Association of cost of the diet with dietary diversity and nutrient adequacy in children aged 12 to 24 months.

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DECLARATION

I, **Tshavhuyo Audry Mulabisano** (student no 4008689), declare that this mini-thesis hereby submitted to the University of the Western Cape for the degree of Masters in Public Health Nutrition has not been previously submitted by me at this university and that it is my own work. The literature sources that I have used have been acknowledged by means of complete reference. Part of this work was presented at the International Dietetics Conference 2021 as a poster presentation and the abstract was published in the ICD abstract book (South African Journal of Clinical Nutrition 2021; 34(3)).

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Tshavhuyo Audry Mulabisano

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Date

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KEY WORDS

Dietary diversity

Nutrient adequacy

Complementary diet

Nutrient density

Energy density

Mean adequacy ratio

Cost

Children age 12 to 24 months

ABBREVIATIONS

AI	Adequate intake
DRIs	Dietary reference intakes
EAR	Estimated average requirement
IQR	Interquartile range
Kcal	Kilocalories
kJ	Kilojoules
MAR	Mean adequacy ratio
NFCS	National Food Consumption Survey
NAR	Nutrient adequacy ratio
NFFP	National Food Fortification Programme
RDA	Recommended dietary allowance
SADHS	South African Demographic and Health Survey
SDGs	Sustainable Development Goals
UNICEF	United Nations Children's Fund
WHO	World Health Organization

DEFINITIONS OF KEY TERMS

Complementary diet: complementary diet was defined as all foods and beverages consumed excluding breastmilk and formula milk feeds.

Cost of the total intake: cost of the total intake in this study was defined as the cost of all foods in the child's diet including formula feeds milk.

Nutrient adequacy ratio: is the ratio of an individual's nutrient intake to the recommended dietary allowance (RDA) of that specific nutrient (INNDEX Project, 2018).

Mean adequacy ratio: is a single indicator that can be used to measure overall nutrient adequacy of the diet at population level. It is calculated as the sum of NARs (capped at 1 for nutrients for which intake exceeds the requirement) for all evaluated nutrients divided by the number of nutrients evaluated (INNDEX Project, 2018).

Milk feeds: include breastmilk and formula milk feeds, but exclude formula milk that was mixed with porridge

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ABSTRACT

Background: The World Health Organization (WHO) and United Nations Children's Fund (UNICEF) recommend exclusive breastfeeding for the first six months of life and introduction of nutritionally adequate and safe complementary foods after 6 months with continued breastfeeding to 2 years and beyond. A variety of foods in the diet is needed to ensure that the nutrient needs of breastfed and non-breastfed children are met. Price of food and affordability are the main barriers of accessing sufficient, safe and nutritious diets to meet dietary needs for an active and healthy life. Many low-income households cannot afford a healthy nutritionally adequate diet, because of the cost of nutrient-rich foods relative to income.

Aim: The aim of the study was to determine whether cost of the diet is associated with dietary diversity, energy and nutrient density, and nutrient adequacy in breastfeeding and non-breastfeeding children aged 12 to 24 months.

Objectives: For breastfed and non-breastfed children age 12 to 24 months, to determine: **(i)** dietary diversity, nutrient adequacy and cost of total dietary intake; **(ii)** dietary diversity, nutrient density, energy density and cost of the complementary diet; **(iii)** the association of cost of the diet with dietary diversity and nutrient adequacy; and **(iv)** the association of cost of the complementary diet with dietary diversity, nutrient density and energy density of the complementary

Study design: The study is a descriptive study and used an existing dataset consisting of pooled previously collected 24-hour dietary recalls for children age 12 to 24 months from the two most recent independent studies (n=1064). The dataset included data on dietary energy and nutrients, mean adequacy ratio, nutrient adequacy ratios, micronutrient density per 100 kcal of the complementary diet and cost of food per 100g edible portion.

Methods: Cost of the total diet and of the complementary diet (all foods excluding breast milk and other milk feeds) was calculated based on cost per 100g edible portion and portion size (gram) consumed for all individual foods reported per 24-hour recall. Food intake data was used to calculate the dietary diversity score and nutrient adequacy of the total diet; and dietary diversity for the complementary diet. Energy density (kcal/100g of food) of the complementary diet was calculated. Diet quality indicators (nutrient adequacy for total intake, dietary diversity, energy and nutrient density of the complementary diet) and diet cost of breastfed and non-breastfed children were compared using the Mann-U Whitney test. Thereafter, the relationship between diet cost and dietary intake indicators was determined for breastfed and non-breastfed babies respectively using Spearman's correlation analysis.

Results: Based on the revised minimum dietary diversity indicator, more than 80% of the total sample did not meet minimum dietary diversity; and a significantly higher percentage of non-breastfed children did not meet minimum dietary diversity compared to breastfed children. However, for the complementary diet (excluding breastmilk and formula milk feeds), a significantly higher percentage of breastfed children had a low dietary diversity compared to the non-breastfed children. Less than 50% of both breastfed and non-breastfed children had consumed foods from the flesh food group (meat, poultry, organ meats, offal & liver) the previous day. More than 75% of both breastfed and non-breastfed children respectively had inadequate intake of calcium, with no significant difference between breastfed and non-breastfed children. Even though breastfed children had higher density for most micronutrients than non-breastfed children, the nutrient density for calcium and iron was not enough to meet the WHO target nutrient density values. Cost of the total diet and the complementary diet respectively was higher for non-breastfed children. The dietary diversity score and mean adequacy ratio of the total diet were positively associated with total diet cost for breastfed and non-breastfed children respectively. For the complementary diet, the dietary diversity score, average nutrient density and energy density were positively associated with the cost of the complementary diet.

Conclusion: The results indicate that a more nutritious diet in terms of nutrient adequacy, nutrient density and dietary diversity costs more. This suggests that for mothers of low-income households it may be challenging to provide their babies with a nutritionally adequate diet.

CHAPTER 1: INTRODUCTION

1.1 Background

For children to grow healthy, they need a nutrient adequate diet. Children who are malnourished are at risk of morbidity and mortality (WHO, 2020a). Globally, 144 million children under the age of 5 were stunted in 2019, and 47 million were wasted, of which 14.3 million were severely wasted. In addition, in 2019 38.3 million children under age 5 years were overweight, an increase of 8 million since 2000 (WHO, 2020a). In Africa, 57.5 million children under age 5 years are stunted (WHO, 2020a). In 2016, South Africa's stunting prevalence in children under age 5 years was 27.4% (NDoH, 2017), which is lower than that of many countries in the Southern African Development Community (SADC) region, however it is still high (De Onis et al., 2019).

Recommendations are that children should be exclusive breastfed for the first 6 months of life. Thereafter they should be introduced to a variety of nutritious complementary foods, while breastfeeding is continued up to age 2 years and beyond (WHO, 2003). Children under age 2 years consume small amount of foods, while they have high nutrient requirements, hence their complementary diet must be nutrient dense (Dewey, 2013). To achieve Sustainable Development Goal (SDGs) 2 by 2030, improving childhood nutrition should be a priority as optimal nutrition will reduce malnutrition and childhood deaths (UNICEF, 2020).

1.2 Problem statement

Children under age 2 years are at particular risk of malnutrition; optimizing nutrition at this stage ensures that they have a healthy early childhood development, with improved life-long benefits. In addition, good nutrition in the first 1000 days of life is important as poor nutrition can cause stunted growth. Stunting in children has been shown to be associated with poor cognitive development (WHO, 2020a).

Eating an unhealthy diet that consist mostly of foods high in sugar and fat, but has little variety and inadequate amounts of essential nutrients during early childhood may lead to obesity and non-communicable diseases later in life (UNICEF, 2019). In South Africa, a minimum acceptable diet is achieved for only 23% of children between age 6 to 23 months (NDoH, 2017). The diet of South African children age 6 to 24 months in low-socioeconomic settings consists mostly of maize (particularly maize meal), while in some areas commercial infant foods are an integral part of the diet (Faber, 2005; Faber et al., 2016; Swanepoel et al., 2019). In the Western Cape, less than half (44%) of children age 6 to 23 months in low-socioeconomic communities were found to have received a diverse diet of minimum acceptability and had consumed foods from at least 4 food groups, as calculated with the related WHO indicator (Du Plessis et al., 2016). A diverse diet as recommended by the South African pediatric food based dietary guidelines (Bowley et al., 2007) is important to ensure that both breastfed and non-breastfed children's nutritional needs are met (WHO, 2005; WHO, 2001).

Households' ability to access safe and sufficient nutritious foods is determined by the cost and affordability of food (Herforth et al., 2020). Consumption of commercial infant products in poor communities depends on affordability (Katepa-Bwalya et al., 2015). Previous literature has shown that nutrient-rich diets have a higher cost compared to diets that provide sufficient energy but consist mostly of basic staple foods (Chastre et al., 2007; Drewnowski & Darmon, 2005; Headey & Alderman, 2019; Masters et al., 2018). Many low-income households are unable to acquire a nutritionally adequate diet, because of the cost of nutrient-rich foods relative to their income (Herforth et al., 2020). For nutrition knowledge and behavior change strategies to influence food choices, the constraints related to cost and income need to be addressed first (Herforth et al., 2020).

Low-income families select food that are cheaper and of low nutritional quality because of affordability, which may result in malnutrition (UNICEF, 2019). A recently published paper reported that for children age 6 to 24 months in low socioeconomic settings in South Africa, underlying dietary patterns differ in dietary quality based on various indicators of dietary quality; and the data suggested that for breastfed children the nutrient density of the complementary diet was lower (Faber et al., 2020). It is therefore important to determine whether cost of the diet is associated with nutrient adequacy and dietary diversity in children under age 2 years; and whether this differs according to breastfeeding status.

1.3 Aim and Objectives

The aim of this study was to determine whether cost of the diet is associated with dietary diversity, energy density, nutrient density, and nutrient adequacy in breastfeeding and non-breastfeeding children age 12 to 24 months.

Objectives

For breastfed and non-breastfed children age 12 to 24 months, to determine:

- dietary diversity, nutrient adequacy and cost of total dietary intake;
- dietary diversity, nutrient density, energy density and cost of the complementary diet;
- the association of cost of the diet with dietary diversity and nutrient adequacy; and
- the association of cost of the complementary diet with dietary diversity, nutrient density and energy density of the complementary diet.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Good nutrition during early childhood is essential for the child's growth and development. Moreover, there is an interaction between undernutrition and infections; illness can result in poor nutritional status, while deterioration of nutritional status may worsen the illness (UNICEF, 2019). In 2016, 45% of early childhood mortality in low- and middle-income countries were linked to undernutrition (WHO, 2020b). Factors contributing to undernutrition include suboptimal breastfeeding (specifically, non-exclusive breastfeeding); complementary diets low in diversity and nutrient density; severe infectious diseases; and infections due to poor hygiene (WHO, 2014).

Malnutrition in children under age 5 years is a global problem. Globally, at least 1 in 3 children under age 5 years is either stunted, wasted or overweight (UNICEF, 2019). A recent WHO report shows that in 2020, approximately 149 million children under 5 years were stunted worldwide, over 45 million were wasted and 38 million were overweight (WHO, 2021a). The 2016 South African Demographic and Health Survey (SADHS) reported that 27% of children under age 5 years in South Africa are stunted (NDoH, 2017). Stunting has increased in South Africa compared to previous data (Shisana et al., 2013), while most other countries, including countries in Africa show a decrease over time (WHO, 2021a). Being overweight is also seen as a major nutritional problem in South Africa, and in 2016, 13% of children under age 5 years were overweight (NDoH, 2017). According to the 2016 SADHS, a higher proportion of deaths that are associated with diarrhea are caused by acute malnutrition (NDoH, 2017).

Malnutrition has been shown to be associated with intellectual development in early childhood, which results in poor cognitive development; this may subsequently result in the individual becoming a social burden, which ultimately impacts the economy of a country (Black et al., 2013; Prado & Dewey, 2014; WHO, 2019). Also, children who are undernourished in the first 24 months of life have a higher chance of becoming obese and developing non-communicable diseases later in life (Black et al., 2013).

In children under age 2 years, dietary quality indicators such as dietary diversity and nutrient adequacy, have an important role in preventing undernutrition during the critical period for growth and development (Black, 2017).

2.2 Importance of optimal nutrition from age 6 months to 2 years

The first 2 years of life are an important period for childhood development and establishing long-term healthy eating and dietary patterns that promote healthy growth (Birch & Doub, 2014; Mennella et al., 2016). Children under the age of 2 years are at risk of undernutrition and common childhood illnesses, such as diarrhea and respiratory infections (Black et al., 2013). Furthermore, undernutrition during infancy increases the risk of childhood mortality, and risk of non-communicable diseases in adulthood (UNICEF, 2019).

Clear recommendations exist regarding nutrition during early childhood. Exclusive breastfeeding up to age 6 months is recommended (WHO, 2003). After age 6 months, the nutritional needs of infants and young children can no longer be met by breast milk alone. After age 6 months, timely introduction of diverse complementary foods is needed to ensure that infants nutritional requirements are met (Tassew et al., 2019).

2.2.1 The role of continued breastfeeding from age 6 months to 2 years

Continued breastfeeding from age 6 to 24 months and beyond with appropriate introduction of complementary foods from age 6 months is recommended (WHO, 2003). A systematic review and meta-analysis showed that infants and young children who received no breastmilk after the age of 6 months had higher risk of mortality compared to children who received breastmilk for 6 months or longer (Sankar et al., 2015). A study done in the U.S. showed that children who were breastfed up to age 6 months and beyond were introduced to solids timely; and consumed more fruit and vegetables, and less fatty and sugary foods in their preschool years (age 2 to 5 years), compared to those who were not breastfed for at least 6 months (Musaad et al., 2015).

Continued breastfeeding up to age 2 years and beyond contributes to the energy and nutrient requirements during the period of complementary feeding (Victora et al., 2015). Breastfeeding is usually continued when children become ill while food intake often decreases, highlighting the importance of continued breastfeeding (Paintal & Aguayo, 2016). In addition, continued breastfeeding during infections have been shown to reduce the duration of illness and improve nutritional status of children (Lutter et al., 2021). Children and adolescents who had been breastfed for a longer duration during early childhood (more than 12 months) have been shown to score better on intelligence tests (Victora et al., 2015).

2.2.2 The role of the complementary diet in children from age 6 months to 2 years

While breast milk continues to be an essential source of nutrition in this period, it is important that a complementary diet of good quality be introduced at age 6 months as breast milk alone can no longer provide sufficient amounts of nutrients to meet the infant's high nutrient requirements to support rapid growth and development (WHO, 2003). Additionally, infants and young children consume small amount of food, thus the complementary diet that they are consuming must have a high nutrient density (WHO, 2003). Adequate intake of recommended foods such as animal derived foods may protect against adverse growth outcomes such as stunting, inadequate weight gain or inadequate head growth (Du Plessis, 2013).

The complementary diet also needs to provide certain key nutrients that are not sufficiently supplied by breast milk at this age, for example iron. Insufficient intake of essential nutrients such as iron and zinc may lead to impaired cognitive development (Prado & Dewey, 2014). In vulnerable populations, the incidence of infections also contributes to increased nutritional needs (Dewey & Mayers, 2011).

Diets with poor quality and low in essential macronutrients and micronutrients are determinants of poor growth in most low- and middle-income countries (Black, 2017). Avoiding excessive intake of food high in calories, salt, sugars, and unhealthy fats during complementary feeding is also important (Lutter et al., 2021). In South Africa, starchy foods (grains, roots and tubers) are the most consumed foods throughout infancy and into early childhood (Budree et al., 2017; Faber et al., 2016). As the consumption of commercial infant cereal decreases with age, the intakes of maize meal porridge and bread increase in South Africa (Budree et al., 2017; Faber et al., 2016). Improper complementary feeding practices in South Africa are a major concern and improving these feeding practices needs appropriate action (Sayed & Schönfeldt, 2020).

2.3 Dietary quality during the complementary feeding period

2.3.1 Dietary diversity

A diverse nutrient adequate diet in infants and young children is needed to support healthy growth and development (Lutter et al., 2021). Diets low in dietary diversity have been reported to be associated with an increased risk of micronutrient deficiencies (Lutter et al., 2021). Consumption of animal food products, fruits and vegetables will increase diversity while improving micronutrient intakes (Dewey, 2003).

A study in Ethiopia showed that the dietary diversity score (DDS) is a good measure of dietary quality and can be used as a predictor of inadequate intakes of micronutrients in breast-fed infants (Wondafrash et al., 2016). Globally, 2 in 3 children between age 6 to 24 months do not receive a diet of adequate diversity needed for healthy growth and development, while only 1 in 5 children from households living in poverty and rural areas is fed the minimum recommended diverse diet (UNICEF, 2019). Dietary diversity may be used to reflect micronutrient adequacy of the complementary diet in infants and young children (Moursi et al., 2008; Steyn et al., 2006). In most households in low-income settings, the ability to access a nutrient adequate diet will depend on which foods are available and affordable to them (Labadarios et al., 2011).

Breastfed and formula-fed babies may have different dietary consumption patterns (Conn et al., 2009; Noble & Emmett, 2006). This was also observed in the 2016 SADHS, which showed that a higher percentage of non-breastfed babies were receiving a minimum acceptable diet, compared to breastfed babies (NDoH, 2017).

The DDS indicator for infants and young children originally recommended by WHO consists of 7 food groups (WHO, 2010). To achieve minimum dietary diversity, children age 6 to 23 months must consume foods from at least 4 food groups (WHO, 2010). The indicator includes infant formula but does not include breast milk, and therefore favours those infants who receive formula milk when calculating the DDS. In 2017, the WHO DDS indicator was revised for children age 6 to 23 months by adding breastmilk as an additional food group (refer to addendum 1). For the revised indicator, minimum dietary diversity is achieved if foods are consumed from at least 5 of the 8 food groups (WHO, 2021b). The original indicator (7 food groups) reflects dietary diversity of the complementary diet, while the revised indicator reflects dietary diversity of total intake. The original (7 food groups) indicator excluded an important component of the infant's diet, as breastmilk is an important source of nutrients and continued breastfeeding to age 2 years and beyond is recommended. Also, the original DDS indicator has to be reported separately for breastfed and non-breastfed children (Heidkamp et al., 2020). When using the revised indicator, the percentage of children with low dietary diversity may be higher compared to when using the original indicator, particularly for countries with low breastfeeding rates, such as South Africa (Heidkamp et al., 2020). Comparing studies that used different indicators should therefore be done with caution.

To improve nutritional status of infant and young child, their complementary foods must be diverse (Rah et al., 2010). Data from Demographic and Health Surveys that were done in low-income countries showed that achieving minimum acceptable diet and minimum dietary diversity were both associated with a reduced risk of undernutrition (Marriott et al., 2012). In addition, a study in Indonesia reported that achieving minimum dietary diversity was associated with a lower risk of stunting in infants and young children age 6 to 23 months (Paramashanti et al., 2017).

In South Africa, a minimum acceptable diet is achieved for only 23% of children between age 6 to 23 months (NDoH, 2017). Dietary diversity is an integral component of the minimum acceptable diet in children 6 to 24 months old (Moursi et al., 2008). A study done in KwaZulu-Natal showed that the complementary diet of urban and rural children, age 6 to 24 months, was lacking in dietary diversity, with fewer than 25% of children consuming foods from at least 4 food groups (Faber et al., 2016). Moreover, infants and young children in South Africa in general have low dietary diversity (Sayed & Schönfeldt, 2020). In South Africa, poor households consume mostly a maize-based diet with low diversity (Faber & Drimie, 2016; Otterbach & Rogan, 2017), and in urban areas in particular, consumption of processed foods with high fat and added sugar has shown an increase in adults (Mchiza et al., 2015). In infants, high consumption of processed meats, crisps and sugar sweetened beverages has been reported in a study conducted in Paarl, South Africa (Budree et al., 2017). Also, the 2016 SADHS reported that 18% of children age 6 to 23 months consumed sugar sweetened beverages, 35% consumed sugary foods, and close to 50% consumed salty snacks during the recall period (NDoH, 2017). In addition, a review of the literature showed that consumption of animal source foods is low during the complementary feeding period in South Africa (Sayed & Schönfeldt, 2020).

2.3.2 Nutrient adequacy

Starting from age 6 months, children should consume animal-source foods as they provide essential nutrients needed for growth and development (UNICEF, 2019). Considering the benefits of continued breastfeeding, complementary foods should not displace breast milk (Dewey, 2013). Infants and young children have small stomachs and therefore eat small amounts of food. Animal-source foods are nutrient-dense and therefore suited to the smaller stomachs (UNICEF, 2019).

Nutrient adequacy can be determined for individual macronutrients and micronutrients (INDDEX Project, 2018). The Dietary Reference Intakes (DRIs) are reference values for nutrient intakes and are used to assess adequacy of nutrient intakes of healthy people (Otten et al., 2006). These are the Estimated Average Requirement (EAR), Recommended Dietary Allowance (RDA), Adequate Intake (AI), and Tolerable Upper Intake Level (UL) (Otten et al., 2006). The EAR is the estimated average daily intake needed to meet the nutrient requirements for half of a healthy population. EAR values are age and gender specific, and are used to assess the adequacy of estimated nutrient intakes of groups (Otten et al., 2006). To determine adequacy of nutrient intake of groups based on EAR, the percentage of intakes below the EAR can be calculated (Otten et al., 2006). Mean adequacy ratio (MAR) is a single indicator that can be used to measure overall nutrient adequacy of the diet of a population based on the RDA (INNDEX Project, 2018). The RDAs are estimates of daily intakes to meet the nutrient requirement of 97-98% of a healthy population. Bioavailability of zinc and iron depends on foods included in the diet and nutrient requirements for these two nutrients may therefore vary (Otten et al., 2006). In most low- and middle-income countries, diets often consist of mostly unrefined grains and some other plant foods that are high in phytates and oxalates. These compounds inhibit the absorption of minerals such as iron and zinc, and bioavailability is therefore low (Otten et al., 2006; Schneider & Herforth, 2020). The early childhood period is a period of rapid growth and development and iron intake requirements are high (Otten et al., 2006).

In low socioeconomic settings, cereal-based porridges with low nutrient content and poor bioavailability of minerals such as zinc and iron are the basis of most complementary diets. In addition, these complementary diets usually have low nutrient density (Dewey, 2013). A study done in Guatemala found that family foods that are nutritionally adequate for most household members will most likely not provide sufficient key nutrients to meet the requirements of breastfed infants, as most family foods are low in nutrient density (Vossenaar & Solomons, 2012). Infants and young children diets have been reported to be lacking iron and zinc (Dewey & Vitta, 2013). In the absence of animal-source foods and fortified complementary foods, it is unlikely that the complementary diet will provide sufficient quantities of iron and zinc (Black et al., 2017).

A study in Guatemala found that the complementary diet of infants are particularly low for calcium, iron and zinc; these three nutrients are referred to as “problem nutrients” (Vossenaar et al., 2013; Vossenaar & Solomons, 2012). Similarly, in South Africa, complementary diets of infants in rural KwaZulu-Natal were found to be inadequate in iron, zinc and calcium (Faber, 2005).

2.3.3 Nutrient density

Nutrient density is the amount of nutrients per 100 kcal (418 kJ). Children under the age of 2 years need a nutrient-dense complementary diet to support their growth and development, because they consume small amount of food (Dewey, 2013). It is however difficult to meet the nutrient density requirements of children during the first 2 years of life. In low-income settings, nutrient intakes are usually below the required amount for most key nutrients, because the diets consist mostly of grain-based foods that are low in nutrient density. Requirements for nutrient density are high at age 6 to 8 months, and the period between 6 and 12 months poses the greatest challenge in meeting the micronutrient needs of infants as they are often fed diluted porridges that are nutrient poor (Dewey, 2013).

A study in rural and urban areas in KwaZulu-Natal in South Africa showed that a complementary diet with adequate dietary diversity had a higher nutrient density for protein and most micronutrients compared to a complementary diet with low diversity; and that the nutrient density of the complementary diet of breastfed children age 6-17 month was less than the recommended density for several micronutrients such as zinc, calcium, iron, niacin, and riboflavin (Faber et al., 2016). In addition, low nutrient density of key nutrients such as iron, zinc and calcium in the complementary diet of children was seen in a study that was done in a low socio-economic peri-urban community in North West province, South Africa (Swanepoel et al., 2019). A recent study done in South African school aged children showed that diets low in nutrient density is associated with low haemoglobin and plasma ferritin concentration in children (Visser et al., 2021).

2.3.4 Energy density

Energy density of the diet is the amount of available energy per unit of weight in the diet (kcal/g). Energy density is a marker of diet quality. From age 6 months, infants require complementary foods of appropriate energy density to meet their physiological requirements (Islam et al., 2016). Children under the age of 2 years are fed mostly low energy-dense cereal-based porridges as their primary complementary food, and in order for them to meet energy density requirements they must consume large volume (Dewey, 2016).

An energy-dense complementary diet is important for children below the age of 2 years, and a complementary diet with low energy density has been shown to be associated with protein-energy malnutrition (Daelmans & Saadeh, 2003).

2.3.5 Cost of the diet

The cheapest source of energy in the diet are usually those foods that have a high energy density but poor nutrient content. This makes it more difficult for an individual with a limited budget to consume a nutrient adequate diet (Darmon et al., 2002; Darmon et al., 2006). Foods that are nutrient-dense, for example fruits, vegetables, and animal-source foods, often cost more compared to nutrient-poor foods, such as oil and sugar (Dizon & Herforth, 2018). Moreover, the cost of nutrient adequate foods differs across income regions. Most nutrient-dense foods are highly perishable and their cost depends on local productivity (Headey & Alderman, 2017; Monsivais et al., 2010). In addition, in South Asia it was found that the cost of nutrient-dense foods was increasing rapidly, and varied more across seasons and geographical location, than that of energy-dense, low micronutrient foods (Dizon & Herforth, 2018).

Findings from the Food and Agricultural Organization (FAO) background paper demonstrated that nutrient adequate diets cost more than high-energy diets. In addition, the cost of a nutritionally adequate diet in the markets was found to be more than what many people can afford (Herforth et al., 2020). Cost of foods has been reported to be a contributing factor to poor quality of the diet as well as malnutrition worldwide, and an estimated 3 billion people globally cannot afford a nutrient adequate diet even at the lowest possible cost (Herforth et al., 2020). Low-income families are prone to select foods of low nutritional quality that costs less, and children living in poverty face the greatest risk of malnutrition in all forms (UNICEF, 2019). Some studies found that the cost of diets is linked to diet quality and to malnutrition (Beydoun et al., 2011; Grossman et al., 2014; Headey & Alderman, 2017).

Diet quality is a critical link between food security and malnutrition. Meeting the targets of the SDG 2 related to hunger, food security and optimal nutrition will be achieved only if people have access to optimal nutritious food at the lowest possible cost (WHO, 2020b).

When food is available, affordability of a nutrient adequate diet might be a challenge (Deptford et al., 2017). In low-income countries, cost rather than health considerations often determine food choices, and diets that have a low cost are often energy-dense but nutrient-poor (Rehm et al., 2011). In the United States, nutrient adequate diets were shown to be associated with higher diet costs, making it more difficult for families with a limited budget to plan a varied diet for their families (Aggarwal et al., 2012). Commercial infant products are consumed as a complementary food and the consumption is dependent on the household being able to afford it (Katepa-Bwalya et al., 2015).

South African studies have shown that low dietary diversity was common in households that are mostly living in poverty (Faber et al., 2009; Labadarios et al., 2011). Healthy eating have been shown to cost more, and it was reported that a nutrient adequate diet was unaffordable for most people in South Africa (Schönfeldt et al., 2013a; Temple et al., 2011). The 2016 SADHS further showed that most children who received a minimum acceptable diet were from households in the upper wealth quintiles (NDoH, 2017). Studies suggest that social inequalities in nutrition can be explained by the cost of food (Aggarwal et al., 2011; Darmon & Drewnowski, 2015), partly because of a direct relationship between the quality of the diet and the cost of the diet. However, according to Drewnowski (2013), eating a nutrient adequate diet at low cost can be achieved by targeting nutrient-rich foods that are affordable.

2.4 Strategies to improve the quality of the complementary diet quality

To ensure good growth and development, children should receive breast milk only (exclusive breastfeeding) from birth to age 6 months. From age 6 months onwards, complementary foods that are safe and nutritious should be given while breastfeeding is continued up to the age of 2 years (WHO, 2003).

There are several options or strategies that can be used to improve dietary adequacy. Promoting consumption of local indigenous foods can increase the intake of key nutrients of complementary foods. Also, access to specialized fortified products such as fortified blended foods, micronutrient powders, and complementary food supplements for infants and young children can improve diet quality (Dewey & Vitta, 2013). The use of fortified products should be combined with educational messages on the importance of continued breastfeeding and complementary feeding (Dewey & Vitta, 2013). Few low-income countries have policies to support integrated strategies to combat micronutrient malnutrition in young children (Neufeld & Ramakrishnan, 2011).

2.4.1 Fortification

2.4.1.1 Large scale fortification

Large-scale food fortification is used to improve micronutrient intakes of populations through the addition of essential vitamins and minerals to basic foods such as maize meal and flour. In addition, large-scale food fortification can be used in improving nutritional status and health of children who are at risk of micronutrient deficiencies (Keats et al., 2021).

In 2003 it became mandatory in South Africa that maize meal and wheat flour (used for making bread) be fortified with vitamin A, thiamine, riboflavin, niacin, pyridoxine, folic acid, iron and zinc (NDoH, 2003). This mandatory fortification programme is known as the National Food Fortification Programme (NFFP) or the "Fortified for Better Health" programme. The programme was implemented following research done by the South African Vitamin A Consultative Group (SAVACG) in 1994 that reported that 33% of children age 6 to 23 months had vitamin A deficiency, one out of ten of had iron deficiency and 25% were stunted (SAVACG, 1996). The SAVACG group recommended fortification as a strategy that will help improve micronutrient intake and nutritional status in children (SAVACG, 1996). The 1999 National Food Consumption Survey identified bread and maize meal as possible vehicles for fortification due to it being staple foods for most South Africans and majority of households can afford it (Labadarios et al., 2001).

Secondary data analyses of 1999 National Food Consumption Survey data showed improvement in micronutrient adequacy of the diets of children age 1 to 9 years when unfortified values for maize meal and bread were substituted with the fortified values in the data analysis (Steyn et al., 2008). Because infants have small stomach capacity, they consume small amount of food, and it is believed that the NFFP may have little effect on infant nutrition (Faber, 2005; Faber et al., 2016). However, fortified maizemeal was shown to contribute significantly to the intake of key nutrients in children age 12 to 18 months (Swanepoel et al., 2019).

2.4.1.2 Targeted fortification.

Targeted fortification refers to the use of fortified products developed for specific population groups, for example fortified infants foods or micronutrient powders (Sprinkles) that are mixed with food before consumption (referred to as "point-of-use" fortification) (Dary & Hurrell, 2006). A study that was done in Guatemala showed that it is challenging to meet the infant's nutritional needs without including fortified infant food products in the complementary diet; the complementary diets of infants in the study consisted mainly of family foods that are typically consumed in a low income population (Vossenaar & Solomons, 2012). The authors therefore suggested the use of fortified infant food products, either as point-of-use fortification or pre-fortified infant foods (infant cereals) (Vossenaar & Solomons, 2012).

In South Africa, iron content of fortified maize meal is relatively low compared to commercial infant cereal (Wolmarans et al., 2010). A study in North West province showed that commercial infant cereal was consumed by most infants at age 6 months, and it contributed significantly to the intake of various micronutrients (Swanepoel et al., 2019). A study done in KwaZulu-Natal showed that children age 6 to 12 months who consumed infant products had significantly higher micronutrient intakes compared to non-consumers (Faber, 2005). The cost of these products however needs to be considered as it may prohibit consumption among lower income communities (Shisana et al., 2013).

2.4.2 Improving dietary diversity by consumption of local/indigenous food in complementary feeding period

Food and nutrition security and in particular diet quality can potentially be improved by the consumption of indigenous foods (Kruger et al., 2015). Indigenous foods are foods that are originate and are produced in specific areas, and are part of the traditional diet (DAFF, 2013). Although not widely used as a complementary food, micronutrients intake in infants and young children can potentially be improved by including indigenous foods in the complementary diet (Kuyper et al., 2013). For example, most African leafy vegetables are rich sources of various micronutrients, particularly iron, zinc vitamin A, vitamin C and magnesium (Uusiku et al., 2010) and consumption of indigenous foods can contribute to dietary diversity (Ghosh-Jerath et al., 2016). In Tanzania, children age 5 years and women of reproductive age from households that participated in a traditional vegetable promotion programme were found to have significantly higher dietary diversity than those who were not participating in the traditional vegetable promotion programme (Ochieng et al., 2016). Promotion of the consumption of indigenous vegetables and fruits through nutrition education will help improve the micronutrient status and quality of life of children at low cost (Mushaphi et al., 2017).

2.5 Conclusion

Malnutrition in infants and young children remains a global problem, as nutritional needs during the first 1000 days of life in many parts of the world have not been met. Dietary quality in children age 6 to 24 months is important for growth and development. Cost has been shown to be a limiting factor for acquiring healthy and nutritious foods in low socioeconomic settings.

CHAPTER 3: METHODOLOGY

3.1 Aim and Objectives

The aim of this study was to determine whether cost of the diet is associated with dietary diversity, energy density, nutrient density, and nutrient adequacy in breastfeeding and non-breastfeeding children age 12 to 24 months.

Objectives

For breastfed and non-breastfed children age 12 to 24 months, to determine:

- dietary diversity, nutrient adequacy and cost of total dietary intake;
- dietary diversity, nutrient density, energy density and cost of the complementary diet;
- the association of cost of the diet with dietary diversity and nutrient adequacy; and
- the association of cost of the complementary diet with dietary diversity, nutrient density and energy density of the complementary diet.

3.2 Study Design and Study Population

The study is a descriptive study and used an existing dataset consisting of pooled previously collected 24-hour dietary recalls (n=3336) for children age 6 to 24 months from four independent studies (Faber et al., 2020). For this study, only children age 12 to 24 months from the two most recent independent studies (n=1064) were included.

Study 1 (Faber et al., 2016): This was a cross-sectional study in which dietary intake data was collected for a randomly selected sample of children age 6 to 24 months in two resource-poor sites in KwaZulu-Natal (an urban area near Pinetown and a rural area in the Valley of a Thousand Hills). Mothers or primary caregivers of the children were recruited through house-to-house visits by fieldworkers. In each of the two sites, children were stratified per age category (6–11 months, 12–17 months, and 18–24 months), with equal numbers of children per age category (Faber et al., 2020). Most of the households had access to tap water and electricity. In addition, more than 80% of the total sample were recipients of a child support grant. Data for the latter two age categories (12-17 and 18-24 months) were included in the current study.

Study 2 (Smuts et al., 2019; Swanepoel et al., 2019): This was a randomized controlled trial in which dietary intake data was collected for children age 6 to 18 months. The study was done in Jouberton, which is a peri-urban area in North West Province. Mothers of eligible children were recruited through primary health care facilities and house-to-house visits by fieldworkers. More than 90% of the households had electricity, access to water and access to flush toilet respectively. The median number of people per household was 5, and more that 85% of households were recipients of a child support grant. Dietary intake data was collected at age 6, 12 and 18 months respectively (Faber et al., 2020). Data for the latter two ages were included in the current study.

Pooling the 24-hr recalls from the two studies provided a dataset with variation in dietary intakes. The pooled 24-hr recall dietary data were linked with 2019 food prices. Variables in the pooled dataset that were used in the current study are energy, macro- and micronutrients; nutrient adequacy ratios (NAR) and mean nutrient adequacy ratio (MAR) for the total diet; nutrient density of the complementary diet; and cost per 100g edible portion for each food item. For the current study, dietary diversity for the total diet and the complementary diet; cost of the total diet and complementary diet; and energy density for the complementary diet were calculated.

3.3 Dietary intake data

The 24-hr recall data for the independent studies were collected by the same research team. For each study, fieldworkers who spoke the local language were trained on collecting dietary intake data using a multi-pass 24-hr recall. Each fieldworker received printed guidelines outlining the procedures to be followed during data collection. A standardized dietary kit was used to estimate and record portion sizes. The dietary kit included examples of food wrappers and containers, household utensils (e.g. spoons and bowls), and a photo-book. Also, a “dish-up and measure” approach was used, particularly for cooked food. Dish-up and measure was done by the mother or caregiver, whereby they used dry oats to dish up the amount that resembled the amount of food they had given their child. The fieldworker then measured the amount of dished-up oats (in mL). For infant cereal and formula milk, the preferred method was to record the amount of dry product and amount of liquid separately. For any leftovers, the amount was also recorded and was factored in the calculation of the estimated actual consumption. (Faber et al., 2020).

For breast milk, the amount was estimated based on published age-specific intakes: 615 mL/day for age 12 to 17 months, and 550/day mL for age 18 to 24 months (WHO, 1998). For formula milk powder that was mixed into either porridge or infant cereal, dummy codes were created. Formula milk mixed with food and formula milk feeds were therefore coded separately. Nutrient analysis of the food intake data was done using the South African Food Composition Database. The section on infant foods in the database was updated before analyses (Faber et al., 2020).

3.3.1 Mean adequacy ratio

The MAR for total intake was determined by calculating the average of the NARs of the individual nutrients of interest. The NAR for each nutrient was calculated as a ratio of the individual's nutrient intake to the age appropriate RDA or, where there is no RDA, the AI of the DRIs (INNDEX Project, 2018). To calculate the MAR, NAR values >1 were capped at 1, and then the average of the capped NARs was obtained.

3.3.2 Nutrient density of the complementary diet

Nutrient density is expressed as the amount of a nutrient per 100 kcal (418 kJ). Infants eat only small amounts of food, and the complementary diet therefore needs to be nutrient-dense (Dewey, 2013). In this study, the complementary diet was defined as all foods and beverages consumed, but excluding breast milk and formula milk feeds. Formula milk mixed with food was considered part of the complementary diet. To calculate the micronutrient density (per 418 kJ), intake of the respective nutrient from the complementary diet was divided by the energy intake (kJ) from the complementary diet, which was then multiplied by 418. Nutrient density of the complementary diet of infants who received breastmilk but not formula milk was compared with the estimated desired nutrient density based on the DRIs as reported in the Dewey and Brown (2003) paper. The micronutrient density of 11 micronutrients were averaged and this average nutrient density value was used to determine the correlation between nutrient density and cost of the complementary diet.

3.3.3 Cost per 100 g edible food portion

Food prices for all food items reported for the 24-hr recalls were collected in 2019 from three of the major supermarket chains in South Africa (Pick n Pay, Checkers and Shoprite). The food prices for the various food items were entered into the dataset, and the average cost per 100g edible portion for each food item was calculated.[1] The average cost per food item for the three supermarkets was calculated; and then yield factors and retention factors (Bognár, 2002) were used to calculate cost per 100g edible portion. To calculate the cost of mixed dishes, the recipes in the Food Quantities Manual (SAFOODS, 2018) were used as guideline.

3.4 Data Analysis Methods for the Present Study

3.4.1 Cost of the total diet and the complementary diet

The aim of the study was to determine whether there is a relationship between cost (ZAR) and indicators of dietary quality. As food prices increase over time, it was important that the calculated diet cost was based on similar food prices for all 24-hr recalls, regardless of when the dietary intake data was collected. Because comparative food prices were used for all 24-hr recalls, there was no need to correct for inflation when calculating diet cost.

For each food item, cost per amount consumed was calculated as:

Cost of food item consumed = Cost per 100g edible portion / 100g * amount (g) consumed.

Cost of the diet = sum of the cost for all food items consumed for each individual 24-hr recall.

Cost of the complementary diet = sum of the cost for all food items, excluding formula milk feeds, consumed for each individual 24-hr recall.

3.4.2 Dietary diversity of the total diet and complementary diet

Food intake data from the 24-h recalls were used to calculate the DDS for the total diet (including formula milk and breast milk) and complementary diet (excluding breastmilk and formula milk feeds) respectively.

DDS for the total diet was calculated for each child based on updated WHO and UNICEF guidelines (WHO, 2021b). The food groups that were used to calculate the DDS were (i)

[1] This was done by the student as an NRF intern (TA Mulabisano)

Grains, roots and tubers, (ii) Legumes and nuts, (iii) Dairy products; (iv) Flesh foods (meat, poultry, organ meat, offal & liver), (v) Eggs, (vi) Vitamin-A rich fruits and vegetables, (vii) Other fruits and vegetables and (viii) Breastmilk (refer to Addendum 1). Commercial baby foods such as pureed foods and infant juices were categorized according to their main ingredient. If a child consumed foods from a specific food group, a score of 1 was allocated to that food group, and 0 was allocated if no food item from the food group was consumed. The scores for the 8 food groups were summed to obtain the DDS of the total diet, which could potentially range from 1 to 8. Minimum dietary diversity was defined as DDS $\geq$ 5 (WHO, 2021b).

DDS for the complementary diet was calculated by excluding breastmilk as a food group and excluding formula milk feeds from the dairy group. Formula milk that was mixed with porridge was however included in the dairy group. The scores for the 7 food groups were summed to obtain the DDS of the complementary diet, which could potentially range from 1 to 7. Minimum dietary diversity for complementary diet (excluding breastmilk and formula milk feeds) was defined DDS $\geq$ 4 (WHO, 2010).

3.4.3 Adequacy of intake of individual nutrients

Percentage of children whose nutrient intake was below the EAR for each nutrient respectively was calculated.

3.4.4 Energy density of the complementary diet

The energy density of a food refers to the amount of kJ (kcal) per 100g of the food and is important in infant feeding because they consume small amounts of food (WHO, 1998). Energy density of the complementary diet (all foods and all beverages but excluding formula milk feeds, breast milk and water) was calculated by (i) summing the amount (in grams) of all complementary foods consumed for each 24-hr recall, and then (ii) expressing the energy intake from the complementary diet per 100g food [energy density = kJ / amount (g) of food * 100].

3.5 Statistical Analysis

Statistical analyses were done using SPSS version 27. The Shapiro Wilk test was used to test the data for normality. The data was not normally distributed. Results are therefore reported as the median and interquartile range (IQR; 25th and 75th percentiles). Children were categorized according to whether they were breastfed during the 24-hr recall period.

Comparison between breastfed and non-breastfed children: Breastfed and non-breasted children were compared for dietary diversity, nutrient adequacy and cost of total dietary intake; and dietary diversity, energy and nutrient density, and cost of the complementary diet. The significance of differences between breastfed and non-breastfed children were determined using the non-parametric Mann Whitney U-test. In addition, for categorical data the Pearson Chi-square test was used to determine the significance of differences between the two groups.

Relationship between dietary cost and dietary intake indicators: The relationship of cost of the total diet with DDS and MAR of the total diet; and the relationship between cost of the complementary diet and DDS, nutrient density and energy density of the complementary diet were determined for breastfed and non-breastfed babies respectively using Spearman (not normally distributed data) correlation analysis.

A p-value < 0.05 was considered statistically significant.

3.6 Reliability and Validity

All 24-hr dietary recalls for the two independent studies were collected by the same research group using the same methodology and similar dietary kits. In addition, all 24-hr dietary recalls were recoded to ensure that coding and analysis were standardized, and all records were analysed with the same version of the food composition database. Dietary kits were also adjusted according to the local consumption and face validity was determined through discussions with local fieldworkers and key informants from the study areas. Although dietary data were collected at different time points all food prices are based on 2019 costs, and it is therefore not needed to consider inflation. The aim of the study was not to describe cost and dietary intake for the different study sites, but rather to look at the association of cost with dietary diversity, nutrient adequacy, and energy and nutrient density of the diet for the pooled 24-hr recalls. Appropriate statistical tests were used depending on the distribution of the data; namely the Mann Whitney U-test and Spearman correlation analysis for not normally distributed data and Chi-square for categorical data.

3.7 Generalizability

This study was done to determine whether the nutritional quality of diets consumed by children aged 12 to 24 residing in resource-poor settings is associated with the cost of the diet. The cost of foods was collected from three supermarket chains that are major food retailers in South Africa. In South Africa, formal retailers such as supermarkets are predominant sources of food shopping (Shisana et al., 2013) and more people in low-middle socioeconomic areas are purchasing their food in main supermarkets (Odunitan-Wayas et al., 2018). The results of this study can be generalized for 12–24 month old children who reside in low-income settings in South Africa and have similar dietary intakes than children included in this study.

3.8 Significance of the study

This study provides insight in relation to dietary cost and various dietary inequalities in nutrition because of the cost of foods. The study results will contribute towards developing guidelines and tools to assist mothers from resource poor communities to plan a varied and nutritionally adequate diet for their children at the lowest possible cost. Improving dietary intake of children during the first two years of life will contribute towards the fight against the burden of malnutrition (in terms of undernutrition, overweight/obesity and micronutrient malnutrition) in South Africa and improve children's growth and development.

3.9 Ethics statement

The independent studies had ethics approval and adhered to the ethical principles of voluntary participation based on informed consent and protection of the interest of participants through anonymity, privacy and confidentiality (Faber et al., 2016; Smuts et al., 2019; Swanepoel et al., 2019). Participation in the two studies was voluntary, and parents could withdraw their children from the study at any time without having to give a reason. For each study, information regarding the study was communicated in the native language spoken in the area or preferred language of the parent. Mothers who agreed to participate signed a consent form. Permission for the studies to be done in the study areas was granted by community leaders/councilors. Study 2 was reviewed by the Department of Health and Social Development and registered with the Directorate for Policy, Planning and Research; and the local District Department of Health granted permission for the study to be conducted in the area.(Faber et al., 2016; Smuts et al., 2019; Swanepoel et al., 2019).

Permission to use the data was granted by the principal investigator from the larger study (refer to Addendum 2). The dataset that was used for this study does not contain any identifying or personal information on participants. The data was stored in a safe and locked computer. Only the student and the supervisor had access to the data. Ethical approval for the current study was granted by the Biomedical Research Ethics committee (BMREC) of the University of the Western Cape (BM21/4/5) (refer to Addendum 3).

CHAPTER 4: RESULTS

4.1 Study participants

The study sample included 537 (51%) girls and 527 (49%) boys. In total, 425 (40%) children were breastfed and 639 (60%) were non-breastfed on the day of recall. From the breastfed children, 385 (90.6%) were given no formula milk feeds, and 40 (9.4%) were given formula milk feeds in addition to breast milk. Of non-breastfed children, 465 (72.8%) received no formula milk feeds, while 174 (27.2%) were given formula milk feeds.

4.2 Dietary diversity

Table 1 indicates the percentage of children who consumed different food groups during the recall period. Almost all children (99.8%) consumed foods from the grains, roots and tubers group. The least consumed food groups were eggs (7.7%) and vitamin A-rich fruits and vegetables (20.2%) with no significant difference between breastfed and non-breastfed children. In total, 60.9% of breastfed and 66.7% of the non-breastfed children received foods from the dairy group, which includes formula milk feeds. There was a significant difference between breastfed and non-breastfed children for both the legumes and nuts group, and the other fruits and vegetables group, with a higher percentage of non-breastfed children consuming foods from these two food groups. The median number of food groups consumed was 3 (3; 4). In total, 84.1% of children had a low DDS (<5 of the 8 groups) for the total diet and therefor did not meet the minimum dietary diversity. There was a significant difference between breastfed and non-breastfed children, with a higher percentage of non-breastfed children not meeting minimum dietary diversity. In addition, 70.6% children of the total group did not meet the minimum dietary diversity for the complementary diet, with a significant higher percentage of breastfed children having a low dietary diversity (<4 of the 7 groups) compared to the non-breastfed children.

Table 1: Percentage of children age 12 to 24 months who consumed different food groups during the 24-hour recall period for the total group, and according to breastfeeding status.

Food group consumed	**Total group (n=1064) n (%)**	**Breastfed (n=425) n (%)**	**Non-breastfed (n=639) n (%)**	**P-Value[1]**
Grains, roots and tubers	1062 (99.8)	424 (99.8)	638 (99.8)	0.771
Legumes and nuts	241 (22.7)	69 (16.2)	172 (26.9)	<0.001
Dairy products:				
Including formula milk	685 (64.4)	259 (60.9)	426 (66.7)	0.056
Excluding milk feeds[2]	583 (54.8)	244 (57.4)	339 (53.1)	0.162
Flesh foods	476 (44.7)	180 (42.4)	296 (46.3)	0.202
Eggs	82 (7.7)	29 (6.8)	53 (8.3)	0.378
Vitamin-A rich fruits and vegetables	215 (20.2)	92 (21.6)	123 (19.2)	0.340
Other fruits and vegetables	506 (47.6)	171 (40.2)	335 (52.4)	<0.001
Breast milk	425 (39.9)	425 (100)	0 (0)	<0.001
DDS, total diet <5[3]	895 (84.1)	316 (74.4)	579 (90.6)	<0.001
DDS, complementary diet <4[4]	751 (70.6)	317 (74.6)	434 (67.9)	0.019

[1] Comparison between breastfed and non-breastfed children; Chi-square test

[2] Excluding breastmilk and formula milk feeds

[3] DDS (dietary diversity score) includes milk feeds

[4] DDS excludes milk feeds

4.3 Nutrient intake of the total diet

Table 2 indicates the median (IQR) nutrient intakes as well as the percentage of children who had micronutrient intakes below the EAR. Breastfed children had significantly higher intakes for energy and fat compared to non-breastfed children; but significantly lower intakes for protein, carbohydrates, vitamin B6, folate, niacin, thiamine, iron, magnesium, zinc, and phosphorus. Overall, calcium intake was below the EAR for 77.4% of children, with no significant difference between breastfed and non-breastfed children. However, the median calcium intake was significantly higher for breastfed children compared to non-breastfed children. Intake of vitamin B12 was below the EAR for 44.4% of children, with no significance difference between breastfed and non-breastfed children. A significantly higher percentage of breastfed children had an intake below EAR for folate and iron respectively compared to non-breastfed children.

Table 2: Median and interquartile range (IQR) for nutrient intake for the total group, breastfed and non-breastfed children 12 -24 months old during the recall period.

	Total group (n=1064) Median (IQR)	**Breastfed (n=425) Median (IQR)**	**Non-breastfed (n=639) Median (IQR)**	**P-value**
Energy (kJ)	4234.5 (3397.1; 5255.7)	4293.7 (3517.0; 5340.3)	4188.2 (3281.0; 5148.2)	0.031[1]
Protein (g)	25.2 (18.2; 34.7)	23.5 (16.8; 32.9)	26.2 (19.7; 36.2)	<0.001[1]
Fat (g)	32.7 (23.7; 42.0)	39.6 (33.8; 46.6)	26.0 (18.1; 36.4)	<0.001[1]
Carbohydrates (g)	152.7 (118.4; 187.7)	143.3 (110.3; 182.3)	158.2 (126.5; 192.5)	<0.001[1]
Vitamin A (µg RAE) <EAR (210 µg RAE)	557.1 (369.4; 822.7) 10.0%	647.1 (527.8; 907.8) 0%	432.5 (272.6; 740.5) 16.6%	<0.001[1] <0.001[2]
Vitamin B6 (mg) <EAR (0.4 mg)	1.0 (0.7; 1.5) 7.7%	0.8 (0.5; 1.2) 12.9%	1.2 (0.8; 1.8) 4.2%	<0.001[1] <0.001[2]
Vitamin B12 (µg) <EAR (0.7 µg)	0.8 (0.3; 1.6) 44.4%	0.8 (0.4; 1.5) 45.9%	0.9 (0.3; 1.7) 43.3%	0.219[1] 0.415[2]
Vitamin C (mg) <EAR (13 mg)	40.1 (24.1; 69.9) 14.9%	47.6 (33.9; 68.4) 0.0%	30.5 (13.1; 72.4) 24.8%	<0.001[1] <0.001[2]
Folate (µg) <EAR (120 µg)	191.5 (106.1; 271.5) 29.9%	167.3 107.7; 262.2) 30.4%	211 (127.6; 211.5) 22.4%	<0.001[1] 0.002[2]
Niacin (mg) <EAR (5 µg)	9.5 (6.7; 12.6) 12.1%	8.1 (5.5; 11.0) 20.0%	10.5 (7.6; 13.5) 6.8%	<0.001[1] <0.001[2]
Riboflavin (mg) <EAR (0.4 mg)	0.8 (0.5; 1.3) 16.4%	0.7 (0.5; 1.1) 12.7%	0.7 (0.5; 1.4) 18.7%	0.087[1] 0.009[2]
Thiamine (mg)	0.9 (0.6; 1.2)	0.7 (0.5; 1.0)	1.0 (0.7; 1.3)	<0.001[1]

	Total group (n=1064) Median (IQR)	**Breastfed (n=425) Median (IQR)**	**Non-breastfed (n=639) Median (IQR)**	**P-value**
<EAR (0.4 mg)	7.6%	12.7%	4.2%	<0.001[2]
Calcium (mg) <EAR (500 mg)	329.9 (211.4; 483.7) 77.4%	358.9 (264.1;482.3) 77.6%	307.2 (148.1; 484.5) 77.3%	<0.001[1] 0.897[2]
Iron (mg) <EAR (3 mg)	6.3 (4.4; 8.7) 11.0%	5.1 (3.4; 7.2) 18.8%	7.1 (5.3; 9.6) 5.8%	<0.001[1] <0.001[2]
Zinc (mg) <EAR (2.5 mg)	6.3 (4.4; 8.7) 6.7%	4.6 (3.5; 6.5) 8.5%	6.1 (4.4; 8.1) 5.5%	<0.001[1] 0.055[2]
Magnesium (mg) <EAR (65 mg)	140.4 (95.8; 190.8) 9.4%	120.4 (81.7; 166.8) 14.6%	152.9 (109.2; 202.3) 5.9%	<0.001[1] <0.001[2]
Phosphorus (mg) <EAR (380 mg)	470.2 (338.9; 627.9) 33.4%	417.7 (296.7; 563.7) 42.1%	508.0 (364.9; 657.3) 27.5%	<0.001[1] <0.001[2]
Potassium* (mg)	963.6 (731.9; 1267.5)	917.5 (698.0; 1200.5)	989.9 (755.7; 1305.9)	0.010[1]

[1]Difference across medians for breastfed & non-breastfed, Mann-Whitney U test

[2]Comparison between breastfed & non-breastfed; Chi-square

*Potassium does not have EAR

Estimated average intake reference values were published by Institute of Medicine (IOM, 2005; IOM, 2011)

4.4 Mean adequacy ratio

Table 3 indicates the median (IQR) for the NARs of the micronutrients and the MAR. For both breastfed and non-breastfed children, the median NAR was above 1 for most nutrients, which means at least half of the children had intakes that exceeded the RDA for these nutrients. Non-breastfed children had significantly higher NARs for most micronutrients compared to breastfed children. The median MAR for the total group was below 1, with no significant difference between breastfed and non-breastfed children for MAR.

Table 3: Median nutrient adequacy ratios of micronutrients for the total group, breastfed and non-breastfed children age 12 to 24 months.

	Total group (n=1064) Median (IQR)	**Breastfed (n=425)** Median (IQR)	**Non-breastfed (n=639)** Median (IQR)	**P-value**[1]
Vitamin A NAR	1.9 (1.2; 2.7)	2.2 (1.8; 3.0)	1.4 (0.9; 2.5)	<0.001
Vitamin B6 NAR	2.1 (1.4; 3.0)	1.6 (1.0; 2.4)	2.4 (1.7; 3.5)	<0.001
Vitamin B12 NAR	0.9 (0.4; 1.8)	0.8 (0.4; 1.6)	0.9 (0.3; 1.8)	0.219
Vitamin C NAR	2.7 (1.6; 4.7)	3.2 (2.3; 4.7)	2.0 (0.9; 4.8)	<0.001
Folate NAR	1.3 (0.8; 1.8)	1.1 (0.7; 1.7)	1.4 (0.9; 1.9)	<0.001
Niacin NAR	1.6 (0.9; 2.6)	1.3 (0.9; 1.8)	1.8 (1.3; 2.2)	<0.001
Riboflavin NAR	1.6 (0.9; 2.6)	1.5 (0.9; 2.1)	1.6 (0.9; 2.8)	0.087
Thiamine NAR	1.8 (1.3; 2.5)	1.5 (1.0; 2.1)	2.0 (1.5; 2.7)	<0.001
Calcium NAR	0.5 (0.3; 0.7)	0.5 (0.4; 0.7)	0.4 (0.2; 0.7)	<0.001
Iron NAR	0.9 (0.6; 1.2)	0.7 (0.5; 1.0)	1.0 (0.8; 1.4)	<0.001
Zinc NAR	1.8 (1.3; 2.5)	1.6 (1.2; 2.2)	2.0 (1.5; 2.7)	<0.001
Magnesium NAR	1.8 (1.2; 2.4)	1.5 (1.0; 2.1)	1.9 (1.4; 2.5)	<0.001
Phosphorus NAR	1.0 (0.7; 1.4)	0.9 (0.6; 1.2)	1.1 (0.8; 1.4)	<0.001
Potassium NAR	0.5 (0.4; 0.6)	0.5 (0.3; 0.6)	0.5 (0.4; 0.7)	0.010
MAR	0.87 (0.79; 0.93)	0.86 (0.78; 0.93)	0.87 (0.78; 0.93)	0.129

[1]Differences between breastfed & non-breastfed; Mann Whitney U test.

NAR- Nutrient adequacy ratio; MAR- Mean adequacy ratio.

Nutrient density of complementary diet

4.5 Nutrient density of the complementary diet

Table 4 indicates the median (IQR) density of various micronutrient for the complementary diet of children. There was no significant difference for the median nutrient density for fat, protein, carbohydrates, folate, niacin, and zinc between breastfed and non-breastfed children. For the other micronutrients, breastfed children had significantly higher median nutrient densities compared to non-breastfed children.

Nutrient density of the complementary diet of breastfed children who received no formula milk feeds was compared with the estimated desired nutrient density based on the DRIs as reported in the Dewey and Brown (2003) paper, and the percentage of children who had low nutrient density for micronutrients is given in table 5. The nutrient density of the complementary diet of breastfed children who received no formula milk feeds was low for calcium (87.4% of children), iron (89.4%), niacin (35.1%), folate (37.6%) and riboflavin (33.2%). The nutrient density of the complementary diet was adequate for nearly all breastfed children for vitamin A and C.

Table 4: Median and interquartile range of nutrient density for macro- and micronutrients for the complementary diet for the total group, breastfed and non-breastfed children age 12 to 24 months

Nutrient density	**Total group (n=1064) Median (IQR)**	**Breastfed (n=425) Median (IQR)**	**Non-breastfed (n=639) Median (IQR)**	**P-value[1]**
Fat (g/418 kJ)	2.38 (1.85; 3.04)	2.37 (1.82; 3.03)	2.39 (1.86; 3.04)	0.904
Protein (g/418 kJ)	2.68 (2.11; 3.33)	2.67 (2.07; 3.39)	2.68 (2.15; 3.31)	0.726
Carbohydrates (g/418 kJ)	16.62 (14.94; 17.99)	16.54 (14.82; 17.99)	16.60 (15.11; 18.00)	0.532
Vitamin A (µg/418 kJ)	40.92 (29.37; 65.19)	45.99 (33.12; 93.28)	37.78 (27.28; 52.64)	<0.001
Folate (µg/418 kJ)	22.26 (14.42; 29.16)	22.73 (14.91; 30.24)	21.95 (14.13; 28;74)	0.132
Niacin (mg/418 kJ)	1.04 (0.84; 1.34)	1.05 (0.83; 1.39)	1.03 (0.85; 1.30)	0.478
Riboflavin (mg/418 kJ)	0.07 (0.04; 0.12)	0.08 (0.05; 0.13)	0.07 (0.04; 0.12)	<0.001
Thiamine (mg/418 kJ)	0.10 (0.08; 0.12)	0.11 (0.08; 0.12)	0.10 (0.08; 0.11)	0.001
Vitamin B6 (mg/418 kJ)	0.12 (0.09; 0.15)	0.11 (0.09; 0.14)	0.12 (0.10; 0.15)	<0.001
Vitamin C (mg/418 kJ)	2.71 (1.07; 5.73)	2.89 (1.04; 6.13)	2.62 (1.09; 5.53)	0.402
Calcium (mg/418 kJ)	24.81 (13.06; 41.98)	27.22 (15.11; 47.71)	22.77 (12.19; 39.44)	0.002
Iron (mg/418 kJ)	0.67 (0.56; 0.84)	0.68 (0.56; 0.92)	0.66 (0.55; 0.81)	0.001
Zinc (mg/418 kJ)	0.58 (0.48; 0.67)	0.58 (0.49; 0.68)	0.56 (0.48; 0.66)	0.055

*418kJ = 100kcal

[1]Difference between breastfed & non-breastfed; Mann Whitney U test

Table 5: Percentage of breastfed children age 12 to 24 months for whom nutrient density of the complementary diet was below the required density.

Nutrient density of the complementary diet	Reference value for adequate nutrient density[1]	Breastfed children who received no formula milk feeds (n=385)
Vitamin A (µg/418 kJ)	5 µg	0.3%
Folate (µg/418 kJ)	19 µg	37.6%
Niacin (mg/418 kJ)	0.9 mg	35.1%
Riboflavin (mg/418 kJ)	0.06 mg	33.2%
Thiamine (mg/418 kJ)	0.07 mg	12.2%
Vitamin B6 (mg/418 kJ)	0.08 mg	12.7%
Vitamin C (mg/418 kJ)	0 mg	0%
Calcium (mg/418 kJ)	63 mg	87.3%
Iron (mg/418 kJ)	1.2 mg	89.4%
Zinc (mg/418 kJ)	0.4 mg	10.4%

[1] Reference values for adequate nutrient density based on the DRIs (Dewey & Brown, 2003).

4.6 Energy density of the complementary diet

Energy density of the complementary for breastfed and non-breastfed children is given in table 6. The median energy density for breastfed children was higher than the median energy density for non-breastfed children, with no significant difference between the two groups.

Table 6: Energy density of the complementary diet for the total group, breastfed and non-breastfed children age 12 to 24 months during recall period.

	Total group (n=1064) Median (IQR)	Breastfed (n=425) Median (IQR)	Non-breastfed (n=639) Median (IQR)	P-value[1]
Energy density (kJ/100g)	423.6 (351.9; 505.7)	428.9 (360.4; 508.4)	418.8 (347.4; 502.4)	0.183

[1]Difference between breastfed and non-breastfed children; Mann Whitney-U test

4.7 Cost of the diet

Cost of the total dietary intake was calculated and compared between breastfed and non-breastfed children (refer to table 7). There was a significant difference between breastfed and non-breastfed child, with non-breastfed children having higher median cost of the total diet and complementary diet compared to breastfed children. The median cost of the complementary diet per 1000kJ of breastfed children was higher compared to non-breastfed children, with a significant difference between the two groups and this may be caused by the difference in energy intake between the two groups (refer to table 2).

Table 7: Median and interquartile range of cost of the total diet and complementary diet for the total group, breastfed and non-breastfed children age 12 to 24 months.

	Total group (n=1064) Median (IQR)	**Breastfed (n=425) Median (IQR)**	**Non-breastfed (n=639) Median (IQR)**	**P-Value[1]**
Cost of the total intake	12.8 (8.1; 18.7)	9.8 (6.3; 14.3)	14.7 (9.8; 20.7)	<0.001
Cost of the complementary diet	10.7 (7.2; 15.9)	9.4 (6.0; 13.7)	12.1 (8.1; 16.9)	<0.001
Cost of total intake per 1000 kJ	2.9 (2.0; 4.3)	2.2 (1.5; 3.1)	3.6 (2.5; 4.8)	<0.001
Cost of complementary diet per 1000 kJ	3.4 (2.4; 4.5)	3.5 (2.4; 4.5)	3.3 (2.3; 4.4)	0.014

Cost values are presented in Rands (ZAR) based on 2019 prices

[1]Difference between breastfed and non-breastfed children; Mann Whitney-U test

4.8 Associations

Table 8 indicates associations between cost and dietary quality indicators of breastfed and non-breastfed children. There was a higher significant positive association between cost of the diet and MAR and DDS of the total diet for non-breastfed children compared to breastfed children. There was a significant association between cost of the complementary diet with DDS, nutrient density and energy density of the complementary diet between breastfed and non-breastfed children.

Table 8: Correlations between cost and dietary quality indicators for the total group, breastfed and non-breastfed children age 12 to 24 months during the recall period.

Correlation	**Total group (n=1064)**	**Breastfed (n=425)**	**Non-breastfed (n=639)**
Total diet: cost versus DDS	$r_s = 0.337$ $p<0.001$	$r_s = 0.570$ $p<0.001$	$r_s = 0.432$ $p<0.001$
Total diet: Cost versus MAR	$r_s = 0.680$ $p<0.001$	$r_s = 0.650$ $p<0.001$	$r_s = 0.762$ $p<0.001$
Complementary diet: cost versus DDS	$r_s = 0.536$ $p<0.001$	$r_s = 0.605$ $p<0.001$	$r_s = 0.473$ $p<0.001$
Complementary diet: Cost versus average nutrient density	$r_s = 0.234$ $p<0.001$	$r_s = 0.246$ $p<0.001$	$r_s = 0.307$ $p<0.001$
Complementary diet: cost versus energy density	$r_s = 0.164$ $p<0.001$	$r_s = 0.206$ $p<0.001$	$r_s = 0.163$ $p<0.001$

r_s = Spearman's correlation coefficient; MAR- Mean Adequacy Ratio; DDS- Dietary Diversity Score

CHAPTER 5: DISCUSSION OF RESULTS

Cost of foods has been reported to be a contributing factor to poor diet quality and malnutrition worldwide (Darmon & Drewnowski, 2015; Headey & Alderman, 2019; Herforth et al., 2020). Affordability of both healthy and unhealthy foods may vary across regions and income levels. Healthy and nutritious foods are generally more expensive in lower income countries (Headey & Alderman, 2019). In these low-income settings, acquiring sufficient and nutritious foods would take a large proportion of the household's income, or even exceed it. In such situations, to be able to afford a healthy diet becomes a challenge, so cost of the diet needs to be addressed before interventions that promote nutrition behavioural change can be effective in changing people's food choices (Herforth et al., 2020). Cost and affordability of healthy diets are two of the biggest challenges to achieving Sustainable Development Goal 2 which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (WHO, 2020b). The first 1000 days of life is a critical period for child growth and development, and children at this period require nutrient adequate diet. Therefore, the aim of this study was to determine whether cost of the diet is associated with dietary quality in children age 12 to 24 months in low-income settings in two provinces in South Africa. Results showed that higher dietary diversity, nutrient adequacy, nutrient density, and energy density were all associated with a higher cost for both breastfed and non-breastfed children.

5.1 Dietary diversity, nutrient adequacy, and nutrient density

More than 80% of the total sample did not meet the minimum dietary diversity, based on the revised indicator that has 8 food groups (WHO, 2021b). There was a significant difference between breastfed and non-breastfed children, with a higher percentage of non-breastfed children not achieving minimum dietary diversity compared to the breastfed children. When milk feeds were excluded (breastmilk and formula milk feeds) in calculating the DDS, a higher percentage of breastfed children did not achieve minimum dietary diversity compared to the non-breastfed children. Low dietary diversity is common not only in infants and young children in South Africa (Faber et al., 2016; Sayed & Schönfeldt, 2020), but also in adults (Labadarios et al., 2011). This is not unique to South Africa as households in eastern and southern African countries generally rely primarily on low cost, nutrient poor staples resulting in low dietary diversity among the children (UNICEF, 2019). The change from using 7 food groups to 8 food groups when calculating DDS will have implications for tracking dietary diversity within countries, particularly for countries with low breastfeeding rates such as South Africa

(Heidkamp et al., 2020). A diet lacking diversity increases the risk of micronutrient deficiencies (Lutter et al., 2021). Dietary diversity has been shown to be associated with micronutrient adequacy of the complementary diet (Moursi et al., 2008). Also, a higher dietary diversity was found to be associated with higher nutrient density for protein and several micronutrients of the complementary diet for 6- to 24-month-old children in urban and rural KwaZulu-Natal, South Africa (Faber et al., 2016).

In the current study, less than 50% of both breastfed and non-breastfed children had consumed foods from the flesh food group, and close to 50% had inadequate vitamin B12 intake. Vitamin B12 is naturally found in animal sources only (Watanabe, 2007). Diets low of flesh foods were found to be associated with low vitamin B12 intake (Obeid et al., 2019). The consumption of flesh foods in children 6 to 23 months of age in South Africa is generally low (Sayed & Schönfeldt, 2020). Low consumption of meat, which is a good source of iron, was also found to be associated with anaemia among children under age 5 years in Tanzania (Kejo et al., 2018). In low- and middle-income-countries, consumption of animal source foods is low due to poor accessibility and affordability (Dewey & Vitta, 2013; WHO, 2003).

Eggs were the least consumed food-group, followed by vitamin A-rich fruits and vegetables. In addition, less than 50% of children consumed foods from the other fruits and vegetables group, with a significantly higher percentage of non-breastfed children consuming other fruits and vegetables compared to breastfed group. According to the revised paediatrics food based dietary guidelines, children age 12 to 36 months should have vitamin A-rich fruits and vegetables (dark-green leafy vegetables and orange-coloured vegetables and fruits) daily (Du Plessis et al., 2020). Improving the intake of fruits and vegetables will be challenging as cost was found to be a limiting factor for consumption of fruits and vegetables in resource poor settings (Faber et al., 2013).

Nearly two-thirds of the total sample had consumed food from the dairy group (including formula milk feeds) the day before. Although breastfed children had a significantly higher calcium intake compared to non-breastfed children, more than 75% of both breastfed and non-breastfed children respectively had inadequate intake of calcium. High prevalence of inadequate calcium intake among infants and young children has been reported in previous studies in South Africa (Faber, 2005; Faber et al., 2016; Senekal et al., 2020). Milk is a major source of dietary calcium in young South African children (Steyn et al., 2006), and the low intake of calcium could be attributed to insufficient consumption of milk (Dror & Allen, 2014;

Swanepoel et al., 2019; Van Stuijvenberg et al., 2015). Furthermore, low intake of calcium was shown to be associated with stunting in children age 2 to 5 years in a study in South Africa (Van Stuijvenberg et al., 2015).

In South Africa, maize meal and wheat flour (used for making bread) are fortified per legislation. Calcium is however not included as one of the fortificants and this could probably have contributed to the low calcium intake. The two staple foods (maize meal and wheat flour) are fortified with vitamin A, thiamine, riboflavin, niacin, pyridoxine, folic acid, iron and zinc (NDoH, 2003). For the total group in the current study, only 29.9% had inadequate intake for folate, 16.4% for riboflavin, 12.1% for niacin, 11% for iron, 10% for vitamin A, 7.6% for thiamine and 6.7% for zinc. Consumption of the two fortified staple foods, as well as fortified infant foods probably contributed to the low percentage with inadequate intake. In addition, consumption of maize meal and bread were reported to have contributed more than 40% towards total dietary intake of iron, zinc, thiamine, vitamin B6 and folate in children age 12 to 18 months from a low socio-economic peri-urban community in South Africa (Swanepoel et al., 2019). Furthermore, consumption of commercial infant products was found to have significant contribution on higher intake of calcium, iron, zinc, vitamin A, thiamine, riboflavin, niacin, vitamin B12 and vitamin C in children age 12 to 18 months (Swanepoel et al., 2019).

For children under age 2, nutrient requirements are high but the portion sizes that they consume are small; complementary foods therefore needs to be nutrient dense (Dewey, 2013). Breastfed children had higher nutrient density for most micronutrients than non-breastfed children in the current study. Target nutrient density in literature is for breastfed children who receive no other milk feeds. When compared with the WHO target nutrient density for breastfed children (Dewey & Brown, 2003), most children had low nutrient density for calcium and iron. Low nutrient density for calcium, iron and zinc have been reported in previous studies in South Africa (Faber et al., 2016; Swanepoel et al., 2019), and in other developing countries (Berhanu et al., 2019; Dewey, 2013; Vossenaar et al., 2013; Vossenaar & Solomons, 2012). These nutrients are often referred to as 'problem nutrients'. Percentage of children with low zinc nutrient density was low in the current study; and this could be due to consumption of fortified maize meal and infant foods. In addition, the target nutrient density values used in the study are based on RDA values (Dewey & Brown, 2003). This may result in an overestimation of percentage of children with low nutrient density as the RDA covers 97% to 98% of the total group (Dewey & Brown, 2003; Otten et al., 2006).

5.2 Cost of the diet in relation to dietary quality indicators

Cost is known to be the most important factor influencing food choices in South Africa (Chakona, 2020; Shisana et al., 2013). The cost of the total dietary intake for non-breastfed children was higher than that of breastfed children, a result that was expected as breastmilk does not have any cost. This is recognised as one of the benefits of continued breastfeeding up to age 2 years and beyond (WHO, 2003). The cost of the complementary diet (excluding all milk feeds, i.e., breast milk and formula milk feeds) for non-breastfed children was also higher than that of breastfed children.

The current study showed a positive correlation between cost and nutrient density of the complementary diet. This is similar to literature which reported that nutrient dense foods cost more (Bai et al., 2021; Headey & Alderman, 2019; Visser et al., 2021). Cost of the complementary diet per 1000 kJ for breastfed children was higher compared to the non-breastfed children, this could be due to breastfed children having significantly higher nutrient density for various micronutrients.

Cost of the complementary diet was significantly correlated with energy density of the complementary diet. Although statistically significant, the correlation coefficient was weak (r_s=0.164). Nonetheless, the weak positive correlation between cost and energy density is contradictory to literature that report that energy dense but nutrient poor foods are often cheaper (Gupta et al., 2019; Headey & Alderman, 2019).

Despite the significant difference in diet cost between breastfed and non-breastfed children, cost was associated with all the dietary indicators in both breastfed and non-breastfed children, respectively. For the total sample, total intake with a higher nutritional adequacy (as reflected by the MAR) had a higher cost. Also, a more diverse complementary diet had a higher cost. To improve dietary diversity and to acquire a nutrient adequate diet will therefore be challenging because of the higher cost. Studies in South Africa showed that households with low dietary diversity were mostly poor or living in poverty (Faber et al., 2009; Labadarios et al., 2011). Affordability has been shown to be a key barrier for accessing a diverse diet globally (Darmon & Drewnowski, 2015; Headey & Alderman, 2019; Herforth et al., 2020).

Cost is a barrier for acquiring a nutrient adequate diet for the world's poorest people (Bai et al., 2021). According to Darmon and Drewnowski (2015), the cost of food plays a major role in differences in dietary quality among people of different socioeconomic status. According to

(Schönfeldt et al., 2013a), the majority of South African population cannot afford a healthy diet. The positive correlation between cost of the complementary diet and nutrient density of the complementary diet observed in the current study, support the findings of a recent South African study in school children which showed that diets with higher nutrient density had a higher cost (Visser et al., 2021). In order to address malnutrition, strategies are therefore needed to enable consumers to access a nutritionally adequate diet at an affordable cost.

Globally, nutritious food such as fruits, vegetables and flesh foods were found to typically cost more than foods with high energy density but low nutrient content (WHO, 2020b). Indigenous foods are not widely used as part of the complementary diet, yet consumption of these foods could potentially improve the intake of micronutrients in infants and young children (Kuyper et al., 2013); for example, African leafy vegetables are rich sources of various micronutrients (Uusiku et al., 2010). Promoting the consumption of indigenous vegetables and fruits as part of the complementary diet through nutrition education is an example of a low-cost strategy to improve micronutrient intake of children, particularly in rural areas in South Africa (Mushaphi et al., 2017). The higher cost of more nutritious diets, as observed in the current study, highlights the importance of considering affordability in interventions aimed at improving dietary quality in children under age 2 years.

5.3 Limitations of the study

The use of 24-hour recall relies upon the respondent memory for data collection and a single day is not representative of the usual intake and limits the ability to determine the adequacy of the total diet nutrient intake. The cost of the diet does not consider cost of food preparation. Because of the difficulty of quantifying breastmilk intake in community-based studies, breastmilk intakes were estimated based on literature (WHO, 1998). This can be a limitation as breastmilk nutrient content is different across different populations depending on maternal nutrient intake and the breastmilk nutrient reference values were based on a specific population that may be different to the current population (Black et al., 2008; Dewey & Brown, 2003).

Although dietary data were collected at different time points, food prices are based on 2019 cost. Although this may be viewed as a limitation, estimating diet cost based on similar food prices for both independent studies from which the dietary data was obtained, eliminated the need to consider inflation. The main aim of the current study was not to determine actual diet cost for the two study sites, but rather to look at associations between cost and dietary indicators. Pooling data from different studies provided a dataset with variation in dietary intakes. Possible bias due to different versions of the food composition database used to convert food intake to nutrient intake was eliminated as all the 24-hr recalls were recoded and reanalyzed.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

Cost of foods has been reported to be a contributing factor to poor diet quality and malnutrition worldwide (Headey & Alderman, 2019; Heidkamp et al., 2020). In low socioeconomic settings, acquiring sufficient and nutritious foods would take a large proportion of the household's income, or even exceed it (Herforth et al., 2020). Optimal nutrition during early childhood is important for child growth and development. The main aim of this study was to determine whether cost of the diet is associated with dietary diversity, nutrient density, and nutrient adequacy in breastfed and non-breastfed children in low socioeconomic settings.

6.1 Conclusion

In conclusion the dietary intake data in this study population illustrated poor consumption of diverse and nutrient dense complementary diet as low dietary diversity was observed in most children for both breastfed and non-breastfed group. Low nutrient intake and low nutrient density of key nutrients iron and calcium was also observed. Cost of the total diet for both breastfed and non-breastfed children was associated with nutrient adequacy and dietary diversity of the total diet. In addition, cost of the complementary diet for both breastfed and non-breastfed children was associated with dietary diversity, nutrient density, and energy density of the complementary diet. These results indicate that cost is indeed a barrier to access a nutrient adequate, nutrient dense and a diverse diet. Furthermore, people from low socio-economic settings cannot afford nutrient dense foods. Interventions should focus on strategies to improve dietary quality in children under age 2 years, such as for example improving dietary diversity. These strategies should however be affordable. To be able to meet the targets of SGD 2, people need to be empowered to give their children enough nutritious food that are diverse at the lowest possible cost.

6.2 Recommendations

6.2.1 Recommendation for future research

Programs that aim to improve childhood nutrition often focus on transfer of knowledge (nutrition education) and/or creating a demand for healthy foods. However, affordability or cost of the diet is a key obstacle for improving nutrition among young children (Ryckman et al., 2021). Further research on cost and dietary quality indexes is needed to better understand the challenges that the lower socio-economic sector of the population has for accessing nutritious adequate diets, particularly within the context of the COVID-19 pandemic and the consequences of the lockdown regulations.

Majority of children had low dietary diversity and low consumption of fruits and vegetables. Households participating in traditional vegetable promotion program in Tanzania were found to have a significantly higher dietary diversity for children under five and women of reproductive age (Ochieng et al., 2016). Including indigenous foods in the complementary diet may potentially improve dietary quality without adding any cost. Future research on South African indigenous foods to be used as complementary food and their contribution to dietary diversity, nutrient adequacy and nutrient density of the complementary diet is needed.

More than 75% of children had inadequate calcium intake and more than 80% had low nutrient density for calcium. Fortification in the form of micronutrient powders could potentially be a good intervention in increasing micronutrient intake (Pelto et al., 2013). Research on including calcium in, for example, (1) micronutrient powders as part of point-of-use fortification, and (2) as part of the NFFP programme to improve calcium intake in children is needed.

Research on cost of different foods that are used in the complementary diet as well as energy and nutrient cost of the diet will provide important information for guidelines to plan nutrient adequate diet at lowest cost.

6.2.2 Recommendation for future practice

Cost of the diet and cost of the complementary diet was lower for breastfed children compared to non-breastfed children. Nutrition strategies and interventions should emphasize the importance of continued breastfeeding until the age of 2 years and beyond, and include education messages on proper complementary feeding practices, which includes what diverse and nutrient dense foods can be given to children at low cost.

The strategies to improve diet quality must also be used as a multisectoral approach whereby the government doesn’t really focus on one strategy and side-line other strategies as they play a big role if they are collaborated. If women can be taught about home farming and the importance of home gardening it will be easier to teach them on how to give their children nutritious and diverse diet from their own local produce which will be cheaper and affordable.

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ADDENDUM 1: Table of the eight food groups that are used to calculate the dietary diversity score, and their examples

Food groups	Examples of food that fall under the group
Grains, Roots and Tubers	Bread, cereal, rice, maize meal porridge, samp, potatoes, breakfast cereal, infant cereal
Legumes and Nuts	Beans, lentils, peanuts, peanut butter
Dairy products	Milk, yoghurt, maas, infant formula, cheese
Flesh foods	Meat, poultry, organ meats, fish, offal, liver
Eggs	Fried eggs, scrambled eggs, boiled eggs
Vitamin A-rich fruits and vegetables	Mango, papaya Pumpkin, butternut, carrots Dark-green leafy vegetables, e.g. spinach
Other fruits and vegetables	Apple, banana, orange, grapes Cabbage, tomatoes
Breast milk	

Pureed baby foods are grouped based on the main ingredient

ADDENDUM 2: PERMISSION LETTER

NON-COMMUNICABLE DISEASES RESEARCH UNIT (NCDRU)

29 January 2021

The Chairperson
Faculty Higher Degrees Committee
University of the Western Cape
Robert Sobukwe Road
BELLVILLE
7535

PERMISSION TO USE THE EXISTING DATA SET OF POOLED 24-HR DIETARY RECALLS

I am the Principle Investigator (PI) for the study "Dietary patterns and dietary quality of 6–24 month old South African children". For this study, we pooled 24-hr recall data that we have previously collected in four independent studies. The uniqueness of this dataset is that includes diverse dietary intakes, ranging from predominantly maize based to predominantly based on commercial infant foods. As such, the dataset provides sufficient variation to interrogate various aspects related to dietary quality. The first paper on the pooled data has recently been published. *Faber M, Rothman M, Laubscher R, Smuts CM. Dietary patterns of 6–24-month-old children are associated with nutrient content and quality of the diet. Maternal and Child Nutrition 2020; 16:e12901.*

As PI of the study on "Dietary patterns and dietary quality of 6–24 month old South African children", I hereby give formal permission to Ms Mulabisano to use the pooled data towards her Masters mini-thesis. I will act as her supervisor, and Prof Ernie Kunneke (UWC) and Dr Jillian Hill (SAMRC) will act as her co-supervisors. We will ensure that she formulates her own research question and objectives within the context of the specific study.

Kind regards

Mieke Faber, PhD
Supervisor
Extra-ordinary Professor, Department of Dietetics and Nutrition, UWC

THE SOUTH AFRICAN MEDICAL RESEARCH COUNCIL
[illegible] Tygerberg, 7505, South Africa
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ADDENDUM 3: ETHICS CLEARANCE LETTER

UNIVERSITY *of the* WESTERN CAPE

60 YEARS *of hope, action & knowledge*

10 June 2021

Ms TA Mulabisano
Dietetics and Nutrition
Faculty of Community Health Sciences

Ethics Reference Number: BM21/4/5

Project Title: Association of cost of the diet with dietary diversity and nutrient adequacy in children aged 12 – 24 months.

Approval Period: 08 June 2021 – 08 June 2024

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report annually by 30 November for the duration of the project.

Permission to conduct the study must be submitted to BMREC for record-keeping.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
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