The 6-23 months age group comprised of 80 females and 94 males, whereas there were 134 females and 117 males in the 24-59 months group. For comparison purposes, younger children were considered as children from 6-24 months and older children were considered as those from 24-59 months in this study. The mean age among participants is 28.9±15.3 months.

The majority of children came from Havana (32.9%), followed by Dordabis (24.7%) and with Otjomuise (0.5%) being the least represented area, as indicated in Table 7. The increased number of participants from Havana was due to the frequency of the

"Mister Sister" mobile clinic visits, seeing that is one of the highly populated informal settlements in Windhoek. The majority of participants were from the Owambo tribe, contributing 62.4% of the study population, and the least represented tribes were the coloured, Nyemba and Bushman with 0.2% each of the population.

Table 7: Sample characteristics of children under five years		
Age in months	**n**	**Mean (range)**
All	425	28.9 (6.0-59.0)
Age group (mo)	**n**	**%**
6-23.9	174	40.9
24-59.9	251	59.1
Sex	**n**	**%**
Female	214	50.4
Male	211	49.6
Ethno linguistic group	**n**	**%**
Bushman	1	0.2
Damara	42	10
Herero	26	6.1
Nama	4	0.9
Nyemba	1	0.2
Mixed	83	19.3
Owambo	265	62.4
Rukwangari	3	0.7
Location	**n**	**%**
Brackwater	31	7.3

Table 7: Sample characteristics of children under five years		
Age in months	**n**	**Mean (range)**
Dordabis	105	24.7
Goreagab	84	19.8
Havana	140	32.9
Okahandja	63	14.8
Otjomuise	2	0.5

4.1.2 Weight and height distribution of children

The minimum weight was 5.1 kg of a 9 month old female child, and the maximum weight measured was 21.10 kg of a 4 years and 7 month old female child. The mean weight of all the children was 11.38±2.9 kg. Children's weight was segregated according their sex and age groups as indicated in Figure 13.

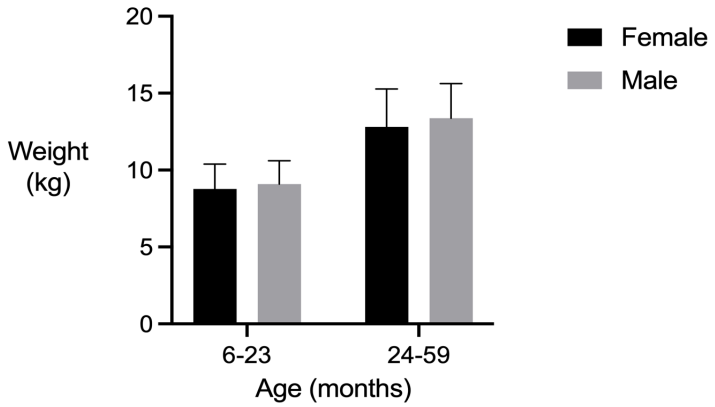


Figure 13: Weight distribution by age group

4.1.3 Height distribution of children according to sex and age groups

Table 8 show the descriptive statistics of height for boys and girls with reference to their age groups. The height ranged from 62 cm to 111.5 cm, with a mean of 84.5±11.8 cm.

Table 8: Distribution of height of under five children by sex and age group						
Height (cm)	**Age of boys in months**			**Age of girls in months**		
	6-23 (n)	**24-59 (n)**	**Total (n)**	**6-23 (n)**	**24-59 (n)**	**Total (n)**
60-70	11	14	25	17	22	39
71-80	24	26	50	24	36	60
81-90	26	36	62	19	27	46
91-100	24	26	50	15	39	54
>100	9	15	24	5	10	15
Total	**94**	**117**	**211**	**80**	**134**	**214**

4.2 Prevalence of malnutrition among children under five years (based on WHO standards 2006)

4.2.1 Quality control - Flagged data

Anthropometric indices likely to be in error (-5 to 5 for weight-for-height (WHZ), -6 to 6 for height-for-age (HAZ), -6 to 5 for weight-for-age (WAZ)) are said to be 'flagged' and are therefore conventionally excluded from the analysis of nutritional status of children. Our study showed no flagged data of WHZ, HAZ and WAZ and hence all data was included in the analysis.

4.2.2 Prevalence of malnutrition by sex

Table 9 indicate the prevalence of malnutrition according to the sex of children under five years. The prevalence of wasting (weight-for-age) among children was 4.2%, of which 2.6% of children were moderately wasted and 1.6% were severely wasted. A total of 407 (95.8%) children presented with a normal weight for height. The

prevalence of boys and girls wasted was similar, 4.3% and 4.2% (p-vaule =0.742). The prevalence of children underweight was 16.5%, with 12% moderately underweight and 4.5% severely underweight. More male children were severely underweight, with 5.2% compared to female children, who were 3.7% but not statistically significant (p-value = 0.322) Overall, 83.5% had a normal weight for age. There were 2.4% of children reported to be overweight, with more boys being overweight than girls (2.8% and 1.9% respectively),. The overall prevalence of stunting was 29.6%, of which 21.9% were moderately stunted and 7.7% were severely stunted. Of the moderately stunted children, 27.0% were male and 16.8% were female, while 7.5% female and 8.1% male were severely stunted. Therefore, more male children were stunted than female children, 34.8% and 24.3% respectively (p-value=0.0174).

Children were also assessed with a mid-upper arm circumference (MUAC) tape, which gave an alternative indication of the nutritional status of the child with regards to wasting. A total of 9 children (2.1%) were <125cm in MUAC, 1.2% were between 115mm and 125mm, being moderately wasted and 0.9% of children were severely wasted (3 females and 1 male). More female children than males were reported wasted by MUAC cut-offs, 2.8% and 1.4% respectively. Children who fall within the normal range by MUAC were 97.9%. Weight-for-age predicted 4.2% of children as wasted, while MUAC for age only predicted 2.1%.

Table 9: Percentage prevalence of malnutrition by sex

	All n = 425 n (%)	**Boys** n = 211 n (%)	**Girls** n = 214 n (%)
wasting	18 (4.2)	9 (4.3)	9 (4.2)

Table 9: Percentage prevalence of malnutrition by sex				
		All n = 425 n (%)	**Boys** n = 211 n (%)	**Girls** n = 214 n (%)
Wasting	moderate wasting	11 (2.6)	4 (1.9)	7 (3.3)
	severe wasting	7 (1.6)	5 (2.4)	2 (0.9)
Underweight	underweight	70 (16.5)	35 (16.6)	35 (16.3)
	moderate underweight	51 (12)	24 (11.4)	27 (12.6)
	severe underweight	19 (4.5)	11 (5.2)	8 (3.7)
Overweight	overweight	10 (2.4)	6 (2.8)	4 (1.9)
	severe overweight	2 (0.5)	1 (0.5)	1 (0.5)
Stunting	stunting	126 (29.6)	74 (35.1)	52 (24.3)
	moderate stunting	93 (21.9)	57 (27.0)	36 (16.8)
	severe stunting	33 (7.7)	17 (8.1)	16 (7.5)
MUAC	wasting (< 125 mm)	9 (2.1)	3 (1.4)	6 (2.8)
	moderate malnutrition (< 125 mm and >= 115 mm)	5 (1.2)	2 (0.9)	3 (1.4)
	severe malnutrition (< 115 mm)	4 (0.9)	1 (0.5)	3 (1.4)

4.2.3 Prevalence of malnutrition by age groups

Table 10 indicate that the prevalence of wasting was higher in children from 24 to 59 months with 4.8% as compared to the 6-23 months age group (3.4%). A 96.6% of children in the 6-23 months age were reported with normal weight-for-height and 95.2% of children in the 24-59 months age group. The prevalence of wasting,

underweight and stunting were higher in the 24-59 months age groups. The prevalence of malnutrition in our study was higher in older children compared to the younger children. There was no prevalence of moderate wasting by MUAC that was observed in children between 24 to 59 months. Figure 14 indicates that children in our study are shorter with less weight than the WHO growth standards, more so for height-for-age as well as weight-for-height. The mean z-score was -0.23, -0.92 and -1.38 for weight-for-height, weight-for-age and height-for-age respectively as indicated in Table 11.

Table 10: Percentage prevalence of malnutrition by age groups

		Total n = 425 n (%)	**6-23 months** n = 174 n (%)	**24-59 months** n = 251 n (%)
Wasting	wasting	18 (4.2)	6 (3.4)	12 (4.8)
	moderate wasting	11 (2.6)	2 (1.1)	9 (3.6)
	severe wasting	7 (1.6)	4 (2.3)	3 (1.2)
Underweight	wasting	70 (16.5)	27 (15.5)	43 (17.1)
	moderate underweight	51 (12.0)	17 (9.8)	34 (13.5)
	severe underweight	19 (4.5)	10 (5.7)	9 (3.6)
Overweight	overweight	10 (2.4)	4 (2.3)	6 (2.4)
	severe overweight	2 (0.5)	1 (0.6)	1 (0.4)
Stunting	normal	126 (29.6)	51 (29.3)	75 (29.9)
	moderate stunting	93 (21.8)	36 (20.7)	57 (22.7)
	severe stunting	33 (7.8)	15 (8.6)	18 (7.2)

Table 10: Percentage prevalence of malnutrition by age groups				
		Total n = 425 n (%)	**6-23 months** n = 174 n (%)	**24-59 months** n = 251 n (%)
	wasting	9 (2.1)	8 (4.6%)	1 (1.7)
MUAC	moderate wasting (< 125 mm and >= 115 mm)	5 (1.2)	5 (2.9)	0 (0.0)
	Severe wasting (< 115 mm)	4 (0.9)	3 (1.7)	1 (1.7)

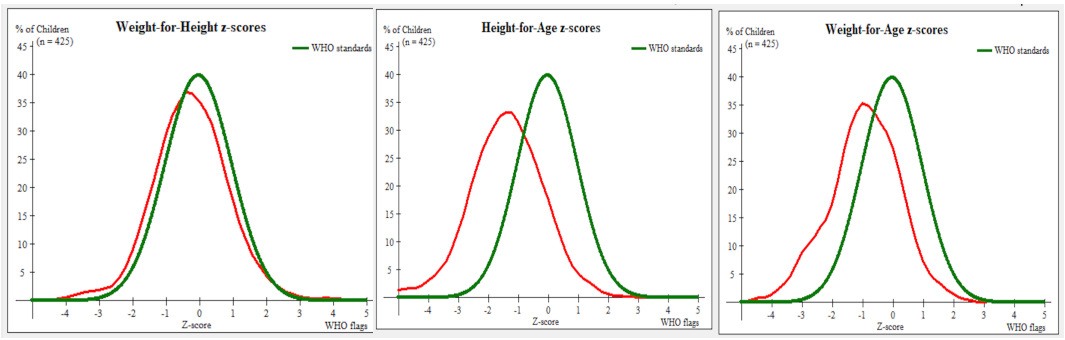


Figure 14: Nutritional indicators of children (red line) in reference to WHO standards (green line).

Table 11: Mean z-scores for weight-for-height, weight-for-age and height-for-age for children under five years

Indicator	n	Mean z-scores ± SD	*p-value
Weight-for-Height	425	-0.23±1.12	0.017
Weight-for-Age	425	-0.92±1.17	0.006
Height-for-Age	425	-1.38±1.22	0.555

*the p-value was calculated based on the z-scores, using a Mann-Whitney's test

4.3 Intra- and inter-observer reliability

Table 12: Intra- & inter-observer reliability for length or height: Mean, standard deviation, mean absolute difference, intra-technical error measurement (intra-TEM), inter-technical error measurement (inter-TEM), relative TEM and intraclass correlation coefficient (ICC) for children 6-59 months by analog and digital height board.

Intra-observer Reliability of Stature (Length or Height)													
Age group (months)	**Sample size [1]**	**Mean (SD) (cm) [2]**		**Mean (SD) Absolute Difference (cm) [3]**		**Technical Error of Measurement (TEM) (cm) [4]**				**Relative TEM (%TEM) [5]**		**Intraclass Correlation Coefficient (ICC) (95%CI) [6]**	
						Analog		**Digital**					
		Analog	**Digital**	**Analog**	**Digital**	**p-value**	**TEM**	**95% precision margin**	**TEM**	**95% precision margin**	**Analog**	**Digital**	**Analog**	**Digital**
All (6-59.9)	820	85.0 (11.6)	85.1 (11.6)	0.20 (0.24)	0.15 (0.17)	<.001	0.22	0.43	0.16	0.31	0.26	0.18	0.999 (0.999-0.999)	1 (1.000-1.000)
Length (6-23)	322	73.5 (5.8)	73.5 (5.8)	0.29 (0.30)	0.20 (0.23)	<.001	0.29	0.57	0.21	0.41	0.39	0.29	0.997 (0.997-0.998)	0.999 (0.998-0.999)
Height (24-59.9)	498	92.5 (7.6)	92.5 (7.7)	0.15 (0.17)	0.11 (0.12)	<.001	0.16	0.31	0.11	0.22	0.17	0.12	0.998 (0.998-0.998)	1 (1.000-1.000)

[1] Sample size: the initial sample size is 425 children, but 15 children did not have two measurements and hence were removed from this analysis. Therefore, the sample size now consists of 410 children who were measured by two different enumerators, providing two observations each, thus a sample size of 820 measurements in total

[2] Mean (SD): mean of all analog and digital measurements (enumerator 1 first and second measurements and enumerator 2 first and second measurement)

[3] Mean absolute difference of intra-observer reliability: mean of the absolute difference between an individual enumerator's measurement 1 and measurement 2

[4] Technical error of measurement (TEM): square root of measurement error variance, TEM $= \sqrt{(\Sigma\, D^2)/2N}$ where D is the difference between measurements and N is the number of individuals measured. The 95% precision margin equals TEM * 1.96.

[5] %TEM = (TEM/mean) × 100

[6] ICC (95%CI): variability between measurement 1 and measurement 2, used ICC single measure with an absolute agreement definition

[7] Mean absolute difference of inter-observer reliability: mean of the absolute difference between two enumerators when comparing measurement 1 to measurement 1 and measurement 2 to measurement 2

Inter-observer Reliability of Stature (Length or Height)													

Table 12: Intra- & inter-observer reliability for length or height: Mean, standard deviation, mean absolute difference, intra-technical error measurement (intra-TEM), inter-technical error measurement (inter-TEM), relative TEM and intraclass correlation coefficient (ICC) for children 6-59 months by analog and digital height board.

Age group (months)	Sample size	Mean (SD) (cm)		Mean (SD) Absolute Difference (cm)[7]			Technical Error of Measurement (TEM) (cm)				Relative TEM (%TEM)		Intraclass Correlation Coefficient (ICC) (95%CI)	
							Analog		Digital					
		Analog	Digital	Analog	Digital	p-value	TEM	95% precision margin	TEM	95% precision margin	Analog	Digital	Analog	Digital
All (6-59.9)	820	85.0 (11.6)	85.1 (11.6)	0.19 (0.25)	0.15 (0.20)	<.001	0.22	0.43	0.17	0.33	0.26	0.20	1 (1.000-1.000)	1 (1.000-1.000)
Length (6-23)	322	73.5 (5.8)	73.5 (5.8)	0.26 (0.33)	0.18 (0.23)	<.001	0.29	0.57	0.19	0.37	0.40	0.27	0.997 (0.997-0.998)	0.999 (0.999-0.999)
Height (24-59.9)	498	92.5 (7.6)	92.5 (7.7)	0.15 (0.17)	0.13 (0.18)	0.004	0.16	0.31	0.16	0.31	0.17	0.17	1 (0.999-1.000)	1 (0.999-1.000)

[1] Sample size: the initial sample size is 425 children, but 15 children did not have two measurements and hence were removed from this analysis. Therefore, the sample size now consists of 410 children who were measured by two different enumerators, providing two observations each, thus a sample size of 820 children in total

[2] Mean (SD): mean of all analog and digital measurements (enumerator 1 first and second measurements and enumerator 2 first and second measurement)

[3] Mean absolute difference of intra-observer reliability: mean of the absolute difference between an individual enumerator's measurement 1 and measurement 2

[4] Technical error of measurement (TEM): square root of measurement error variance, TEM $= \sqrt{(\Sigma\, D^2)/2N}$ where D is the difference between measurements and N is the number of individuals measured. The 95% precision margin equals TEM * 1.96.

[5] %TEM = (TEM/mean) × 100

[6] ICC (95%CI): variability between measurement 1 and measurement 2, used ICC single measure with an absolute agreement definition

[7] Mean absolute difference of inter-observer reliability: mean of the absolute difference between two enumerators when comparing measurement 1 to measurement 1 and measurement 2 to measurement 2

Table 12 presents both intra- and inter-observer reliability for length and height measurements, disaggregated by age groups. Reliability was evaluated using the technical error of measurement (TEM), relative TEM (%TEM), intraclass correlation coefficient (ICC) and mean absolute difference. Wilcoxon signed-rank test (98) was used to test if there is a statistically significant difference between the absolute differences of the analog and digi- height boards.

TEM analyses the standard deviation between repeated measurements obtained from the two methods (analog and digi-board) on the same child. In comparison to analog board TEM (0.22), the digi-board TEM (0.16) was lower, indicating that the digi-board had lower measurement error and better reliability (p-value: <0.001). The 95% precision margin showed that when using a digi-board the enumerator's second measurement was within ±0.31cm of their first measurement 95% of the time for the entire sampled population, compared to ±0.43 cm for the analog board. Both age groups showed a lower 95% precision margin when using the digi-board. The digi-board had better reliability within both age groups; with relative TEM of 0.29% compared to 0.39% for analog boards in the 6-23 months age group, and a relative TEM of 0.12% compared to 0.17% for the 24-59 months age group. Reliability was also assessed using ICC, which gave a correlation coefficient of nearly 1.0 for both types of boards across all age groups, confirming an excellent correlation between repeated measurements for both manual and digi-board.

For inter-observer reliability, the digi-board TEM (0.17) was lower than the analog board TEM (0.22), again indicating that the digi-board had lower measurement error and better reliability in comparison to the analog board. When using a digi-board, the enumerator's second measurement was within 0.33 cm of their first measurement 95% of the time when using a digi-board, compared to 0.43 cm when using an analog board.

While the 6-23 months age group's relative TEM were lower when using the digi-board compared to the analog board, the reliability for inter-observer was similar for both the analog and digi-board for the 24-59 months age group (0.17%). The correlation coefficient for ICC was close to 1.0 for both analog and digi-board across all age groups. Similar to the intra-observer reliability, the analog mean absolute difference (0.19 cm) between observers was slightly higher than digi-board (0.15 cm) and it was statistically significant (p-value: <.001).

Differences in reliability in the two age groups was observed. For intra observer reliability, the relative TEM (0.39%) was higher in the 6-23 months age group in comparison to the 24-59 months age group (0.17%) for the analog boards. For the digi-boards, relative TEM was also higher in the 6-23 months age group (0.29%) compared to the 23-59 months age group (0.12%). This indicates that reliability was better in the 24-59 months age group compared to the 6-23 months age group when using both types of height board. Similar to intra-observer reliability, inter-observer's relative TEM was higher in the 6-23 months age group (0.40%) compared to the 24-59 months age group (0.17%) for the analog boards and 0.27% for 6-23 months age old and 0.17% for 24-59 months old for the digi-board. In both intra- and inter-observer reliability, the improved reliability increases with increasing age. The absolute difference for the 6-23 months age group was higher than that of the 24-59 months age group for both the analog and digital boards and was a significant different at a p-value <.001 for intra observer reliability and a p-value of 0.004 for inter-observer reliability.

4.4 Dietary diversity score

Dietary assessment was performed on a total of 413 children aged 6 to 59 months old. The questionnaire consisted of questions that recorded eight different food groups:

breastmilk, grains and roots tubers, legumes and nuts, dairy products, flesh foods, eggs, vitamin A-rich fruits and vegetables and other fruits and vegetables. Grains and root tubers were the popular food group consumed by 100% of children. These include fortified baby foods such as cereal, nestum, purity, food made from grains such as bread, rice, noodles, porridge and foods made from roots such as white potatoes, white yams and cassava. Flesh foods was the second most popular food consumed at 88.6%, referring to foods such as visceral organ meats (liver, kidney, heart, intestine, tripe etc), other meats such as beef, pork, lamb, goat, chicken, duck, or sausages made from these meats, fish and sea-food. Legumes and nuts were the least consumed food group, consumed by 20.7% of the children, and these included beans, peas, lentils, nuts and others. Eggs were the second least food consumed, by 26.1% of the children, followed by foods that contain Vitamin A (37.9%). Sources of vitamin A are foods such as pumpkin, carrot, sweet potatoes, dark green and leafy vegetables, mangoes, papayas and others. Any other vegetables apart from the dark green and leafy vegetables were consumed by 52.9% of children and dairy products such as milk, yoghurt, cheese and other foods made from animal milk, were consumed by 40% of the children. In terms of the minimum acceptable diet diversity, it is recommended that children reach their minimum dietary diversity if they received food from at least four of the eight groups mentioned above for the children being breastfed and five or more for children not breastfeeding (99). In our study, 42.9% of children received a minimum dietary diversity and the majority of children (57.1%) did not receive the minimum dietary diversity. The results of our study are summarised in Figure 15.

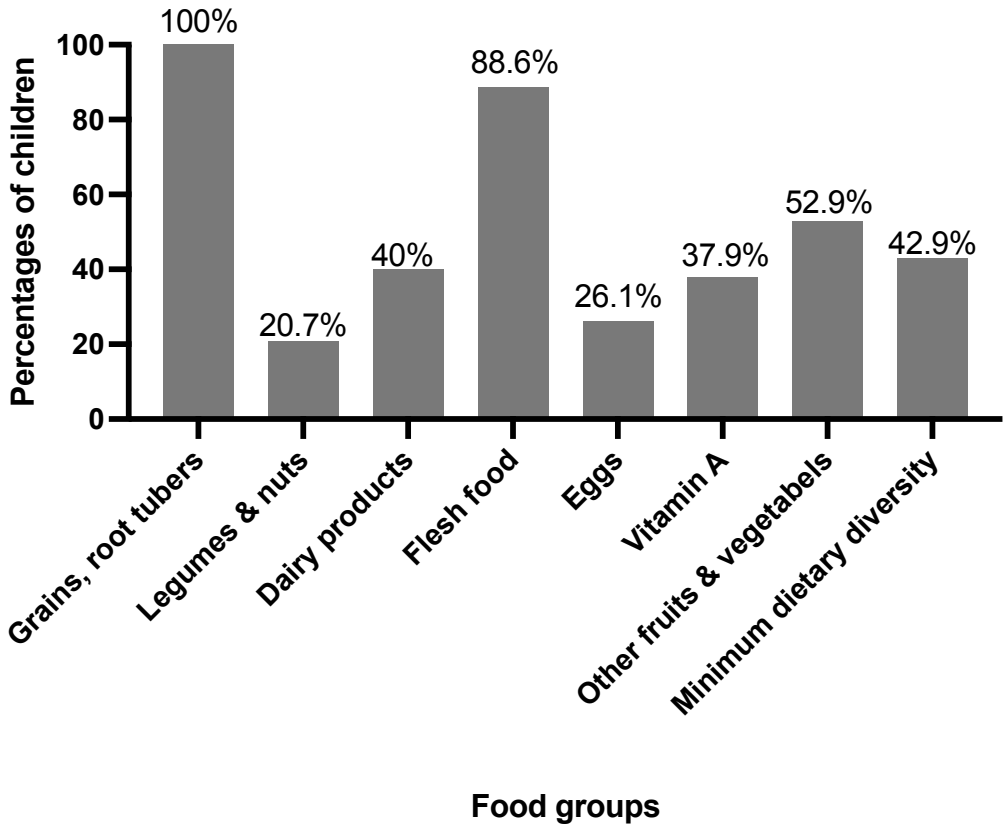


Figure 15: Percentage of children consuming different food groups

Figure 15 indicates the percentage of children consuming each food group, which are used to calculate the minimum dietary diversity score indicator of children and table 13 show the association between dietary diversity and nutritional status of children. In order to assess if diet affected the nutritional status of children, the minimum dietary diversity was divided into two categories, those with low diversity (<4 food groups) and those with high dietary diversity (5-8 food groups). For dietary diversity, only 280 out of 413 children were assessed, excluding 133 children who were exclusively breast fed.

Table 13: Association between dietary diversity and child nutritional status			
	Children not breast fed		
	Wasting	Underweight	Stunting
z-score mean difference	-0.26	-0.25	-0.387
p-value	0.05	0.05	0.156
95% CI	-0.521; 0.002	-0.521; 0.002	-0.393; 0.153
Mean z-scores			
Low dietary diversity n (160)	-0.35	-0.20	-1.44
Hight dietary diversity n (120)	-0.10	0.06	-1.32

There was little difference in malnutrition by dietary diversity among children being breastfed. From the children that were not being breast-fed (n=280), 120 (42.9%) children received a minimum dietary diversity and 160 (57.1%) children did not. For underweight, the mean z-score for children with low dietary diverse meals was -0.20 while for children with a high diverse diet it was 0.06. Underweight was positively associated with low dietary diversity (D=-0.259, p-value= 0.052, 95%CI= -0.521; 0.002). More children with poor dietary diversity were wasted compared to those with good dietary diversity, as indicated by their mean z-scores (D=-0.260, p-value= 0.051, 95%CI= -0.521; 0.002). The p-value of both underweight and wasting was 0.05 and 0.05, respectively, which was found to be statistically significant. Both groups showed stunting (mean = -0.35, for low dietary diversity and -0.10 for high dietary diversity), but the difference was not statistically significant (D= -0.120, p-value= 0.387, 95%CI=-0.393; 0.153).

4.5 Three-Dimensional imaging

This sub-section presents the results of child growth monitor (CGM) 3D imaging software, which was used to scan children for height and weight to determine their nutritional status of stunting, wasting and underweight. The same measurements of height were obtained by an analog height board and a digital weight scale and the results from the analog height board were considered as "gold standard" and compared to the CGM 3D imaging results. Descriptive statistics of children (based on analog height board), and the statistical analysis of comparison between the two instruments are presented.

4.5.1 Descriptive statistics

Descriptive statistics of children measured with CGM 3D imaging is presented in Table 14. A total of 187 children were measured using both the analog height board and CMG 3D imaging on a mobile phone. The data was collected to assess the accuracy of the CGM 3D imaging in detecting children for malnutrition in comparison to the manual height board. Of the 187 children that were measured, 97 were female and 90 were male A total of 47 children were 6-23 months old, and 140 children were 24-59 months old. The minimum weight and height measurements were 5.1kg and 62.6cm of a 9-month-old girl. Conversely, the maximum weight was 22.4kg of a 58-month-old boy while the maximum height was 111.7cm of a 56 months old girl.

Table 14: Descriptive statistics of children under five years measured by analog height board and CGM scan

Age in months	**n**	**Mean (range)**
All	187	37.3 (7.2-59.7)
Age group (mo)	**n**	**%**

6-23.9	47	25.1
24-59.9	140	74.9
Sex		**%**
Female	97	52.1
Male	90	47.9

4.5.2 Results of scans from the CGM 3D imaging

Figure 16A shows the results of scans of children that were measured lying down and Figure 16B those that were measured standing up. These were considered as good scans on the basis that the entire child is captured, without any parts of children cut out of the image and there was no background noise that was picked up by the scans. Again, all the joints of the child needed for height prediction were clearly visible. The faces of children that were picked up by the camera were automatically blurred to avoid facial recognition as seen in the images above. In Figure 16C, the images were considered as bad scans because the child was either not fully visible, lying in a position that the scan could not pick, or too much background noise.

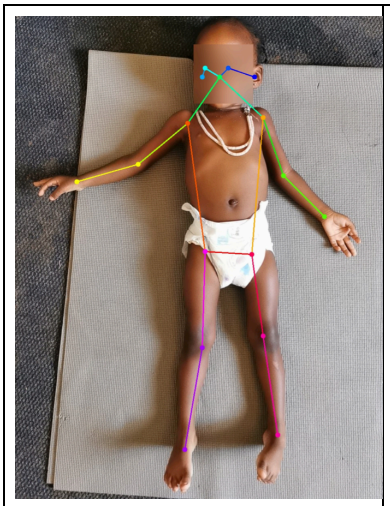
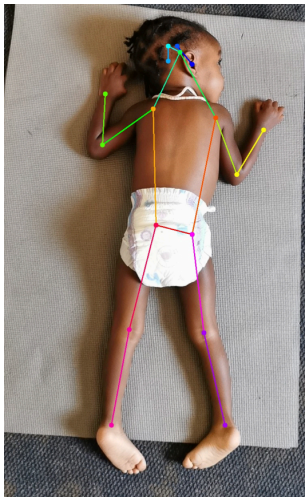
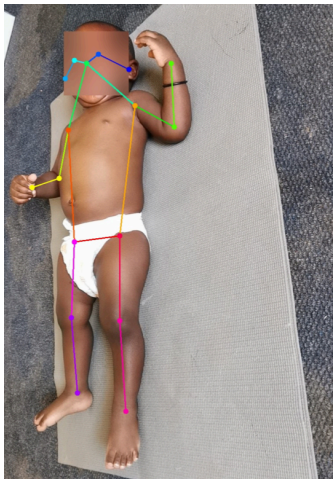




Figure 16A: Scan image of children's front, back and side, lying down.

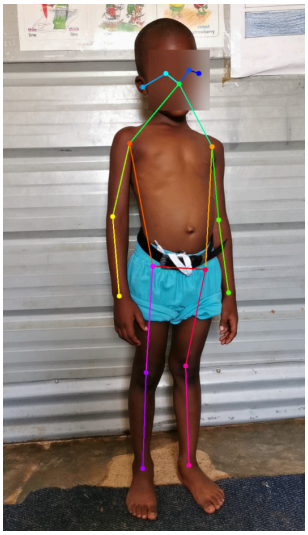
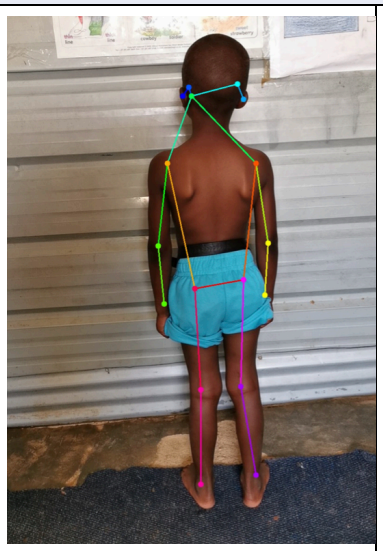
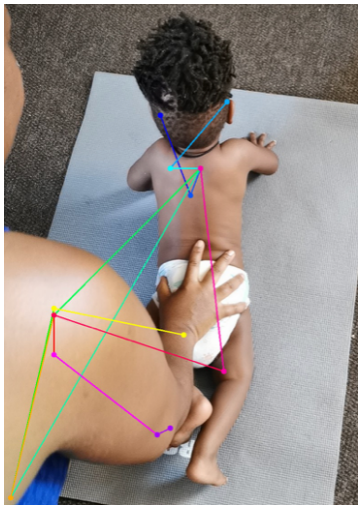




Figure 16B: Scan image of children's front, back and side, standing up



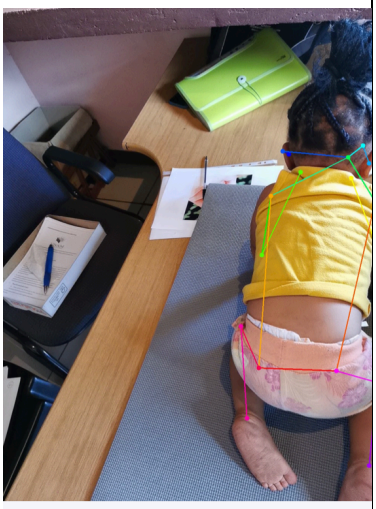


Figure 16C: Images considered as bad scans

Figure 16: Images of children from the CGM 3D imaging phone

4.5.3 Nutritional status of children under five years by analog height board and CGM 3D imaging

Table 15: Nutritional status of children under five years using analog height board and CGM 3D imaging

		Analog board Height n=187 n (%)	**3D scan Average Height n=187** n (%)	***P-value**
Wasting (WHZ)	Normal	174 (93.0)	185 (98.9)	0.0517
	Moderate wasting	9 (4.8)	2 (1.1)	
	Severe wasting	4 (2.1)	0 (0.0)	
Underweight (WAZ)	Normal	158 (84.5)	162 (86.6)	0.0019
	Moderate underweight	20 (10.7)	21 (11.2)	
	Severe underweight	9 (4.3)	4 (2.1)	
Stunting (HAZ)	Normal	136 (73.1)	135 (73.0)	0.0143
	Moderate stunting	40 (21.5)	35 (18.9)	
	Severe stunting	10 (5.4)	15 (8.1)	

*The p-values were calculated from the z-score

Table 15 shows the nutritional status of children under five years by analog height board and CGM 3D imaging. The analog height board determined 93.0% of children as normal from wasting, whereas CGM 3D imaging identified 98.9% of children as normal. The prevalence of children under five years that were determined as moderately wasted were 4.3% by analog height board compared to 1.1% using the scan. There were no children determined as severely wasted by the scan however, 2.1% of children were reported as severely wasted by the analog height board. This observation indicates that the scan underestimated the prevalence of wasting when

compared to the analog height board (true value). The prevalence of moderate underweight was nearly similar between the two measurement tools, reported as 10.7% and 11.2% for analog height board and CGM 3D imaging, respectively. Both the analog height board and the CGM 3D imaging estimated the prevalence of stunting equally, with the analog estimating 26.9% and the scan estimating 27%. The scan underestimated moderate stunting and conversely overestimated severe stunting. Of the three nutritional indicators assessed (wasting, underweight and stunting), both the analog height board and the CGM 3D imaging predicted almost similar results for stunting. According to Wilcoxon sign rank test, the difference between the z-sores for underweight and stunting was found to be statistically significant, except for stunting which was not statistically significant.

4.5.4 Measures of agreement and accuracy

4.5.4.1 Agreement

Table 16: Statistics related to Wilcoxon statistical test and Bland-Altman plot

Age (months)	Sample size (n)	Mean (SD) (cm)		Mean (SD) Absolute Difference (cm)	p-value	95% Limit of Agreement	
All (6-59.9)		**Analog**	**Scan**			**Lower**	**Upper**
Height	188	90.7 (11.8)	90.1 (11.1)	2.41 (2.63)	<.0001	-6.4	7.5

The absolute mean difference between the analog height board and the CGM 3D imaging was recorded as 2.41 cm as indicated in Table 16. According to the Wilcoxon signed rank test, this difference is statistically significant (p-value<0.0001). Further analysis was done using a Bland-Altman test (95), to analyse the degree of agreement and difference between the two methods with 95% of the observations falling within ± 1.96 limit of agreement (LoA) (100, 101). As indicated in Figure 17, 95% of the

individual differences falls within -6.4 to 7.5 cm, lower and upper LoA, respectively. This indicates that the differences between the analog height board and the CGM 3D imaging are relatively large. The children outside of the 95% LoA were of shorter stature, indicating that the worst disagreement occurred among younger children.

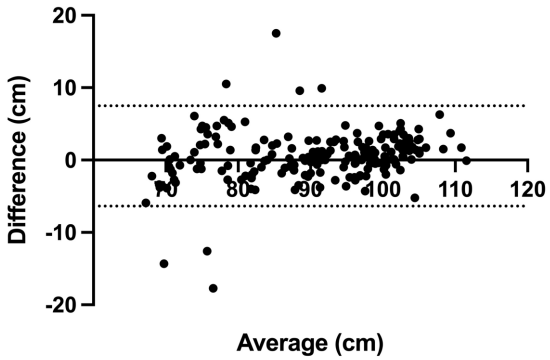


Figure 17: Bland-Altman plot. Single length/height manual measurements subtracted from single scan length/height measurements (y-axis), plotted against the average of both measurements (x-axis) among children under five years.

4.5.4.2 Accuracy

Table 17 shows the results of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the CGM 3D imaging for stunting. Of the 187 children, the CGM 3D imaging indicated that 51 children were stunted and 136 children were not stunted. The sensitivity of the CGM 3D imaging to detect children who were stunted as truly stunted was 72.6% (95% CI 60.3 to 84.8) while for specificity, the scan was correctly able to classify 89.0% (95% CI 83.7 to 94.2) children who were not stunted. The positive predictive value (PPV) of the CGM 3D

imaging compared to the manual scan was 71.2% (95% CI 58.8 to 83.5) and the negative predictive value (NPV) was 89.6% (95% CI 84.5 to 94.8).

Table 17: Sensitivity, specificity, PPV and NPV of the CGM 3D imaging

Manual / CGM 3D scanner	**Stunted (Analog)**	**Not Stunted (Analog)**
Stunted (scan)	37 (TP)	15 (FP)
Not Stunted (Scan)	14 (FN)	121 (TN)

Accuracy	**%**	**95% CI (cm)**	
		Upper limit	Lower limit
Sensitivity [1]	72.6	84.8	60.3
Specificity [2]	89.0	94.2	83.7
PPV [3]	71.2	83.5	58.8
NPV [4]	89.6	94.8	84.5

TP – True positive
FP – False positive
FN – False positive
TN – True negatives

[1] Sensitivity = TP/(TP+FN)
[2] Specificity = TN/(TN+FP)
[3] PPV = TP/(TP+FP)
[4] NPV = TN/(FN+TN)

5. DISCUSSION

This section presents the discussion of the results on child nutritional status of children under five years in the context of the locations that were sampled. The nutritional status of children was assessed with reference to the WHO growth standards for children below five years old. Results were also compared to those of the Namibian Demographic Health Survey of the previous years and other studies from the literature that was done in similar settings. This section also focuses on the comparison between the analog and digital height board in regards to the reliability between the two height boards by intra- and inter-observer reliability. A focus on the association between children's diet and their nutritional status is also discussed as well as the accuracy of the CGM 3D imaging in comparing to the analog height board as a diagnostic tool for child malnutrition.

5.1 Anthropometric measurements using conventional methods of measurement

Anthropometric measurements and dietary evaluations have been widely used in different settings to assess the nutritional assessment of an individual or in population-based studies. Malnutrition in children under five years remains a concern all over the world especially in developing countries such as Namibia. According to the WHO reports, malnutrition is commonly assessed by using anthropometric indicators such as stunting, wasting, underweight and overweight (102). In our study, stunting (29.6%) had the highest prevalence of all the indicators in children, followed by underweight (16.7%). Wasting (4.5%) and overweight status (2.4%) were relatively low. WHO classifies the severity of malnutrition by comparison with a reference population, as low, medium, high and very high (Table 3) (97). According to the WHO classification,

the overall prevalence of stunting in our sample was medium (20-29%), while wasting (5-9%), and underweight (<20%) were low.

The overall prevalence of stunting (29.6%) in our study was higher than the national prevalence in under-fives, which was reported as 22.7% in 2013, while severe stunting was 7.8% in our study and 8% in the 2013 NDHS national survey (77). For wasting (low weight-for-height), the overall wasting was reported at 4.2%, with 1.6% severely wasted. In contrast, the overall percentage wasting was high, reported at 6% for overall wasting and slightly higher for severe wasting at 2% in the 2013 NDHS (77). Underweight (low weight-for-age) was 13% overall, and 5% for severe underweight for the 2013 NDHS (77) while for our study, the overall underweight was higher (16.5%) and lower for severe underweight (4.5%) (77), severe stunting (7.8%) and overweight (4.9%). Stunting in the under-fives in this study was also higher than the developing country average of 25% (23). Since our study only focused in Windhoek and surrounding areas, these findings may vary in different parts of the country due to different geographic locations and characteristics of the study area, the study period seasonally, and socio-economic characteristics of the children's parents.

Results of our study shows a similar general pattern with that of the national surveys for nearly 10 years ago, indicating medium to high rate of stunting and a fairly low wasting and underweight. Although there have been improvements in the previous years to reduce malnutrition in Namibia, progress has been slow. The biggest problem in our study population is chronic malnutrition which leads to stunting, and there are still some children with severe wasting that need immediate treatment. Moderate prevalence of stunting in our study population is an indication that the children in this population will grow up to have poor cognitive abilities and poor educational

achievement, which will lead to reduced productivity as an adult. The negative consequences of stunting impair economic development of the country as a whole.

Akombi and others (23) did a meta-analysis on the nutritional status of children under five years of sub-Saharan Africa. Results of their study indicated that, compared to our study, stunting was higher in low- and middle-income countries such as Burundi (57.7%), Malawi (47.1%) and Nigeria (36.8%), and lower Ethiopia (18.0%), Ghana (18.8%) and Gabon (16.5%). The prevalence of wasting was higher in Ethiopia (8.7%), Niger (18.0%) and Burkina Faso (15.5%), and lower in Kenya (4.0%), Rwanda (2.2%) and Swaziland (2.5%). Underweight was reported higher than results of our study in countries such as Burundi (28.8%), Ethiopia (25.2%), Nigeria (28.7%) and lower in Kenya, Malawi, Tanzania (11.0%, 12.8%, 1.5%), respectively. Although Namibia is a middle-income country, the prevalence of malnutrition in our study is higher than some low-income counties such as Tanzania, Kenya and Malawi. This could be because of high levels of inequality in economic opportunity and access to services which result in poverty within the affected population.

Wasting was assessed using mid-upper arm circumference (MUAC) Z-scores and weight-for height (WHZ) Z-scores. Despite the fact that both of these indices were used to assess the same indicator of malnutrition (wasting), using only one method may lead to misdiagnosis of some cases (103). In our study, the prevalence of wasted children identified by MUAC was 2.1% while those identified by WHZ was 4.2%. Our study identified WHZ to be a more sensitive marker of child malnutrition, classifying twice as many children with wasting compared to MUAC. This could be because, there are more children above 2 years (59,1%) in our study, and according to Kumar et al.

having an excess number of older and taller children would diagnose more children using WHZ (104). It is also evident that in comparison to MUAC, WHZ appeared to be a more sensitive metric in children between 6-23 months old and less sensitive in children from 24-59 months, as there was no prevalence of wasting observed in older children by MUAC while WHZ identified 3.6% for moderate acute malnutrition (MAM) and 1.2% for severe acute malnutrition (SAM). This can be explained by the fact that MUAC relies on a single absolute cut-off point independent of age, sex, and height to diagnose acute malnutrition (105). A child's height, weight, and MUAC all rise steadily as they become older, but at varying rates. Because WHZ depends on height, which is dependent on age, and because the relative weight for height for acutely malnourished children declines with age, older children are more likely to be identified with SAM by WHZ than MUAC (54). Our findings are in agreement with a study by Kumar et al., (104) in which 84.5% of children under-five were identified by WHZ as wasted, while only 38.4% of the children of the same population were identified by MUAC. WHZ was also more sensitive in children less than a year old compared to MUAC and the magnitude of mismatch increased with age (103, 106). A Cambodian study analysed secondary data from 11,000 datasets between 2010 and 2012 and found that the current MUAC screening standards failed to identify a significant proportion of children at risk, and that the severity of the mismatch between the MUAC measurements and WHZ increased with age (107). According to their results, when the WHO-recommended cut-off of <115 mm was applied, the sensitivity for detecting SAM was 51.2% for children aged 6 to 24 months, 18.5% for children aged 25–36 months, and 13.7% for children aged 37–60 months. In another study by Laillou et at., wasting was present in 3.3% of the population using MUAC versus 10.6% utilising WHZ (108). In contrast to our findings, a study by Tadesse et al.,

(109) reported the prevalence of wasting as 10.5% by MUAC and 5.4% by WHZ, indicating that MUAC classified more children as wasted compared to WHZ. The same observation was reported in several studies (110-112). Myatt and others (113) further elaborated in their study that WHZ is considerably influenced by age (i.e. less sensitive in older children). While this indicate using WHZ in SAM identification may overestimate wasting (compared to MUAC) in populations with longer legs, MUAC may similarly overestimate SAM in children as it employs a fixed cut-off for both sexes and all ages. In our context, with a general prevalence of wasting, our population have short legs. As a result, interpretations based on anthropometric measures may vary depending on the context and setting.

Findings of our study are clear that, if the current WHO MUAC cut-off alone had been applied, a large number of children would not have been identified as severely or moderately malnourished. Both WHZ and MUAC have been shown to identify different groups of children, and the two groups have a similar elevated risk of mortality compared to non-wasted children. Relying on just one method may underestimate the prevalence of SAM or MAM in the community. The decision on which method to use depends on the objectives of the study for research as well as the feasibility for both research and clinical use. MUAC tape is a quick diagnostic screening tool for nutritional status and is usually used to provide immediate diagnosis for children at high risk of mortality; however, if the objective is to identify and manage all cases of wasting, WHZ or a combination of both methods can be used (107).

5.2 Prevalence of malnutrition by age and sex

The age group of children in our study was divided into two; the under two (6-23 months) and over two years (24-59 months). All the nutritional indicators assessed in this study showed higher prevalence children from the 24-59 months age group compared to the younger age group. These results are similar to the findings of several studies in similar settings (114, 115), indicating that there is an increase in malnutrition with increased age. Children in the younger age group were at a lower rate of malnutrition than those in the older age group, and this may be due to the fact that younger children would still being breast-feeding and benefiting from the protective effects of breast milk. On the other hand, older children who are transitioning from breast-feeding to solid food may not have access to food with all the nutrients they needed for growth, decreasing immune-protective benefits of breast milk combined with increased exposure to contaminated supplemental meals, resulting in infectious illnesses and increased dietary requirements (116).

Our study shows that stunting was boys higher in boys than in girls, which was found to be statistically significant. Our results are in agreement with a meta-analysis study by Wanani et al., (117), obtained from 16 DHS studies across 10 countries in sub-Saharan Africa, in which Namibia was included. The prevalence of undernutrition in boys was higher than in girls of the same age group, as seen in 17 out of 20 studies for wasting, 33 of 39 studies for stunting and 20 of 25 studies for underweight. Their pooled findings demonstrated that the prevalence of stunting was higher in boys (40%) than in girls (36%) in all the studies, and that male children were consistently more likely to be stunted than their female counterparts. Similar results were also reported by Cruz et al., (116) and Wamani et al., (117). The reason for this discrepancy is not well understood in the literature (114), however some studies believe that girls are

given priority of care compared to boys (especially in low and middle income countries), first because of their great worth in agriculture, and second because they are considered as an investment, leading to preferential dietary treatment (116). Gender inequalities may also be caused by behavioural and sociocultural factors. Parents may prefer a girl child, and discriminate against a male child (118, 119). However, these theories of child discrimination are unproven and they also depend on the community being studied. It is thus difficult to be certain that these theories apply to the Namibian population. Epidemiological studies find that male children have a greater vulnerability to general insults such as infections to diseases, other morbidities and malnutrition than female children (120, 121). As reported by NDHS 2013 (77), in Namibia, childhood mortality is higher in boys than in girls under five years old, which could be related to differences in levels of malnutrition between girls and boys in our population. It has also been suggested that female sex hormones could modify lipid levels and enhance the immune response, causing females in general to have better health and longer survival than males (115, 122, 123).

5.3 Reliability

This study is the first of its kind to analyse such data in the Namibian population. One of the main objectives of our study was to obtain reliable data from a prototype digi-board and compare it to data collected from the traditional height boards recommended by WHO. To assess the reliability of height measurements using the manual and the digi-board, various indices where selected and calculated, namely TEM, %TEM, ICC and p-value. These indices have been widely used in the literature to assess both intra- and inter- observer reliability (124). Reliability is known to be high when the

variability between repeated measurements of the same subject by one (intra-observer differences) or two or more (inter-observer differences) observers is lower (92).

According to the findings of the present study, TEM was lower for the digi-board in comparison to the analog height board, indicating that the digi-board had better reliability and measurement error. Better reliability for the digi-board was also shown by the %TEM and ICC, which were all in favour of the digi-board. According to the enumerator's field experience, it was easier and quicker to measure children using the digi-board, because once the child is positioned and ready for measurement, all the enumerator had to do is click one button and the measurement was displayed on the screen. However, with the analog height scale, the enumerator had to take time to adjust their eyes to the measuring scale to manually take the reading. In addition, especially with younger children, the enumerator may be distracted and have forgotten the reading from the analog height board before it was captured on paper and the child would have to be remeasured. Contrarily, since the reading is already locked in on the digi-board screen, the enumerator can retrieve and record it. The reliability of both height boards increases with age. This can be explained by the fact that younger children (6-23 months group) are more difficult to measure, they can hardly stand still, cry a lot and cannot take instructions. This makes it difficult for the enumerator to focus on both positioning the child and concentrating on the scale to take the reading. As a result, the reliability of the measurements may be affected. On the other hand, the older children are calmer during measurement. Our results are in agreement with similar studies that looked at reliability of anthropometric measurements in children (125). This finding suggests that younger children have higher levels of measurement error, because they are unable to co-operate with measurement compared to older children (126).

A good intra- and inter-observer agreement was achieved by both enumerators, with %TEM of all values <2%, and had high reliability as indicated by TEM, ICC and p-values. The findings of our study are similar to that of various studies that measured reliability of anthropometric measurements among two or more anthropometrists (127). According to De Onis and others (128), a TEM threshold of 0.7 cm difference for length/height measurements was considered acceptable, as was found in this study. In a study by Carsley et al (127), they assessed the reliability of anthropometric measurements in individuals from 0-18 years, where all %TEM values for height were <2% for both intra- and inter-observer reliability, indicating good quality of measurements. Results of this study are also similar to ours with regards to children below two years having a higher intra-TEM (0.73 cm) and inter-TEM than children from 2-5 years who reported to have a TEM of 0.69cm. This observation was similar to our intra-TEM at 0.29cm and 0.21cm (analog and digital, respectively) for younger children and TEM at 0.16cm and 0.11cm (analog and digital, respectively), for older children. The relative TEM value of <2% in our study is within the acceptable range, indicating a very good reliability between the repeated measurements of two independent enumerators.

Our study strived to improve child anthropometry using digital innovations, and our results suggest that, with the digi-board showing better reliability than the analog height board, increased accuracy of height measurements can be achieved in the public health sector. This is especially during large national surveys, where reliable measurements are crucial in correctly identifying levels of malnutrition of the country. A study by Gupta et al. emphasised the challenges that clinicians' experiences with the current analog height board and failure to accurately measure anthropometric

measurements in children has been associated with misdiagnosis and treatment of undernutrition (129). This was observed in the Namibian population, as shown by national surveys with biologically implausible data (15). While access to digital height boards and other forms of anthropometry digital innovation may currently be limited, it is important that the children and areas affected by malnutrition are correctly identified, so that the correct treatment and interventions are given to those who really need it. Although the current study found the digi-board to be reliable and practical against the analog height board, accuracy was not accessed study. The next step is to use the digi-board in a clinical and survey settings to assess accuracy, reliablility and practicality when used outside of a research setting.

5.3 Dietary diversity score

Dietary diversity is a good predictor of dietary quality in children (130). Our study aimed to determine whether there was an association between the nutritional status of children under five years with their dietary diversity. Dietary diversity refers to the number of different foods or food groups consumed in a given period (131), while minimum dietary diversity is the consumption of at least four or more food categories from the eight food groups, which is used to assess infant and young child feeding practices (132). The majority of children in our study (57.1%) did not meet the required dietary diversity score indication that they are unlikely to have adequate nutrients required for growth. This is because an increase in individual dietary diversity score is likely to correspond to an increase in the variety and amount of nutrient intake, children need to be fed a broader variety of foods. Improving dietary diversity could also indicate a higher possibility of achieving daily energy and nutrient requirements, resulting in better nutrition in children (133). The most consumed food group in our

study was grains and root tubers (97.8%), and the majority of children were reported to consume porridge every day. This is a reflection of a typical Namibian diet due to our availability of pearl millet and maize meal flour in high quantities, which are also inexpensive. This is consistent with data from other countries, which reveal that children eat mostly starch-based staples and seasonal fruits and vegetables (134). Low intake of Vitamin A-rich foods (37.9%), eggs (26.1%), legumes & nuts (20.7%) and dairy products (40%) seen in our study is a reflection of less diverse diets among children under five years in Namibia. The influence of food diversity in the nutritional status of children can be affected by other factors. Economic factors, knowledge of the parent on child nutrition, intra-household food allocation and location are all possible explanations for the low consumption of these food groups, and probably all contribute to lack of food diversity in children. The majority of children with low dietary diversity live in areas of Dordabis and Brakwater, and parents in these areas have explained that since they live far from the city, access to diverse foods can be a challenge. This results in limited access to nutritious food for children which affects children's feeding behaviours. Parents from poor households also experience financial challenges, as there are insufficient funds to buy a diverse diet for their children, and as a result children are fed whatever is available, mostly porridge (eaten with grains of sugar) or *mahou* (maize meal flour, mixed with water and sugar), every day. There is also lack of awareness and/or responsibility among parents regarding children's balanced diet, because it was observed that some parents of children who have been diagnosed with malnutrition receive ready-to-use therapeutic food from the clinic but instead of giving it to the child, they exchanged it with alcohol for themselves.

Our study observed, that dietary diversity increases as a child gets older, as similarly seen in other studies (135). This is a positive trend for child nutrition, as parents and caregivers recognise the need of meeting their children's nutritional needs as they grow. Given that, continued efforts should be made to educate parents and caregivers about the benefits of feeding children a diverse diet.

The relationship between dietary diversity and undernutrition (stunting, wasting, and underweight) was investigated in this study. The association between dietary diversity and wasting as well as underweight was found statistically significant, and suggested that having enough dietary diversity lowered the risk of malnutrition in children under five years. Our findings are consistent with those of similar studies in, South Africa (136), Ghana (135), Ethiopia (137). On the contrary studies done in Ethiopia (138) and Tanzania (139), did not find an association between minimum dietary diversity and wasting as well as underweight. It is likely that malnutrition in Namibia is due to low dietary diversity and other dietary diversity related factors such as cultural practices where meat is allocated to the head of the household, the mother’s knowledge of infant and young child feeding practices or other above-mentioned factors, as were seen in Dordabis and Brakwater. A multivariate logistic regression model could elucidate the most significant explanatory predictors for malnutrition in Namibia and focus intervention efforts by the MoHSS.

While high dietary diversity shows a significance association with both wasting and underweight, the same was not observed for stunting. Similar results were observed in a meta-analysis study (140). Adequate dietary diversity entails that since child malnutrition is influenced by their diet, and an increase in the consumption of diversified foods could reduce malnutrition among children (132, 141).

In general, our findings demonstrate that dietary diversification improves child health in Namibian children under the age of five. Because dietary diversity was examined within a one-day recall period, the results should be interpreted with caution because they may not be an accurate reflection of food patterns over a longer period, which is a limitation we acknowledged. Despite this constraint, our findings reveal that all three anthropometric indicators have a slightly positive association with dietary diversity, were children with poor dietary diversity experience malnutrition. This association was not found to be statistically significant.

5.5 Three-Dimensional imaging

The CGM 3D imaging was developed to answer the needs of screening children for malnutrition with a digital innovation. Currently, children are measured with height boards, which are heavy and bulky, making it difficult to carry around in a field setting. In addition, manual height boards are subject to human error, they make children uncomfortable and measurement takes too much time to complete considering that the enumerator has to concentrate both on positioning the child and focusing on the scale to take the reading. The CGM 3D imaging eliminates the limitations that come with the analog height boards. However, in order for this tool to be accepted as a diagnostic tool for child malnutrition, its accuracy was assessed in this study. While the 3D imaging tool largely underestimated the prevalence of wasting (difference = 5.9%) compared to the analog height board, underweight (difference = 1.7%) and stunting (difference = 0.1%) was estimated similarly. The CGM 3D imaging tool may be poor at estimating weight, causing these differences. The sensitivity and specificity of the CGM 3D imaging for stunting was 72.6% and 89.0% respectively. The sensitivity and specificity of the 3D imaging tool in determining underweight and wasting was not

assessed in this study. According to WHO, a tool is considered good when its specificity, sensitivity, PPV and NPV are 90% and above (16). This indicates that the CGM 3D imaging was not sensitive enough to pick up about 27.4% of children as stunted, which would be likely to lead to underestimation. Most screening tests prefer sensitivity and NPV because it is crucial not to overlook individuals who may be at risk of malnutrition.

The results of our study help determine whether there is a difference between the two methods or not. Based on the p-value (<0.001), the difference between the heights estimates of the two methods was statistically significant, with a significant underestimation of height using the CGM 3D imaging technique. Potential differences in weight were not of interest to the manufacturer at this point in time, however future releases may improve the predictive qualities of the scan. Results of our study vary from that of a study by Conkle and others (18), who looked at the accuracy of a handheld 3D imaging system for children anthropometry and found that 3D imaging was comparable to gold standard manual measurements for child anthropometry, however, there was systemic bias when compared to manual measurement. The accuracy for the CGM 3D imaging reported in our study was generally poor and not acceptable for the tool to be recommended as a diagnostic tool yet.

The poor results of the CGM 3D imaging could also be because of the following limitations. Children under 2 years were only 25.1% of the total population. It was challenging to recruit the younger children in the study because they can hardly remain still to complete the scan, which made it difficult to capture the acceptable scan. Some part of data collection was done in winter which provided some challenges with

undressing children for the scan. Parents did not feel comfortable to undress their children in the cold, so many of them did not consent to it. As a result, recruiting children in winter was slow. The same challenge was not observed in the months of summer, as parents were willing to undress their children. It was also a challenge to measure children in a space with background 'noise'. The CGM 3D imaging was able to pick up other objects in the background and focus was moved away from the child, as a result, such scans could not be used. This is concerning because then it means that it will be a challenge to use the scan in a community-based survey or household survey, where the background is likely not to be clear of objects.

Results of this pilot study on the CGM 3D imaging were used to inform the developer on certain issues in order for them to be improved. The goal is to achieve an accuracy of 100% so that all children that are malnourished can be diagnosed and treated, and the differences in height estimated by the CGM 3D imaging tool appear to have clinical significance. With the sensitivity and specificity currently at 72.6% and 89.0%, there is room for improvement. Since this study was a pilot, further limitations of this study should be addressed in a larger study, with a larger sample size. Measures of reliability of the new method also need to be analysed in order to make conclusions of the use of the software as a diagnostic tool for malnutrition.

Parents were interested and fascinated by the CGM 3D imaging and reacted positively towards it, similarly, older children enjoyed being in front of the camera and spinning around for the 360-degree scans. It was also beneficial to use the CGM 3D imaging in the field setting because results of the nutritional status of the child are produced immediately after measurement. This gave room for the enumerator to inform the

parent of the nutritional status outcome of the child at that moment, and if the child is malnourished, the child was then referred to the clinic for treatment. In addition, parents were briefly educated on issues of malnutrition, child feeding practices, and how to identify signs of malnutrition.

Although there is a lot of improvement that needs to be done on the CGM 3D imaging, there is potential for it to improve data quality in anthropometry. In comparison to the analog height board, the CGM 3D imaging took less time to measure the child. It is also easy and feasible to carry around and inexpensive (once the app is ready for use, it will be freely available on Google Play store for smart phone download). It is however clear that the CGM was not accurate enough to be used in a clinical or survey setting, and more work is needed to improve the software before it can be tested clinically.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The findings of this study were reported in line with the study objectives and the following conclusions were made.

The study investigated the prevalence of malnutrition in Namibian children under five years, in which stunting was found to be 29.6%, wasting was 4.2% and underweight was 16.5%, indicating that malnutrition is still a health concern in Namibia.

The boys were more stunted than girls in our study, which is consistent with other studies, however the reason is not fully studied or documented in the literature. The prevalence of malnutrition observed in our study was higher in older children.

Both mid upper arm circumference (MUAC) and weight-for-height (WHZ) were shown to classify children of the same group differently with regards to wasting. Despite the ease of use and lower cost of MUAC, MUAC identified less children as wasted in the same population compared to WHZ. It is clear to conclude that, enumerators should rather use a combination of both methods to avoid underestimation.

Our study was the first of its kind in Namibia, to carry out a study that assessed the reliability of a digi-board in comparison to the traditional analog height board. All measures of reliability (TEM, %TEM, ICC, p-value), pointed towards the digi-board being superior over the analog height board. The digi-board also carries more advantages over the analog height board because it was quick to use, and the value was displayed on a screen while the analog height boards, the enumerator had to adjust their eyes to the scale to take the reading. Reliability of both height boards decreases in younger children because they cannot take instructions and cannot remain still, which increases the chances of errors in measurement.

The study found that 57.1% of children were unlikely to meet an adequate dietary diversity and only 42.9% met their required dietary diversity score. However, the study's findings should be seen in the context of its limitations. The study relied on caregiver dietary memory, which may not capture the full range of children's dietary information. The 24-hour food recall questionnaire depends on what the child ate in the last 24 hours and does not take into account food eaten in the days or weeks prior. We found a modest positive relationship between poor dietary diversity and malnutrition, which is suggestive that a good dietary diversity lowered the risks of malnutrition in children under five years and improves child health.

Our study was also the first of its kind in the Namibian context to assess the accuracy of a mobile CGM 3D imaging in detecting child malnutrition. The sensitivity, specificity, PPV and NPV were found to be 72.6%, 89.0%, 71.2% and 89.6%, respectively. This accuracy was not good nor acceptable. At the moment, the CGM 3D imaging leads to underestimation of malnutrition and is not sensitive enough to be used as a diagnostic tool for child malnutrition in public health practices. The software thus needs to be further developed and researched before it can be recommended as a diagnostic tool for malnutrition.

6.2 Recommendations

1. The current study only looked at the nutritional status of children in correlation with their diet, however it did not look at other factors associated with child malnutrition such as maternal educational level, nutritional status of the mother, household income and birth weight. Further research needs to be done to explore these factors in the Namibian population. A longitudinal study of this nature is recommended to assess children affected by malnutrition after an intervention, to determine the impact of

nutritional support interventions over time and what interventions are likely to result in long-term and sustainable changes in the vulnerable population.

2. Further studies should use other methods of dietary questionnaire such as the dietary record and food frequency questionnaires which look at dietary intake over a period of time. Because this study was cross-sectional, we were unable to evaluate the timing of eating patterns, hence a longitudinal study is recommended in the future to address such issues.

3. More research on the food children ate at different seasons of the year is recommended, especially in Namibia where food availability differs from when it is a rainy season or a dry season.

4. Our study revealed that children with a poor dietary diversity are more malnourished than those with a good dietary diversity and some parents lack the knowledge of the importance of good feeding practice for their children. It is thus important that the Ministry of Health and Social Services, the Ministry of Gender Equality and Child Welfare and UNICEF invest in community-based programs that provide awareness to the caregivers on nutritional education and feeding practices for children.

5. Interventions that address dietary diversity such as growing vegetables in their household and donations of food to those in need, should be put into practice for affected communities. There is a need for organisations like the Ministry Agriculture, Water and Land reforms to invest in irrigation agriculture in order for the country to be self-sufficient in food security.

6. Namibia has policies and guidelines in place that are aimed at improving malnutrition in the country, and while this is the case, the number of children in Namibia that are malnourished is still considerably high. Some of these policies have been developed since independence in 1990. They are old, outdated and need to be

revised and put to work in order to tackle the issue of malnutrition in Namibia. Issues pertaining to malnutrition in children needs to be addressed as a dynamic new challenge in Namibia, and all aspects need increased attention and close monitoring.

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Appendices

a) HREC Ethical clearance certificate

UNAM
UNIVERSITY OF NAMIBIA

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: H-G /581/2020 **Date: 31 August, 2020**

This Ethical Clearance Certificate is issued by the University of Namibia Research Ethics Committee (UREC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the Faculty/Centre/Campus Research & Publications Committee sitting with the Postgraduate Studies Committee.

Title of Project: Assessment Of Nutritional Status Correlated With Dietary Practice Of Namibian Children Under 9 Years: A Cross-Sectional Study

Researcher: JOHANNA NAMENE

Student Number: 201060931

Supervisor(s) *Prof Christian Hunter*

Campus: Hage Geingob Campus
Take note of the following:

(a) Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the HREC. An application to make amendments may be necessary.
(b) Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the HREC.
(c) The Principal Researcher must report issues of ethical compliance to the UREC (through the Chairperson of the Faculty/Centre/Campus Research & Publications Committee) at the end of the Project or as may be requested by HREC.
(d) The HREC retains the right to:
(i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,
(ii) Request for an ethical compliance report at any point during the course of the research;
(iii) Cognizance and the observation of Namibia's Research Science and Technology Act, 2004 which makes it compulsory for Non-Namibian based researchers to obtain the compulsory Research Permit from the National Commission on Research Science and Technology (NCRST), FIRST, BEFORE the research can commence.

HREC wishes you the best in your research.

Dr. J.E. de Villiers HREC Chairperson

Ms. P. Claassen: HREC Secretary

b) MoHSS Ethical clearance certificate

REPUBLIC OF NAMIBIA

Ministry of Health and Social Services

Private Bag 13198
Windhoek
Namibia

Ministerial Building
Harvey Street
Windhoek

Tel: 061 – 203 2537
Fax: 061 – 222558
E-mail: itashipu87@gmail.com

OFFICE OF THE EXECUTIVE DIRECTOR

Ref: 17/3/3/JN
Enquiries: Mr. A. Shipanga

Date: 03 December 2020

Ms. Johanna Namene
PO Box 990
Oshakati
Namibia

Dear Ms. Namene

***Re:* Assessment of nutritional status correlated with dietary practice of Namibia Children under 9 years: A cross-sectional study.**

1. Reference is made to your application to conduct the above-mentioned study.
2. The proposal has been evaluated and found to have merit.
3. **Kindly be informed that permission to conduct the study has been granted under the following conditions:**

3.1 The data to be collected must only be used for academic purpose;
3.2 No other data should be collected other than the data stated in the proposal;
3.3 Stipulated ethical considerations in the protocol related to the protection of Human Subjects should be observed and adhered to, any violation thereof will lead to termination of the study at any stage;
3.4 A quarterly report to be submitted to the Ministry's Research Unit;
3.5 Preliminary findings to be submitted upon completion of the study;
3.6 Final report to be submitted upon completion of the study;
3.7 Separate permission should be sought from the Ministry for the publication of the findings.

4. All the cost implications that will result from this study will be the responsibility of the applicant and **not** of the MoHSS.

EXECUTIVE DIRECTOR
MINISTRY OF HEALTH AND SOCIAL SERVICES

Yours sincerely,

BEN NANGOMBE
EXECUTIVE DIRECTOR

"Your Health Our Concern" 10/14849

c) Patient information leaflet and Informed assent

PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM

TITLE OF THE RESEARCH PROJECT: ASSESSMENT OF NUTRITIONAL STATUS CORRELATED WITH DIETARY PRACTICE OF NAMIBIAN CHILDREN UNDER 5 YEARS: A CROSS-SECTIONAL STUDY

REFERENCE NUMBER: H-G/581/2020

PRINCIPAL INVESTIGATOR: Johanna Namene

ADDRESS: University of Namibia, Physiology division.

CONTACT NUMBER: +264 81 2765 502

Your child is being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how your child could be involved. Also,

your child's participation is entirely voluntary and you are free to decline his/her participation. If you say no, this will not affect your child negatively in any way whatsoever. You are also free to withdraw your child from the study at any point, even if you do agree to take part.

This study has been approved by the Research Ethics Committee at The University of Namibia and the Ministry of Health and Social Services and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and Namibian National Research Ethics Guidelines.

1. What is this research study all about?

a) Where will the study be conducted; are there other sites; total number of participants to be recruited at your site and altogether.

The study will be conducted at your child's respective school, kindergardern or any health centre close to you.

b) Explain in participant friendly language what your project aims to do and why you are doing it?

We are conducting this research to help with the issue of child malnutrition in Namibia, which is still a burden in the country. This study will provide recent data which are currently not available. With this data, we will inform the ministry and other nutrition programs about the communities severely affected by malnutrition. It is easier to do

interventions, when such communities have been identified. In addition, knowing the nutrition status of your child is of great importance.

c) Explain all procedures.

A trained survey team will be working in the field to collect data on children from six months-five years about their nutritional status. Information on anthropometric measurements and dietary practices will be collected. We have four different measuring devices, two height boards (digital and non-digital), a 3D imaging phone and a Mid Upper Arm Circumference tape. All the measurements are estimated to take 10-15 minutes per child and another 5-6 minutes on the dietary questionnaire. The data collected and images taken may be used in the publication of my study. We will be happy to provide feedback of the nutritional status of your child after completion of the study.

d) Explain any randomization process that may occur.

Not Applicable

e) Explain the use of any medication, if applicable.

Not applicable

2. Why have you been invited to participate?

a) Explain this question clearly.

Your child have been invited to participate in this study because he/she is in the age group of the selected participants, who are Namibian children less than 5 years.

3. What will your responsibilities be?

a) Explain this question clearly.

Your child's responsibilities as a participant will be to participate in the research study by giving their anthropometric measurements.

b) Explain the duration the participant is expected to participate in the study (i.e. 2 hours, 4 days, etc.)

It is estimated that, at least 10-15 minutes is required for each participant.

4. Will you benefit from taking part in this research?

a) Explain all benefits objectively. If there are no personal benefits then indicate who is likely to benefit from this research e.g. future patients.

Your child will have direct benefit from participating in this study as knowing your child's nutritional status is important in determining if your child is growing healthy or not. If your child is not nutritionally healthy, we will advise you as a parent or

caregiver on what and how to feed the child. And if the condition is severe, we will direct you to the hospital/clinic right away.

5. Are there in risks involved in your child taking part in this research?

a) Identify any risks objectively.

Not applicable

6. If you do not agree to take part, what alternatives do you have?

a) Clearly indicate in broad terms what alternative treatment is available and where it can be accessed, if applicable.

Not applicable. Participants who do not wish to take part may refuse with no consequences.

7. Who will have access to your medical records? (Where applicable)

The information collected will be treated as confidential and protected. If it is used in a publication or thesis, the identity of the participant will remain anonymous. Only the principal investigator and research team will have access to the information.

8. What will happen in the unlikely event of some form injury occurring as a direct result of your taking part in this research study?

It is very rare that your child will become ill and/or get physically injured as a result of participation in this study, however should such events happen there is registered nurse on site who will attend to your child immediately, or refer him/her for any necessary medical treatment. However, as this study is largely a measurement and questionnaire type of study, we do not anticipate this occurring.

9. Will you be paid to take part in this study and are there any costs involved?

You will not be paid any money. Your child will be given a participant's remuneration in the form of a toiletries pack and a healthy snack for taking part in the study.

10. Is there anything else that you should know or do?

You should inform your family practitioner or usual doctor that you are taking part in a research study. (Include if applicable)

You should also inform your medical insurance company that you are participating in a research study. (Include if applicable)

You can contact Johanna on +264 81 2765 502 or Prof Jane at tel +264 813417593 if you have any further queries or encounter any problems.

You can contact the Centre for Research and Publications at +264 061 2063061; **pclaassen@unam.na** if you have any concerns or complaints that have not been adequately addressed by the investigator.

You will receive a copy of this information and consent form for your own records.

11. Declaration by participant

By signing below, I ……..……. agree to take part in a research study entitled *(*ASSESSMENT OF NUTRITIONAL STATUS CORRELATED WITH DIETARY PRACTICE OF NAMIBIAN CHILDREN UNDER 5 YEARS: A CROSS-SECTIONAL STUDY*)*.

I declare that:

a) I have read or had read to me this information and assent form and it is written in a language with which I am fluent and comfortable.
b) I have had a chance to ask questions and all my questions have been adequately answered.
c) I understand that taking part in this study is voluntary and I have not been pressurised for my child to take part.
d) I may choose for my child to leave the study at any time and will not be penalised or prejudiced in any way.
e) I may be asked for my child to leave the study before it has finished, if the study doctor or researcher feels it is in his/her best interests, or if do not follow the study plan, as agreed to.

Signed at (*place*) .....….....…….. on (*date*) ……...…….. 2021.

Signature of participant Signature of witness

12. Declaration by investigator

I (Johanna Namene*)* declare that:

a) I explained the information in this document to ……..
b) I encouraged him/her to ask questions and took adequate time to answer them.
c) I am satisfied that he/she adequately understands all aspects of the research, as discussed above
d) I did/did not use an interpreter. (If an interpreter is used then the interpreter must sign the declaration below.

Signed at (*place*) .....….....…….. on (*date*) ……...…….. 2021.

Signature of investigator Signature of witness

13. Declaration by interpreter

I *(name)*declare that:

I assisted the investigator (*name*) ……. to explain the information in this document to (*name of participant*)

……..…….. using the language medium of (Oshiwambo, Oshiherero, Afrikaans, etc.)

d) Data collection instrument: Questionnaire

QUESTIONNAIRE FOR CHILDREN UNDER FIVE

INTRODUCTION AND CONSENT

INFORMED CONSENT

Hello. My name is _____. I am working with the University of Namibia, UNICEF and the Ministry of Health and Social Services. We are conducting a dietary survey of Namibian children under five years. The information we collect will help the government to plan health services. Your child was selected for the survey. The questions usually take about 10-15 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of our survey team. Your child does not have to be in the survey, but we hope you will agree to answer the questions since your views are important. If I ask you any question you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time.

In case you need more information about the survey, you may contact me personally. Do you have any questions? May I begin the interview now? (If yes, let the parent sign on the assent form provided)

SIGNATURE OF INTERVIEWER: _____

DATE: _____

RESPONDENT AGREES TO BE INTERVIEWED . . . 1 RESPONDENT DOES NOT AGREE TO BE INTERVIEWED . . . 2 END

RESPONDENT'S BACKGROUND

Name of the child:
Sex:
Tribe:
Location:
Met inclusion criteria?

UNDER-FIVE'S BACKGROUND UB		
UB0. *Before I begin the interview, could you please bring (name)'s Birth Certificate, National Child Immunisation Record, and any immunisation record from a private health provider? We will need to refer to those documents.*		

UB1. ON WHAT DAY, MONTH AND YEAR WAS (*name*) BORN? *Probe:* WHAT IS (HIS/HER) BIRTHDAY? *If the mother/caretaker knows the exact date of birth, also record the day; otherwise, record '98' for day.* *Month and year must be recorded.*	Date of birth Day .....__ __ DK day .....98 Month .....__ __ YEAR .....2 0 __ __	
UB2. HOW OLD IS (*name*)? *Probe*: HOW OLD WAS (*name*) AT (HIS/HER) LAST BIRTHDAY? *Record age in completed years.* *Record '0' if less than 1 year.* *If responses to UB1 and UB2 are inconsistent, probe further and correct.*	Age (in completed years) .....__	
UB3. *Check UB2: Child's age?*	Age 0, 1, or 2.....1 Age 3 or 4.....2	1⇨UB9

Let the mother/caregiver know that you will now begin the dietary questionnaire. Explain the questionnaire to the caregiver before beginning. Help her/him to remember the previous day, based on the times when the child woke up, the activities the child had, etc. Go slowly, do not rush.

Ask the caregiver/child: Please tell me everything that the child ate and drank yesterday. After the child woke up, what was the first thing you gave to him/her to eat or drink? After that, what other food or drink did you offer the child? Write all the foods or preparations consumed the day before that the caregiver mentions.

Do not forget to ask: What is the name of that meal time (for example, breakfast, lunch, dinner, snack)? Write down the quantities of each food and beverage mentioned. Ask about the breastfeeding of the child. Is there a fixed schedule for breastfeeding, indicate how many times a day. Does the child drink formula milk, breastmilk or both? How is the child's appetite? Who feeds the child?

breastfeeding and dietary intake		Bd
BD1. CHECK UB2: CHILD'S AGE?	Age 0, 1, or 2 ..... 1 Age 3 or 4 2	 2⇨END

BD2. Has (***name***) ever been breastfed?	Yes 1 No 2 DK 8	2⇨BD3A 8⇨BD3A
BD3. Is (***name***) still being breastfed?	Yes 1 No 2 DK 8	
BD3A. CHECK UB2: CHILD'S AGE?	Age 0 or 1 .....1 Age 2 2	2⇨END
BD4. Yesterday, during the day or night, did (***name***) drink anything from a bottle with a nipple?	Yes 1 No 2 DK 8	
BD5. Did (***name***) drink Oral Rehydration Salt solution (ORS) yesterday, during the day or night?	Yes 1 No 2 DK 8	

BD6. Did (***name***) drink or eat vitamin or mineral supplements or any medicines yesterday, during the day or night?	Yes 1 No 2 DK 8	
BD7. Now I would like to ask you about all other liquids that (***name***) may have had yesterday during the day or the night. I am interested in whether your child had the item I mention even if it was combined with other foods. Please include liquids consumed outside of your home. Did (***name***) drink (***name of item***) yesterday during the day or the night:	Yes No DK	
[A] Plain water?	Plain water 1 2 8	
[B] Juice or juice drinks?	Juice or juice drinks 1 2 8	

[C] Clear broth/clear soup?	Clear Broth 1 2 8
[D] Milk such as tinned, powdered, or fresh animal milk? IF YES: How many times did (NAME) drink milk? IF 7 OR MORE TIMES, RECORD '7'.	Number of times drank milk 1 → BD7[E] 2↘ 8↘ BD7[E]
[D1] Infant formula? If yes: How many times did (***name***) drink infant formula? If 7 or more times, record '7'.	1 2 8 Number of times drank infant formula __ DK 8
[E] Milk from animals, such as fresh, tinned, or powdered milk?	Milk 1 → BD7[X] 2↘ 8↘ BD7[X]

[E1] How many times did (***name)*** drink milk? If 7 or more times, record '7'.	Number of times drank milk __ DK 8	
[X] Any other liquids?	Other liquids 1 2 ⇩ 8 ⇩ BD8 BD8	
[X1] Record all other liquids mentioned.	(Specify)	

BD8. Now I would like to ask you about <u>everything</u> that (***name***) ate yesterday during the day or the night. Please include foods consumed outside of your home.

- Think about when (***name***) woke up yesterday. Did (he/she) eat anything at that time?

If 'Yes' ask: Please tell me everything (***name***) ate at that time.

Probe: Anything else?

Record answers using the food groups below.

- What did (***name***) do after that? Did (he/she) eat anything at that time?

Repeat this string of questions, recording in the food groups, until the respondent tells you that the child went to sleep until the next morning.

For each food group not mentioned after completing the above ask: Just to make sure, did (***name***) eat (***food group items***) yesterday during the day or the night	Yes No DK	
[A] Yogurt made from animal milk? Note that liquid/drinking yogurt should be captured in BD7[E] or BD7[X], depending on milk content.	Yogurt 1 2 ⇩ BD8[B] 8 ⇩ BD8[B]	
[A1] How many times did (***name)*** eat yogurt? If 7 or more times, record '7'.	Number of times ate yogurt __ DK 8	
[B] Any commercially fortified baby food e.g. Cerelac, Nestum, Purity?	Fortified baby food 1 2 8	

[C] Bread, rice, noodles, porridge, or other foods made from grains?	Foods made from grains	1 2 8
[D] Pumpkin, carrots, squash, or sweet potatoes that are yellow or orange inside?	Pumpkin, carrots, squash, etc.	1 2 8
[E] White potatoes, white yams, cassava, or any other foods made from roots?	Foods made from roots	1 2 8
[F] Any dark green, leafy vegetables, such as insert locally available vitamin A-rich dark green, leafy vegetables?	Dark green, leafy vegetables	1 2 8
[G] Ripe mangoes or ripe papayas or insert locally available vitamin A-rich fruits?	Ripe mango, ripe papaya	1 2 8
[H] Any other fruits or vegetables, such as insert most commonly eaten fruits and vegetables?	Other fruits or vegetables	1 2 8

[I] Liver, kidney, heart or other organ meats?	Organ meats	1	2	8	
[J] Any other meat, such as beef, pork, lamb, goat, chicken, duck or sausages made from these meats?	Other meats	1	2	8	
[K] Eggs?	Eggs	1	2	8	
[L] Fish or shellfish, either fresh or dried?	Fresh or dried fish	1	2	8	
[M] Beans, peas, lentils or nuts, including any foods made from these?	Foods made from beans, peas, nuts, etc.	1	2	8	
[N] Cheese or other food made from animal milk?	Cheese or other food made from milk	1	2	8	
[X] Other solid, semi-solid, or soft food?	Other solid, semi-solid, or soft food	1	2 ⇩ BD9	8 ⇩ BD9	
[X1] Record all other solid, semi-solid, or soft food that do not fit food groups above.	(Specify)				

BD9. How many times did (***name***) eat any solid, semi-solid or soft foods yesterday during the day or night? If BD8[A] is 'Yes', ensure that the response here includes the number of times recorded for yogurt *in BD8[A1]*. If 7 or more times, record '7'.	Number of times __ DK 8	
INTERVIEWER'S OBSERVATIONS		

UF13. LANGUAGE OF THE INTERVIEW.	ENGLISH **Other language** (*specify*).....	
UF14. NATIVE LANGUAGE OF THE RESPONDENT.	ENGLISH **Other language** (*specify*)	
UF15. WAS A TRANSLATOR USED FOR ANY PARTS OF THIS QUESTIONNAIRE?	YES, THE ENTIRE QUESTIONNAIRE 1 YES, PARTS OF THE QUESTIONNAIRE 2 NO, NOT USED 3	
UF16. *Tell the respondent that you will need to measure the weight, height and MUAC of the child and a colleague will come to assist with the measurement. Issue the ANTHROPOMETRY MODULE FORM for this child and complete the ANTHROPOMETRY MODULE INFORMATION PANEL on that Form.*		

ANTHROPOMETRY MODULE INFORMATION PANEL AN	
AN3. Child's name NAME.....___ ___	**AN4**. Child's age from UB2: Age (in completed years) .....__
AN5. Mother's / Caretaker's name Name.....	**AN6**. Interviewer's name Name.....

ANTHROPOMETRY		
AN7. MEASURER'S NAME	Name_	

AN8. TAKE TWO MEASUREMENTS OF **WEIGHT** AND RECORD AS READ OUT BY THE MEASURER: READ THE RECORD BACK TO THE MEASURER AND ALSO ENSURE THAT HE/SHE VERIFIES YOUR RECORD. IF THE MAXIMUM ALLOWABLE DIFFERENCE BETWEEN THE TWO MEASUREMENTS IS 0.1KG, TAKE A THIRD MEASUREMENT.	1. Kilograms (kg).....___ ___. ___ 2. Kilograms (kg).....___ ___. ___ Child refused.....99.4 Respondent refused.....99.5 Other (*specify*).....99.6	99.4⇨AN10 99.5⇨AN10 99.6⇨AN10
AN9. WAS THE CHILD UNDRESSED TO THE MINIMUM?	Yes.....1 No, the child could not be undressed to the minimum.....2	
AN10. CHECK AN4: CHILD'S AGE?	Age 0 or 1.....1 Age 2, 3 or 4.....2	1⇨AN11A 2⇨AN11B

AN11A. THE CHILD IS LESS THAN 2 YEARS OLD AND SHOULD BE MEASURED LYING DOWN. TAKE TWO MEASUREMENTS OF **LENGTH** AND RECORD AS READ OUT BY THE MEASURER: READ THE RECORD BACK TO THE MEASURER AND ALSO ENSURE THAT HE/SHE VERIFIES YOUR RECORD. IF THE MAXIMUM ALLOWABLE DIFFERENCE BETWEEN THE TWO MEASUREMENTS IS 0.7CM, TAKE A THIRD MEASUREMENT.	Non-digital Height measurement 1. Length / Height (cm)... ___ ___ ___. ___ 2. Length / Height (cm)... ___ ___ ___. ___ Child refused.....999.4 Respondent refused.....999.5 Other (*specify*).....999.6 height measurement 1. Length / Height (cm)... ___ ___ ___. ___ 2. Length / Height (cm)... ___ ___ ___. ___	999.4⇨AN13 999.5⇨AN13 999.6⇨AN13
AN11B. THE CHILD IS AT LEAST 2 YEARS OLD AND SHOULD BE MEASURED STANDING UP. TAKE TWO MEASUREMENTS OF **HEIGHT** AND RECORD AS READ OUT BY THE MEASURER:	Child refused.....999.4 Respondent refused.....999.5 Other (*specify*).....999.6	

READ THE RECORD BACK TO THE MEASURER AND ALSO ENSURE THAT HE/SHE VERIFIES YOUR RECORD. IF THE MAXIMUM ALLOWABLE DIFFERENCE BETWEEN THE TWO MEASUREMENTS IS 0.7CM, TAKE A THIRD MEASUREMENT.		
AN12. HOW WAS THE CHILD ACTUALLY MEASURED? LYING DOWN OR STANDING UP?	Lying down .....1 Standing up 2	
AN13. Day / Month / Year of measurement: ___ ___ /___ ___ / 2 0 __ ___		

AN14. TAKE TWO MEASUREMENTS OF **MUAC** AND RECORD AS READ OUT BY THE MEASURER: READ THE RECORD BACK TO THE MEASURER AND ALSO ENSURE THAT HE/SHE VERIFIES YOUR RECORD. IF THE MAXIMUM ALLOWABLE DIFFERENCE BETWEEN THE TWO MEASUREMENTS IS 0.5CM, TAKE A THIRD MEASUREMENT.	1. MUAC (cm) ..... ___ ___ ___. ___ 2. MUAC (cm) ..... ___ ___ ___. ___	
AN15. TAKE TWO MEASUREMENTS OF **HEIGHT AND MUAC** BY A 3D IMAGE AND RECORD THE READING.	1. Length / Height (cm)... ___ ___ ___. ___ 2. Length / Height (cm)... ___ ___ ___. ___ 1. MUAC (cm) ..... ___ ___ ___. ___ 2. MUAC (cm) ..... ___ ___ ___. ___	
AN16. *Thank the respondent for his/her cooperation and hand over their participant's remuneration pack.*		

OBSERVATIONS

MEASURER'S OBSERVATIONS FOR **NON-DIGITAL MANUAL** HEIGHT BOARD

MEASURER'S OBSERVATIONS FOR **DIGITAL MANUAL ANTHROPOMETRY** HEIGHT BOARD

MEASURER'S OBSERVATIONS FOR **3-D IMAGING**

e) Permission letter to the school and parents

SCHOOL OF MEDICINE
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UNAM
UNIVERSITY OF NAMIBIA

To: **The school principal and parents**
Name of the school

From: **Ms Johanna Namene (Principal investigator)**
Human,Biological&Translational Medical Sciences
UNAM school of Medicine
jnamene@unam.na

cc: **Prof Jane Misihairabgwi (Associate Professor)**
Human,Biological&Translational Medical Sciences
UNAM school of Medicine
jmisihairabgwi@unam.na

Re: Request for participation of your child in a nutrition screening study

Dear Parents

The University of Namibia is conducting a study in partnership with UNICEF and UNDP to screen children for malnutrition in Namibia. The study has been supported and approved by the Ministry of Health and Social Services. Under nutrition remains a high burden among Namibian children and knowing the nutritional status of your child is important in early detection of malnutrition. A healthy eating behavior at childhood is very important as it helps prevent malnutrition, growth retardation, and acute child nutrition problems.

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We hereby would like to invite your child to participate in the study in order to assess the nutritional status of individual children and that of the country. Our target age group is children from 6 months to <5 years. The planned date of this exercise is from **08 March 2021.** We have four different measuring devices, two height boards (digital and non digital), a 3D imaging phone and a Mid Upper Arm Circumference tape. All the measurements are estimated to take 10-15 minutes per child. We will be happy to provide feedback of the nutritional status of your child after completion of the study.

Attached, please find the MOHSS approval letter for the study and an assent form for your information. Should you agree for your child to participate in our study, please sign the assent and send it back to us through the school principal. For any further information, please contact me anytime at +264 81 2765 502.

Thanking you for your kind support and understanding.

Sincerely yours,

Johanna Namene

(f) Methods protocol for height, length, weight and MUAC measurements

Child height measurement procedure: Height was measured only for children who were two years or above and able to stand on their own. The height board was placed on a hard flat surface and against a wall, tree or table to ensure that it was stable. The mother or enumerator (with the mother's permission) removed the child's shoes, socks, any heavy garment, hair accessory and un-braid/un-tie any interfering hair. The child was then placed on the height board, with the feet together and flat on the foot piece. The research assistant placed the child on the height board such that the child's heel, knee, buttocks, shoulder blade and back of the head are against the back of the board. The assistant made sure the head of the child was in the right position and the knees did not bend and the feet did not lift from the ground, by holding the child in position during measurements. After the assistant ensured that the child's position was correct, the PI placed the headpiece gently on the child's head, making sure that the hair did not interfere. Once the PI was comfortable with the position, the reading was taken on the measuring scale of the analog height board, while with the digi-board, a button was pressed and the reading was displayed on the screen of the board. The PI read the measurement to the assistant for recording. The roles were switched between the PI and the assistant. This procedure was repeated twice for each child by each enumerator, for both the analog and digi-board. The first and the second measurements between each enumerator were compared to ensure that they were both within the maximum allowed difference (Table 6). Any measurement that was falling outside the maximum allowed difference was repeated. Height was recorded to the nearest 0.1cm. Both height boards were calibrated regularly on a daily basis using metal rods of known height.

Child length measurement procedure: Length was measured for children from 6 months to 23 months, or children that could not stand on their own. The measuring board was placed on the ground or the floor and with the mother's help, the child was gently laid on the board with the head facing the base of the board and the feet facing the headpiece. The assistant gently pressed the child's knees firmly against the head board such that the legs were straight. Once the child's position was correct, the measurement was taken. For each child, the roles were reversed between the research assistant and the principal investigator.

Intra- and inter-observer assessment for height: Each enumerator took four measurements of each child, two measurements were taken using the analog height board, and two measurements were taken using the digi-board. This was done to test for reliability of measurements within (intra-observer) and between (inter-observer) measures for both types of height boards.

Weight: Weight measurements were done according to the WHO standards (16). Weight was measured with a portable digital scale (Figure 9-A). The parent was asked to remove their child's shoes, as well as any heavy garments (children were measured with minimal clothes). Children above two years were asked to stand calm at the centre of the scale platform, with the weight evenly distributed on both sides. For infants, the scale had a taring capability that allowed infants to remain in their mother's arm where they were calmer and more relaxed while on the scale. The mother was asked to step onto the scale first alone, and the scale saved the weight. Then the scale was tared and the baby was given to her. The weight of the baby was then recorded. Weight was recorded to the nearest to 0.1 kg. The scale has a self-calibration function, which ensures accuracy of the scale.

MUAC: WHO standard procedures (16) were followed when measuring MUAC. MUAC was measured using a MUAC tape (Figure 9-D). A standard MUAC tape (S0145620 MUAC) was used in this study, which is colour coded with red, yellow and green, indicating the nutritional status of the child (Table 5). To measure MUAC, the parent was asked to remove any clothing that was covering the child's left arm. The child's arm was bent at 90^{o} to the body by the elbow to locate the midpoint. With a non-stretchable string, the upper arm was measured from the top of the shoulder (acromion) to the tip of the elbow (olecranon) and the string was folded in half to located the midpoint on the child's arm, which was marked with a removable make-up pencil. After the midpoint was located, the child's left arm was then straightened and held by the assistant in a relaxed position and the tape was wrapped around the arm at the midpoint, making sure it is not too tight or too loose on the skin (the assistant made sure that the tape was in a perfect position, with no gaps or any compression and assured the PI before taking the reading). All measurements were repeated twice and recorded to the nearest 0.1 cm.

To assess the nutritional status of children using MUAC, the following cut-off points were used. A child whose MUAC was less than 11.5 cm (in the red colour) was considered severely malnourished and between 11.5-12.5 cm (yellow) was considered moderately malnourished. In such cases, the parent was informed of the child's condition and referred to a nearby clinic/health centre for treatment and/or for therapeutic/supplementary feeding (if available). The child was considered healthy if MUAC was more than 12.5 cm. In this case, the PI encouraged the parent/caregiver to continue with the healthy feeding practices.