

THE ASSOCIATION OF DENTAL CARIES AND PERIAPICAL LESIONS WITH  
ANTHROPOMETRIC MEASUREMENTS IN POSTPARTUM WOMEN IN  
MANGOCHI, MALAWI.

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**Background:** Obesity, stunting, malnutrition and dental diseases are major public health challenges globally. Dental diseases and anthropometrics are of multifactorial nature and share the same risk factors; diet, socioeconomic status and education. People who have dental caries or periapical lesions suffer pain and discomfort during eating which might be associated with less food intake and low anthropometrics. No previous studies, that investigated the association of dental diseases (dental caries and periapical lesions) with anthropometric measurements (body mass index BMI and middle upper arm circumference MUAC) among post-partum women or in a rural Sub-Saharan Africa has been published before.

**Objective:** The objective of this study was to investigate the association of dental caries and periapical lesions with anthropometric measurements (BMI and MUAC) among post partum women in rural Mangochi, Malawi. The study's hypothesis was that dental caries and periapical lesions are associated with low anthropometrics in this low resource setting in Sub-Saharan Africa.

**Methods:** The study had cross-sectional design. The study used secondary data from larger nutrition interventional trial iLiNS-DYAD ([www.ilins.org](http://www.ilins.org)). The sample size of this study was 1016 participants. The anthropometric measures (BMI and MUAC), age, gestational age at enrolment and the number of previous pregnancies were collected during early pregnancy of maximum twenty weeks at the study enrolment. The dental data (periapical lesions and dental caries) and the gestational age at delivery were collected postpartum within maximum 6 weeks of delivery. Unadjusted multinomial logistic regression was performed to investigate the association among variables.

**Results:** 1016 women were enrolled in the study, with the age range of 14-49 years and the mean age of 25.5 years. Of the study participants, 580 (57.1%) had one or more carious teeth and 240 (23.6%) had one or more periapical lesions. For the anthropometrics, 54 participants (5.3%) had low BMI, 844 (83.1%) had moderate BMI and 118 (11.6%) had high BMI. Measuring the MUAC, 71 participants (7%) had low MUAC, 603 (59.4%) had moderate MUAC and 342 (33.6%) had high MUAC. The study did not find statistically

significant association of dental caries and periapical lesions with BMI (low or high) or low MUAC. Nevertheless, there was a statistically significant association between caries and high MUAC (OR= 1.3, 95% CI 1.0 - 1.7, p=0.046) and stronger significant association between periapical lesions and high MUAC (OR=1.6, 95% CI 1.2 - 2.2, p= 0.002).

**Conclusion:** The study results suggest rejecting the hypothesis that dental caries and periapical lesions are associated with low anthropometric measurements (BMI and MUAC) among the study participants. Further studies are recommended to investigate whether the association of dental caries and periapical lesions with high MUAC is causal or could be better explained by the common risk factors.

**Key Words:** Dental caries, Periapical lesions, Anthropometric, BMI, MUAC, Malawi, Sub- Saharan Africa.

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## 1. INTRODUCTION

Sub-Saharan Africa has been witnessing a nutrition transitional phase due to the shift in the lifestyle and eating patterns (Selassie et al. 2011) with a big variation between rural and urban settings (Van de Vijver et al. 2013). Malawi has been suffering from the high prevalence of low body mass index (BMI) since a long time and that pattern changed recently to a double burden pattern of both low and high BMI (Msyamboza et al. 2013).

Pregnant women have been among the most vulnerable groups to the adverse effect of the extreme BMI values (Veleva et al. 2008). The adverse effects may extend to the fetus resulting in further complications of preterm birth or low birth weight (Ehrenberg et al. 2003). Pregnancy complications are also found in women who have oral infections (Agueda et al. 2008). Oral infections have been associated with many systemic diseases and might lead to systemic complications, such as cardiovascular diseases, bacteria-caused pneumonia, and diabetes mellitus (Xiaojing et al. 2000). Dental caries is the most common chronic disease globally and when left untreated, it usually leads to dental infections. In the developing countries and low-resource settings, 90% of caries is left untreated (Marcenes et al. 2013).

A strong association between caries-related odontogenic infections and low BMI was found in 12 years old children in the Philippines (Benzian et al. 2011). However, no previous published studies investigated this association among other groups like adults, pregnant women, and the elderly or in other contexts, for example, in rural contexts in Sub-Saharan Africa. Therefore, the need for further studies and researches to investigate this association among different target populations and in different contexts arose.

The aim of the study is to investigate the presence of an association between dental caries and caries related periapical lesions and anthropometric measurements (BMI and Middle Upper Arm Circumference MUAC) in postpartum women in rural Malawi. Previous studies that investigated the association of dental caries and periapical infections with BMI and MUAC showed controversial results, among different targeted populations, different contexts and socio-economic status. (Hooley et al. 2012).

## **2. LITERATURE REVIEW**

### **2.1. Introduction and literature review methodology**

The literature review included the unsystematic review of articles specializing and analyzing the different study themes. When searching literature, the following key words were used: dental caries, periapical lesions, weight, BMI, MUAC, pregnancy, Malawi and Sub-Saharan Africa. Medline and PubMed were the main portals used to search and identify the relevant scientific articles. Also, the relevant references of these articles were included in the literature review. A comprehensive literature review methodology was done, using the articles found, that took into consideration reviewing articles from the different journal, different study designs, methodologies, from different countries and contexts.

### **2.2. About Malawi health context**

Malawi is a developing Sub-Saharan African country, located in the southern third of the African continent with a population of 17,215,000 (WHO Malawi Country Profile 2015) of which 85% live in rural settings. Almost half of the Malawians live under the national poverty line (Malawi WHO Country Cooperation Strategy 2008-2013). Malawi has a relatively low life expectancy at birth with 57 years for males and 60 years for females (WHO Malawi Country Profile 2015). Nevertheless, the life expectancy in Malawi has an increasing pattern as it increased steadily from 47 years in 2005 (Malawi WHO Country Cooperation Strategy 2008-2013) to 57 years for males and 60 years for females in 2015 (WHO Malawi Country Profile 2015).

The under-five child mortality rate was 68 per 1,000 live births (UNICEF Malawi Country Office 2015) and under-five child mortality was 41,000 deaths in 2015 (UNICEF Malawi Country Office, 2015). The neonatal mortality rate was also high, 23.2 per 1000 live births (UNICEF Malawi country Office, 2015). The maternal mortality ratio has one of the highest globally with an estimate of 675 deaths per 100, 000 live births within the period from 2004 to 2010 (Colbourn et al. 2013).

The main leading cause of death is HIV/AIDS, attributing to the quarter of overall deaths. The second leading cause of death is lower respiratory tract infections that cause about 12% of total deaths, followed by malaria and diarrheal diseases that both account for 16% of the total mortality. Other causes of death include cerebrovascular diseases (4%), ischemic health diseases (4%), perinatal conditions (3%), tuberculosis (3%), road traffic accidents (2%) and chronic obstructive pulmonary diseases (1%) (Bowie et al. 2011).

The causes of maternal mortality are different from the causes of mortality for the rest of the population. The most common underlying causes of maternal mortality were obstetric - related hemorrhage (32.1%), pregnancy-related infections (22.6%) and non-obstetric complications (24.5%) (Owolab et al. 2014). One of every 5 reported cases of maternal mortality is due to delivery complications that include obstructed delivery or ruptured uterus which attributes to 20% of the total maternal mortality in Malawi. In addition, about 18% of the maternal mortality reported cases are due to abortion and miscarriage complications (Kumbani et al. 2007).

There is a steady increasing pattern in the life expectancy at birth in Malawi for both men and women. However, this increased life expectancy is accompanied with a high burden of diseases including both communicable diseases which accounts for 73% of the total years of life lost (WHO Malawi Country Profile 2008) and non-communicable diseases which have increased recently to attribute to 17% of the years of life lost (WHO Malawi Country Profile 2008).

In addition to the double burden of communicable and non-communicable diseases, high rates of maternal mortality, child mortality and morbidity and the increase of the neglected tropical diseases are very challenging to the developing Malawi health system (National Statistical Office 2011).

However, Malawi has achieved good progress in reducing maternal mortality and enhancing the health of mothers and pregnant during the last decade (Colbourn et al. 2013). Although the fertility rate of Malawian women has decreased from 6 to 5.7 children per woman (2004). It is still relatively high compared to the global average of 2.4 and the regional average of 4.8 (World Bank Malawi fact Sheet 2010). Fertility varies with mother's education and economic status, (World Bank Malawi fact Sheet 2010).

The maternal mortality ratio has decreased to 510 deaths per 100,000 live births but it is still above the African regional average of 480 death per 100,000 Live births and almost double the global average of 210 deaths per 100,000 live births (UNFPA 2011). Depending on the information resource, 54% to 71% of all deliveries in Malawi have been attended by a skilled health worker (UNFPA 2011, World Bank Malawi factsheet 2010).

### **2.3. Nutritional status and anthropometric measurement**

Anthropometry is a term that has been used to describe human body composition and physical development and its indicators have been extensively used in epidemiological studies of under- nutrition, overweight, and obesity.

#### **2.3.1. Body mass index (BMI)**

BMI has been one of the most reliable, widely used anthropometric measures that identify changes in weight for height with limits for underweight, normal weight or overweight.

BMI is defined as weight (in kilograms) divided by the height squared (in square meters) (WHO 2000).

For adults, the defined BMI cut-offs are underweight ( $\text{BMI} \leq 18.5 \text{ kg/m}^2$ ), normal weight ( $\text{BMI} 18.5\text{-}24.99 \text{ kg/m}^2$ ), overweight ( $\text{BMI} 25\text{-}29.99 \text{ kg/m}^2$ ), and obese ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ) (WHO global database on Body Mass Index). The international classification of adult underweight, overweight, and obesity according to BMI is illustrated in table 1. Additional BMI cut-off points are used for some ethnic populations to better indicate the risk sensitivity for a specific population or ethnicity (WHO, 2004).

There is another BMI chart tailored for children, which is taking into account the different growth patterns of children and adolescents (Pinson 2011). In general, for a male and female who have the same BMI value, a female tends to have more body fat content than the male has. In addition, older people have more body fat than their younger peers who has the same BMI value (Deurenberg et al. 1998).

BMI has often been referred to as an indicator of overweight and obesity rather than being an indicator of underweight and malnutrition because of the extensive studies that investigated the higher risk factors of being obese/overweight than being underweight. Overweight and obesity are considered the leading risk factor for the rapidly increasing morbidity, disability, premature mortality from hypertension, dyslipidemia, diabetes type 2, musculoskeletal disorders, coronary heart diseases, stroke, gallbladder disease, osteoarthritis, sleep apnea and respiratory problems (WHO 2012, Pinson 2011).

Table 1: the International Classification of adult underweight, overweight and obesity according to BMI (WHO, 1995, WHO, 2000 and WHO 2004).

Classification	BMI(kg/m <sup>2</sup> )	
	Principal cut-off points	Additional cut-off points
<b>Underweight</b>	<b>&lt;18.50</b>	<b>&lt;18.50</b>
Severe thinness	<16.00	<16.00
Moderate thinness	16.00 - 16.99	16.00 - 16.99
Mild thinness	17.00 - 18.49	17.00 - 18.49
<b>Normal range</b>	18.50 - 24.99	18.50 - 22.99
		23.00 - 24.99
<b>Overweight</b>	$\geq 25.00$	$\geq 25.00$
Pre-obese	25.00 - 29.99	25.00 - 27.49
		27.50 - 29.99
<b>Obese</b>	$\geq 30.00$	$\geq 30.00$
Obese class I	30.00 - 34.99	30.00 - 32.49
		32.50 - 34.99
Obese class II	35.00 - 39.99	35.00 - 37.49
		37.50 - 39.99
Obese class III	$\geq 40.00$	$\geq 40.00$

It has been suggested that high BMI is a risk factor for some cancer cases such as endometrial, breast and colon cancers. In addition, it is noted that for every 5 points more than the overweight BMI value of 25 kg/m<sup>2</sup>, there is a 30% higher risk of mortality and a 40% higher risk of cardiovascular mortality (Nguyen et al. 2008). Although the association between BMI and mortality has been a topic of controversy, extremely low and high BMI are known to be linked to mortality (McGee 2005).

It is important to clarify that BMI is not a measurement of body fat but an indicator of body fatness as BMI correlates with body fatness. BMI has also an indicator of the status of nutrition and nourishment but can be a better indicator if combined with other measurements or indicators like mid-arm circumference (MAC), mean arm muscle circumference (MAMC) or MUAC.

### 2.3.2. Middle upper arm circumference (MUAC)

MUAC is an anthropometric indicator that is frequently used specifically in cases of emergency and where measuring BMI is hard to be implemented. Some studies suggest using MUAC as an anthropometric indicator in pregnancy instead of BMI. Some other studies suggest that the best anthropometric indicator is a combination of MUAC and BMI (James et al. 1994, Rivaled et al. 1997).

MUAC is best measured around the left arm midway between the tip of the upper shoulder and the tip of the elbow when the arm is positioned at a 90-degree angle. There are color-coded tapes that make measuring the MUAC easier, for example, the UNICEF tapes that were released in 2009 (UNICEF 2009). Unlike BMI, there is no universally accepted unified MUAC cut-off point as they differ from one country or region to another and usually, ranges from 22-24 cm for adults (Tang et al. 2013). Since MUAC is used mostly to diagnose malnutrition, the MUAC cut-off is the cut-off defining the low MUAC.

MUAC can be used in combination with other indicators for better measurement accuracy. Due to the faster growth rate of children, WHO recommend a new MUAC-for-age reference for the under-five years children. Another MUAC related reference, MUAC-for-height reference was made for situations where determining the child age is not possible, for example, in emergencies (Mei et al. 1997).

### 2.3.3. Anthropometric measures and pregnancy

The maternal nutritional status has been a key determinant of birth outcome and the presence or absence of birth complications. Due to this, special attention has been given to the maternal pre-pregnancy BMI, BMI at conception, weight gain during pregnancy and weight at delivery. However, some studies argue that only pre-pregnancy BMI and pregnancy weight gain are the most reliable and consistent pregnancy weight indicators (Hickey et al. 1995, Siega-Riz et al. 1994).

Extreme values of BMI are considered as pregnancy risk factors that have a possible adverse effect on the delivery outcome and the fetus health status as they cause an increased risk of miscarriage (Veleva et al. 2008). Low maternal BMI or low weight gain during the pregnancy attribute to the increased risk of low infant birth weight, premature delivery (Ehrenberg et al. 2003), intra-uterine growth retardation ( Schieve et al. 2000) and later child growth retardation (Neggers et al. 2003).

Low pre-pregnancy weight is the most manageable among the other weight problems, such as low BMI at conception, low weight gain during pregnancy and low BMI at delivery. (Neggers et al. 2003). On the other hand, maternal overweight and obesity are associated with high incidence of pre-eclampsia, gestational hypertension, macrosomia, labor induction, caesarean delivery and preterm delivery (Bhattacharya et al. 2007).

Among other determinants of maternal and newborn health is the gestational weight gain, known also as pregnancy weight gain (Moore Simas et al. 2013). Appropriate gestational weight gain that is matching the guidelines is recommended for all pregnancies and is linked with better maternal and neonatal health in the long and short terms. The gestational weight gain beyond the recommended guidelines is linked with post-delivery retention of the gained weight and obesity (Moore Simas et al.2013).

Some studies argued that BMI is not recommended to be used during pregnancy as it is not a valid indicator of the maternal nutritional status but may be related to the fetal weight (Nightingale et al. 1996, Collins 1996, Kyle et al. 2002, UNHCR 2005). In addition, during pregnancy in the presence of edema, the body gains artificial weight due to fluid retention which gives inaccurate indicators of body fat and the nutritional status (Campillo et al. 2004). MUAC is recommended to be used as a reliable index of maternal nutritional status because it is not been influenced dramatically by pregnancy (Sebayang et al. 2011).

#### 2.3.4. Anthropometric trends in Sub-Saharan Africa

In most of the developing countries, the prevalent pattern of low BMI and underweight has been rapidly changing to high BMI and obesity to make it one of the leading global public health issues. The fast urbanization, change in diet, change in eating habits, increase in high fatty food consumption and decreased physical activity have been attributing to the global nutrition shift (Ogunbode et al. 2011, Selassie et al. 2011, WHO 2000).

The nutrition and weight pattern change in the low and middle-income countries has taken place mainly in urban settings more than in rural setting and in women more than in men (Ziraba et al. 2009, Van de Vijver et al. 2013, Msyamboza et al. 2013). The increase in BMI has a socio-cultural dimension in Sub-Saharan Africa, especially among the poor as obesity is perceived as a sign of wealth, health and higher social status (Duda et al. 2007).

That perception changes by the wealth and level of education gained (Swami et al. 2010, Holdsworth et al. 2004). Another issue among the poor population of Sub-Saharan Africa is the underestimation of the actual body weight that was prevalent among as many as half of the overweight/obese adults (Ettrah et al. 2013).

The relative weight increase doesn't necessarily express a state of good nutrition (UNHCR 2005). High prevalence of micronutrient malnutrition has been recorded, especially in low and middle-income countries which are known also as hidden hunger (World Bank 2011). In hidden hunger, essential minerals and vitamins are absent in adequate amounts in the diet or have not been supplemented by a nutritional supplement.

#### 2.3.5. Anthropometric trends in Malawi context

Studies from 1990 to early 2000 concluded that Malawi has been known for having underweight and low BMI as the common trend, affecting 40.9% of the population. More men were found to be underweight than women. Few cases of overweight or obesity were identified and they represented 0-6% of the whole population (Chilima et al. 1998, Zverev et al. 2004, Msamti et al. 2000).

Malawi has been witnessing a dramatic epidemiologic change that included a shift in eating habits, food preferences, lifestyle, urbanization, education, increased standards of living, increased income and decreased physical activity. A change in diet and eating habits was observed, due to the relative increase in standards of living, which was manifested by the introduction of fast food, calorie-dense food and increased frequency of meals. That lifestyle change included the obesity burden and the already existed malnutrition problem as the current studies show that 22% of the adult population of Malawi are overweight (Msyamboza et al. 2013). Obesity is more prevalent in women than in men and in urban settings than in rural settings. (Msyamboza et al. 2013).

For Malawian women aged between 15 -49 years, a majority, 74% have a normal BMI, about 9% are too thin and 17% are overweight. In Sub-Saharan Africa. Malawi has the 5<sup>th</sup> highest global rate of stunting (low height for age) due to the prevalent malnutrition in all the socio-economic classes due to the shortage of food variety (World Bank 2011).

About 34% of the Malawian have zinc deficiency and in about half of the households salt that been used in Malawi is iodinated. Malnutrition is a critical public health issue that is worth investing. It would cost 0.5-3.6 US dollars per person annually to integrate micronutrients interventions into the life of Malawi citizens and the results of the investments are worth 8-30 times the cost paid (World Bank 2011).

Hidden hunger and malnutrition are common in Malawi. Anemia is more prevalent in pregnant women (38%) than in non-pregnant women (28%) and 14% of pregnant women have vitamin A deficiency (National Statistical Office 2011). A complex synergistic relation between malnutrition and the presence of infections was discovered as early as 1986 (WHO 1986) and later studies showed that the mortality rates due to infections increased proportionally with the severity of malnutrition (Müller et al. 2003).

#### **2.4. Oral health**

Oral health is an integral part of the state of complete health and wellbeing. Oral Infections are virally spreading among all the world populations and dental caries is the most common infectious diseases that affect human beings (Balakrishnan et al. 2000). In 2012, 60-90% of school children and almost 100% of the adults suffered from dental caries (WHO Oral Health, 2017).

Periodontal diseases are the most common causes of tooth loss globally (Darveau 2010). They affect 15-20% of middle-aged (35-44 years) adults. It has been estimated that about 30% of the world population aged 65-74 are edentulous because of teeth extraction due to extensive caries or because of periodontal diseases (WHO Oral Health, 2017).

#### 2.4.1. Oral infections

Oral Infections are classified according to the origin of the infection to either odontogenic or non-odontogenic infections. Odontogenic infections constitute the majority of the oral infections and are initiated from the tooth structure, dental pulp or the periodontium. The odontogenic infections are classified into three main categories, according to the etiology, dentoalveolar infections, gingivitis and periodontal infections and deep facial space infections (Leggiadro 2009).

Non-odontogenic infections are usually formed after being subjected to a thermal, chemical or traumatic injury and it includes ulcerative mucositis, stomatitis and major salivary glands infection (Dahlén 2008). People who have compromised immunity or patients living with HIV are among the risk groups of having frequent, multiple and chronic non-odontogenic infections and also the secondary opportunistic infections like candidiasis, aspergillosis, mucomycosis, herpetic or gingivostomatitis.

Most of the tooth-related oral infections are bacteria dominated polymicrobial infections, (Featherstone 2008). Spreading infections to the deep facial spaces are usually more serious including both aerobic and anaerobic bacteria (McHenry et al. 1995). There are also suppurative orofacial infections that originate from the oronasal, oropharynx, middle ear, mastoid or paranasal sinuses and spread to the neighboring soft tissues.

#### 2.4.2. Dento-alveolar infections

Dental caries, pulpitis, periapical abscess, alveolar abscess, periapical granuloma or periapical cyst are classified as dentoalveolar infections because they share the same etiology of being initiated by dental caries (except in rare conditions the physical, chemical or traumatic injury can cause pulpitis). Cariogenic bacteria on the dental tooth surface produce acids during fermentable carbohydrates metabolism and that acid works to demineralize the dental Enamel which makes the first clinical sign of dental decay; the discoloration of the tooth surface (Loesche 1986, Keyes 1960). The demineralization and remineralization of dental hard tissue alternate (Kidd et al. 2004). Demineralization can happen if calcium, fluoride, and phosphate are found in the saliva and that remineralization may stop the progress of dental caries (Nyyad et al. 1999).

Enamel demineralization may be followed by dentine demineralization that may reach the pulp to cause pulp infection known as pulpitis. If drainage from the pulp is obstructed, pulp necrosis and rapid endodontic microorganism proliferations happen and the infection spreads outside the root canal either to the periapical area forming “periapical abscess” or to the alveolar bone forming “alveolar abscess” which is larger in size than the periapical abscess. The infection may extend also to the surrounding and neighboring mucosal membranes, skins and deep facial spaces. (Nygaard-Ostby et al. 1971).

Clinically, dental caries is diagnosed by probing. A tooth with reversible pulpitis is sensitive to percussion and to both hot and cold stimulus and characterized with pain relief upon the withdrawal of the stimulus. A tooth with irreversible pulpitis is very sensitive to hot stimulus and whiteness an immediate pain relief if a cold stimulus is applied. Despite that, some dental infections are clinically asymptomatic like periapical granuloma and these are best diagnosed by radiographic x-rays and in some cases by microbiological examination (Selwitz et al. 2007).

The main treatment in dentoalveolar infections is the immediate elimination of the infection. Dental caries is treated by removal of dental caries and making an appropriate restoration. Infected pulp is treated with deep periodontal scaling, endodontic treatment or tooth extractions as the possible treatment trajectories. In cases of the presence of suppurative lesions or abscesses, drainage is essential for case management. In cases of inadequate drainage, antibiotic are highly recommended. Other supportive measures are recommended to avoid patient discomfort, for example, hydration, soft diet, maintaining good oral hygiene and analgesics. (Selwitz et al. 2007).

#### 2.4.3. Gingivitis and periodontal infections

Gingivitis is the inflammation of the gum and a periodontal disease is a chronic oral infection that affects the periodontium and causes the destruction of the connective tissues and the alveolar bone (Oliver et al. 1998). Terminology wise, periodontal diseases are all diseases associated with tooth periodontium which includes gingivitis, acute necrotizing ulcerative gingivitis, periodontitis, periodontal abscess, and pericoronitis.

Gingivitis is initiated by irritation caused by the presence of subgingival plaque and progress with infection invasion to the gingiva (Rautemaa et al. 2007). The infection may extend to the underlying periodontal ligaments causing periodontitis that lead to the alveolar bone loss. Despite that, periodontal diseases rarely spread to the deep facial space infections. The periodontal infection may initiate periodontal abscess that can be either diffuse or localized.

Clinically, gingivitis can be diagnosed by the gingival discoloration, slight swelling of the gingival margins and bleeding upon probing. Although, more severe signs and symptoms appear in other forms of gingivitis ex. acute necrotizing ulcerative gingivitis (ANUG). In general, the gingivitis and periodontal diseases have open access for draining freely and that prevents pus collection pressure which is the main reason for pain and discomfort in

the dent alveolar infections. Based on that, patients with gingivitis and periodontal infections show no pain or only minimal discomfort (Pari et al. 2014).

The key diagnostic symptoms of periodontitis are the change of taste, jaw pain, gingival discoloration, bleeding gum, pus presence and in more aggressive forms of periodontitis tooth mobility that might be accompanied by a vertical bone loss. Periodontal abscess clinically appears as red gingival swelling that is very sensitive to palpation. A similar clinical appearance is found in pericoronitis which is an infection of the surrounding tissues of a partially erupted tooth, most often the wisdom tooth. (Research, Science, and Therapy Committee of the American Academy of Periodontology, 2001).

Gingivitis is reversible if plaque and calculus are removed and it is best treated by maintaining good oral hygiene through self-care with regular brushing and flossing. If the infection does not resolve, periodontal scaling, root debridement, and analgesics are considered. Periodontitis is best treated by combining local periodontal treatment involving root debridement and surgical resection of inflamed periodontal tissue (Loesche 2005).

Odontogenic infections can spread hematologically which can cause complications like bacteremia which usually happens after extraction of infected teeth (Lockhart et al. 1999).

#### 2.4.4. Oral health in Sub-Saharan Africa

Globally, tooth decay is influencing 82% of adults aged between 35-44 years according to WHO (1998). The prevalence of dental caries and related oral infections in developing countries is lower than their prevalence in developed countries (Petersen et al .2005), although it is rising in Sub-Saharan Africa a due to the lifestyle shift from rural lifestyle that adopts raw unrefined food to urbanized lifestyle that consumes more calorie-dense and sugary sticky food (Sreebny 2006). The dental caries increase is dependent on the sex, urbanization, socio-economic status, and accessibility to oral hygiene (Petersen et al. 2003).

With the high HIV and AIDS prevalence in Sub-Saharan Africa, the unexpectedly low prevalence of oral hairy leukoplakia was recognized in Malawi (Muzykaa et al. 2001).

## **2.5. Oral health and pregnancy**

### **2.5.1. Oral health and pregnancy on the global level**

During pregnancy, many systemic changes happen in the woman's body. One of them is the increase of gastric acidity which leads to increase of oral acidity level which is a risk factor for tooth erosion (Silk et al. 2008). In addition, pregnancy sugar craving and the neglect in maintaining good oral hygiene put pregnant women among the risk group of developing dental caries at a higher rate than the other groups (Kumar et al. 2006).

Gingivitis is the most common dental disease during pregnancy as it affects 60-75% of the pregnant women. It has been shown that 50 % of the women who had pre-pregnancy gingivitis, had more severe gingivitis during pregnancy that might be accompanied with exacerbations. (Loe et al. 1963, Tilakaratne 2000). However, these pregnancy changes disappear after the delivery (Gürsoy et al. 2008). The pregnant women are more likely to suffer from gingival bleeding and inflammation than women who have delivered recently, regardless of the amount of plaque present (Loe et al. 1963, Raber-Durlacher et al. 1994).

Increased pregnancy progesterone in the presence of irritation and bacteria may cause pregnancy oral tumors that affect up to 5% of the pregnant women (Sills et al. 1994). It is not possible to differentiate between pyogenic granuloma and pregnancy oral tumor clinically, but oral pregnancy tumors usually recede after the end of pregnancy.

It was also evident that the high level of progesterone and estrogen affect the periodontium causing relative loosening of the teeth even if the gingival was healthy. In the case of the

healthy periodontium, the tooth mobility usually resolves after delivery but it may not if the pre-pregnancy periodontal disease exists (Scheut et al. 2002).

#### 2.5.2. Dental infections and pregnancy outcomes

The aggregated periodontium infection in combination with bacteria indirectly stimulates the hepatic acute phase response which releases a high level of inflammatory markers for example cytokines, prostaglandins or; interleukins which may adversely influence the pregnancy outcome. These inflammatory markers are present with higher amounts in the amniotic fluid of pregnant women with periodontitis and preterm birth than in healthy pregnant women (Dortbudak et al. 2005).

The relation between periodontitis and poor pregnancy outcome has been controversial despite the high number of studies investigating this relation. Some studies found a positive association between periodontitis and preterm delivery (Offenbacher et al. 1998). Other studies discovered an association between periodontitis and the low preterm birth weight (Yeo et al. 2005). On the other hand, some studies have found no association between periodontitis and neither preterm delivery nor low birth weight (Ali et al. 2012, Sugita et al 2012, Abati et al 2013).

The relation between dental caries and pregnancy complications were investigated too in some studies that found no association between dental caries and preterm birth (Durand et al. 2009, Harjunmaa et al 2015). Although a study reported the presence of a strong association between dental decay and preterm birth (Agueda et al. 2008). The mother's oral health does not only influence her systematic health but also her child as children of mothers with high caries prevalence are more likely to more dental caries than those who were born to mothers with no dental caries (Berkowitz 2003, Alalluusua et al. 1996).

## **2.6. Association between anthropometric measurements and dental diseases and nutrition**

The association between anthropometric measurements (BMI and MUAC) and dental decay has been investigated in several previous studies, reaching out to different conclusions. Few studies targeted adults or women in rural contexts in low-resource settings (Alswat et al. 2016). Among children, a significant association between childhood obesity and dental caries was found, where the socioeconomic status and age were important confounders (Hayden et al. 2013, Alma et al. 2008, Gerdin et al. 2008, Thippeswamy et al. 2011). The previous association was explained that dental caries is associated with increased food consumption, the number of meals, food frequency, coarse and texture of food intake which attributes to BMI increase and obesity.

Another study investigating the association between the weight and dental caries in 12 years Brazilian children found that there was no significant difference in caries prevalence among the different BMI categories (Alves et al.2013). High caries prevalence in children might be an indicator for their future BMI status as they will have less probability of being overweight and that was only significant among children of families having higher socioeconomic status and this association was not significant among children belonging to families of lower socioeconomic status. (Lempert et al.2014).

The presence of dental caries or periapical lesions that are usually accompanied with pain and discomfort can be linked with the decreased number of meals, meals frequencies and avoidance of coarse food, which can lead to weight loss and possible malnutrition. The malnutrition affects the body defense mechanism to the bacteria (including the oral bacteria), suggesting a probable higher risk of caries development. That is supported by another study that found a significant association between low BMI and the risk of caries development in children, that was explained by the dietary habits and the poor oral health practice (Norberg et al. 2012). In addition, a significant association between periapical lesions and low BMI among school children in the Philippines (Benzian et al.2011).

Regarding malnutrition, previous studies find a strong association between malnutrition and increased prevalence of dental caries (Alvarez 1995). However, the association is often explained by the common risk factors between dental caries and malnutrition, for example, diet, socioeconomic status, education, urbanization, eating habits and lifestyle. People who have an unbalanced diet that includes sugary and calorie-dense food with low nutritional value, usually suffer from both malnutrition and dental caries (Alvarez 1995, Kandelman 1997, Stookey 2008). Malnutrition in return decreases the secretion of stimulated saliva (Johansson et al. 1992) which is among the causes of increasing cariogenic activity that increases the risk of caries development (Kandelman 1997, Stookey 2008).

Sugary and calorie-dense diet are associated with obesity but not necessarily with good nutritional status, if the diet is deficient in micronutrient and essential elements (Asfaw et al. 2007).

Also, there is a positive association between caries and obesity (overnutrition) among adults (Alswat et al. 2016) which is explained by increased food intake, meal frequencies and the consumption of refined food. That is more observed in urban contexts and in developed countries.

### **3. OBJECTIVE OF THE STUDY**

The general objective of the study is to investigate the association of dental caries and periapical lesions with anthropometric measurements (BMI and MUAC) among postpartum women in rural Malawi. The study specific objectives are to investigate:

- The association between caries and BMI.
- The association between periapical lesions and BMI.
- The association between caries and MUAC.
- The association between periapical lesions and MUAC.

Dental diseases and anthropometrics share common causes and risk factors that include diet, socioeconomic status, and education. People who have dental caries or periapical lesions usually suffer pain and discomfort during eating which may result in less food intake and low anthropometrics. Therefore, the study hypothesis is that there is an association between dental caries and periapical lesions and low anthropometrics among postpartum women in rural Malawi where untreated dental diseases and malnutrition are common.

## **4. METHODOLOGY**

### **4.1.iLiNS study**

This substudy has been done within the framework of the international lipid-based nutrient supplement project (iLiNS). iLiNS was an international randomized controlled clinical trial that aimed at finding new ways of preventing malnutrition globally. The project was implemented in Burkina Faso, Ghana, and Malawi. (iLiNS Project, 2009).

iLiNS study aimed at developing and evaluating the efficacy of low-cost locally-available lipid-based nutrient supplement (LNS) for infants, 6-18 month children, pregnant and early lactating women. In addition, the study investigated the optimal dose of zinc to be added in LNS. The study also questioned the influence of socio-economic dimension of LNS for malnutrition prevention and management (iLiNS project website, 2011).

The study followed the ethical standards of Helsinki declaration. The detailed ethical guidelines, approvals and protocols were published elsewhere (Ashorn et al. 2015, Harjunmaa et al 2015). Only participants who signed or thumb printed the consent form were included in the study.

#### **4.1.1. iLiNS-DYAD-M sub-study**

The data obtained for this thesis was a secondary data from the cross-sectional dental sub-study, implemented within the framework of iLiNS-DYAD-M trial of iLiNS research project (Harjunmaa et al. 2015). The iLiNS-DYAD-M hypothesis was that home fortified diet of pregnant women with nutrient supplement would positively influence the baby birth size in low-resource settings.

As per that, women who were enrolled in the study were given either a capsule of iron and folic acid capsule per day, one capsule with 18 micronutrients, or one 20 grams sachet of lipid-based nutrient supplement containing 118 kcal, protein, carbohydrates, essential fatty acids and 21 micronutrients (Ashorn et al. 2015, Harjunmaa et al. 2015).

The data derived from the sub-study investigated the association between dental periapical infections and pregnancy outcomes. The sub-study found an association between periapical infections and shorter pregnancy duration and intra-uterine growth retardation, among the study participants in rural Malawi (Harjunmaa et al. 2015).

#### 4.1.2. iLiNS-DYAD-M study site:

Mangochi district is located in the southeastern part of Malawi (Figure 1). Mangochi district has a population of 100,000 inhabitants who work mainly in farming and fishing. Mangochi has one district-level hospital and its surrounding area is considered to be rural. Mangochi is connected by a transportation network internally and to the other parts of the country.



Figure 1. Map of study site

## **4.2. Study participants**

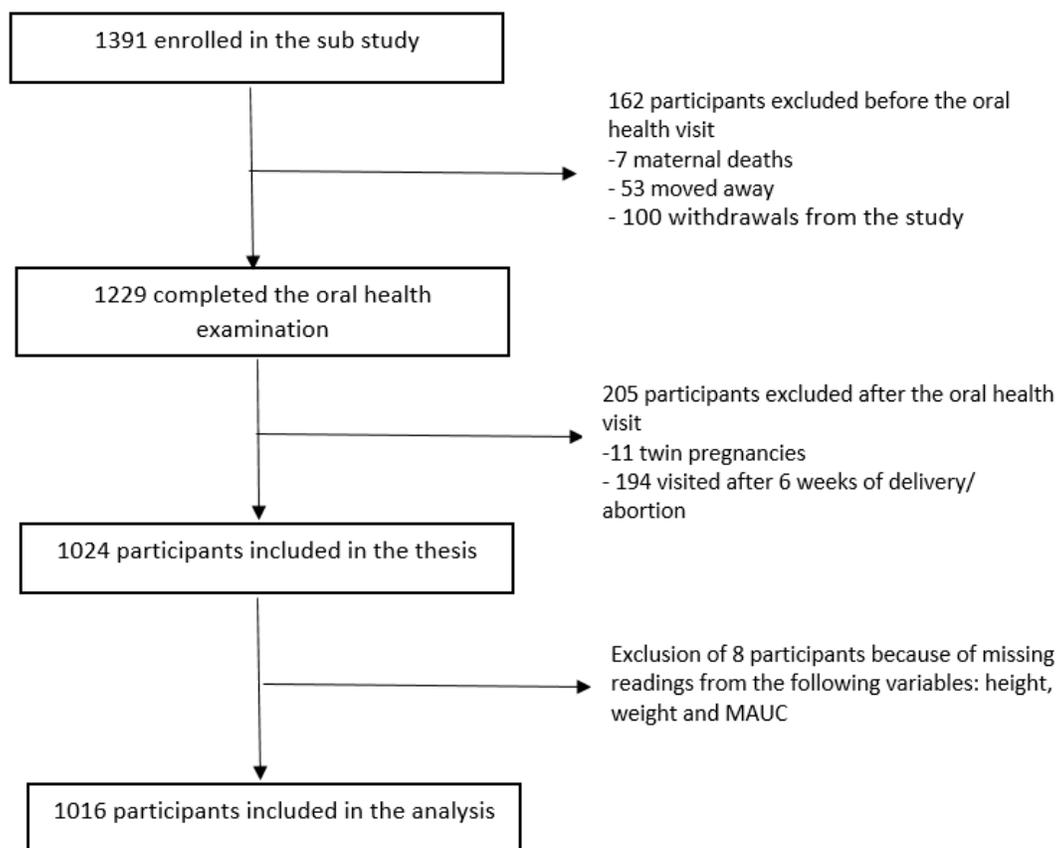
This cross-sectional study used the available data from iLiNS-DYAD-M oral health sub-study. For iLiNS-DYAD-M study, 1391 pregnant women were enrolled who met all the inclusion criteria and none of the exclusion criteria, and who visited the antenatal clinics in four different health facilities. Facilities included two district-level hospitals (Mangochi and Malindi) and two health centers (Lungwena and Namwera). Three of the facilities were located in rural areas and one, Mangochi district hospital, was located in a semi-urban context (Harunjmaa et al. 2015).

At enrolment, the research personnel performed health and antenatal examination, recording the medical and obstetric history of the participants. The inclusion criteria of iLiNS-M study included an ultrasound confirmed pregnancy that did not exceed 20 completed gestational weeks, minimum age of 15 years, permanent residency within the research designated area, availability during the period of the study, informed consent signing or thumbprint and the absence of any of the exclusion criteria.

The exclusion criteria included presence of chronic diseases or conditions that requires regular medical treatment, frequent hospitalization and hospital referral, presence of allergies, expected pregnancy complications (either the presence of moderate to severe oedema, blood haemoglobin concentration less than 50 g/l, systolic blood pressure more than 160 mmHg or diastolic blood pressure more than 100 mmHg), earlier participation in this trial or parallel participation in other clinical trial.

The inclusion criteria for the oral health substudy included participants of iLiNS-DYAD-M study who had delivered a singleton infant and completed the dental examination visit within a maximum 6 weeks of delivery.

Of the 1391 participants enrolled in the iLiNS-DYAD-M study, 1229 participants completed the oral health examination. Of them, 1024 participants completed the oral health examination within six weeks after delivery and were considered for this current analysis. Of those, two participants had missing data from variable “History of the previous pregnancies”, five had missing data of variables “Mean weight of the mother” and “Mean height of the mother” and three participants had missing data from variable “Mean MUAC”. All these eight participants with missing data were excluded from the analysis, leading to a final sample 1016 (figure 2).



**Figure 2. Substudy participant flow**

### **4.3.Methods used for data collection, accuracy and bias minimization**

The dental data were recorded in structured study forms during the dental examination visit which was done within 6 weeks after delivery. Anthropometric measures (height, weight, and MUAC) were recorded earlier at enrollment (< 20 GW), using standardized highly sensitive scales, (SECA 874 flat scale; Seca GmbH & Co.) stadiometers (Harpender stadiometer; Holtain Limited) and non-stretchable plastic tapes (Shorrtape; Weigh and Measure LLC) with reading increment of 50gm, 1 mm and 1mm respectively.

To ensure the minimization of bias and the most accurate measurements, the anthropometric measurements were recorded three times, and the mean value of the first two readings was used if the difference between them was beyond the previously-specified tolerance limit. In the case of presence of a difference between the first and second readings beyond the tolerance limit, the third measurement was compared to the first and second readings and the pair of readings that showed the least difference were used to calculate the mean value.

A registered nurses collected participants' obstetric histories and performed the antenatal examination to collect the following variables: the participant age (in years), the number of previous pregnancies (in numbers), gestational age at enrolment (in weeks) and gestational age at delivery (in weeks).

Dental data were obtained by two trained dental professionals who conducted a full mouth examination and took digital panoramic x-rays (PlanmegaProline XC, Planmega, Finland) of all the study participant. The digital x-rays were diagnosed by an oral and maxillofacial radiologist and an experienced dentist at Tampere University hospital (Oral radiology department) using digital imaging software (PlanmegaRomexis™, Planmega, Finland) and a good quality monitor in a darkened room. They recorded the number of teeth, the presence of dental caries and periapical lesions, and identification of whether the caries is confined to dentine or extended to the pulp, Periapical lesions were recorded if at least

1mm osteolytic finding was seen at the tip of the root. Dental caries and periodontitis were diagnosed by clinical examination and radiographic examination. Periapical lesions and deep caries were diagnosed by radiographic examination.

Measurement bias was minimized by using accurate and sensitive measurement devices and tools in measuring the anthropometric measures. In addition, dental caries was diagnosed both clinically and radiographically through a standardized practice that included the re-assessment of at least two earlier radiographs each week to identify and resolve any possible deviance or conflicting readings. The calibration, standardization measures and guidelines were followed strictly before and during the data collection every four months.

The substudy was double blinded where the dental professionals and radiographs analyst were blinded to the anthropometric measurements. The data collection methodology and results were stated in details elsewhere (Ashorn et al. 2015, Harjunmaa et al. 2015).

#### **4.4.Data preparation for analysis**

Then variable management was performed by generating a new variable of the Mother BMI using the height and the weight of the study participants following the follow formula:

$$\text{BMI} = \frac{\text{mass}(\text{kg})}{(\text{height}(\text{m}))^2}$$

The dental caries variable was classified according to the presence or absence of caries and the frequency of dental caries presence was counted and categorized to mild (from 1-3 carious teeth), moderate (from 4-6) and severe (more than 6 carious teeth). Same process and categorization were applied to periapical lesions. The anthropometric measures were used as both continuous and categorical variables. BMI was categorized to low BMI (less than 18.5 kg/m<sup>2</sup>), normal BMI (18.5-24.99 kg/m<sup>2</sup>) and high BMI (more than 25 kg/m<sup>2</sup>) (WHO 2002).

Unlike BMI, MUAC doesn't have a universal cut-off point but it has a cut-off range for low MUAC instead (from 21-23 cm). Following the Sub-Saharan African mean cut-off point, the cut-off point of 23 cm was adopted. Upon that, the mean MUAC was categorized to low MUAC (less than 23 cm), normal MUAC (from 23-27 cm) and high MUAC (more than 27 cm) (James et al. 1994).

#### **4.5. Statistical methods**

Statistical analysis was performed using Stata 12.1 (StataCorp, College Station, TX, USA) statistical analysis software for windows. The statistical analysis started with data cleaning, exclusion of participants who had a missing variable, checking and correcting illogical values, generating the required new variables and categorization.

Descriptive analysis was first performed to have an overview of the variables and the measures of their central tendencies. The descriptive analysis included the number, percentage, mean, median, minimum and maximum values. For group comparisons, dental caries or periapical infections and the anthropometric variables were tabulated using dichotomous variables (Yes/No). Tests of associations (t-test) were performed between different explanatory variables and the continuous anthropometric variables. Unadjusted multinomial logistic regression was performed to assess the association between dental caries and periapical lesions and the anthropometric measurements (categorical BMI and MUAC) by getting the odds ratio with 95% confidence interval.

## 5. RESULTS

### 5.1. Descriptive analysis

#### 5.1.1. Study participants characteristics

As described in Table 2, 1016 participants were included in the analysis. Their age range varied from 14 to 49 years, with the mean age of 25.5. The mean number of previous pregnancies of the study participants was 2.3. The mean gestational age at enrolment was 16.8 weeks and at delivery 39.4 weeks.

#### 5.1.2. Dental caries and periapical lesions

Out of the 1016 study participants, 580 (57.1%) participants had dental caries (Table 2). Of those, the number of dental caries per participant varied from 1 to 14 carious teeth. About two-fifths of the study participants (42%) had mild caries (1-3 carious teeth), 10.9% had moderate caries (4-6 carious teeth) and 4.1% had severe dental caries (more than 6 carious teeth).

Among the study participants, 240 (23.6%) had at least one periapical infection. The number of periapical infections per participant varied from 0 to 19 periapical infections. About one-fifth of the study participants (21.1%) had mild periapical infections (1-3 lesions), 2.3% had moderate periapical infections (4-6 lesions) and 0.3% had severe periapical infections (more than 6 lesions) (table 2).

215 participants (21.2%) had both periapical lesions and dental caries. 89.6% of the participants who had periapical infections had also dental caries.

Table 2. Background characteristics and descriptive analysis (n= 1016)

<b>Variable</b>	<b>Count (%)</b>	<b>Mean (SD)</b>	<b>Median</b>	<b>Minimum</b>	<b>Maximum</b>
Mother age, years	1016	25.5 (6.1)	25.0	14.4	49.2
Gestational age at enrolment, weeks	1016	16.8 (2.1)	17.0	11.6	21.0
Gestational age at delivery, weeks	1016	39.4 (2.3)	39.7	17.7	45.0
Participants with carious teeth	580 (57.1%)	N/A	N/A	NA	NA
Participants with periapical lesions	240 (23.6%)	N/A	N/A	NA	NA
Participants with dental caries & periapical Lesions	215 (21.2%)	N/A	N/A	N/A	N/A
Number of carious teeth per participant	NA	1.6 (2.2)	0.0	0.0	14.0
Number of periapical lesions per participant	NA	0.5 (1.2)	0.0	0.0	19.0
BMI	1016	22,1 (2.7)	21.6	16.1	36.9
Low BMI	54 (5.3%)				
Normal BMI	844 (83.1%)				
High BMI	118 (11.6%)				
MUAC	1016	26.3 (2.5)	26.1	19.7	39.6
Low MUAC	71 (7%)				
Normal MUAC	603 (59.4%)				
High MUAC	342 (33.6%)				

### 5.1.3. Anthropometric measurements

Table 2 describes MUAC and BMI values of the participants. The BMI value among study participants varied from 16.1 to 36.8 kg/m<sup>2</sup>, with the mean BMI of 22.1 kg/m<sup>2</sup>. The majority of participants (83.1%) had normal BMI value. Participants who were underweight represented 5.3% of the study population and the overweight represented 11.6% of the study sample.

The MUAC varied among the study participants from 19.7 cm to 39.6 cm, with mean MUAC of 26.3 cm. 59.3% of the study population had normal MUAC (23-27 cm), 33.7% had high MUAC (>27 cm) and about 7% had a low MUAC (<23cm) (Table 2.).

## **5.2. The association of dental caries and periapical lesions with anthropometric measurements.**

As described in table 3, participants who had dental caries, had a higher mean BMI, compared to those who did not have any dental caries (p=0.061). Also, participants who had periapical lesions had slightly higher mean MUAC than those who did not have any periapical lesions (p=0.191).

Regarding the MUAC, participants who had dental caries had a higher mean MUAC than those participants who did not have any dental caries (p= 0.007). In addition, mean MUAC of participants who had periapical lesions was higher than mean MUAC of participants who did not have periapical lesions (p= 0.01).

Table 3: Comparison between dental diseases (dental caries and periapical lesions) and anthropometric measurements (BMI and MUAC)

Variables	Dental Caries				Periapical Lesions			
	No	Yes	Crude difference in Means	p-value	No Mean (SD)	Yes Mean(SD)	Crude difference in Means	p-value
<b>Mean BMI, (SD)</b>	21.9 (2.5)	22.2 (2.8)	0.3	0.061	22.0 (2.6)	22.2 (2.9)	0.2	0.191
<b>Mean MUAC, (SD)</b>	26.1 (2.3)	26.5 (2.6)	0.4	0.007	26.2 (2.5)	26.7 (2.7)	0.5	0.010

### **5.3. Multinomial logistic regression**

The unadjusted univariate multinomial logistic regression found that there was no statistically significant association between the presences of dental caries or periapical lesions and BMI (either low or high) (Table 4). In other words, the insignificant odds ratio of having low BMI, over having normal BMI, was 1.1 for participants with dental caries, relative to those who do not have caries. The insignificant odds ratio of having high BMI, over having normal BMI, was 1.5 for participants with dental caries, relative to those who do not have caries. The insignificant odds ratio of having low BMI, over having normal BMI, was 1.3 for participants who had periapical lesions, relative to those who do not have them. The insignificant odds ratio of having high BMI, over having normal BMI, was 1.3 for participants who had periapical lesions, relative to those who do not have them.

As indicated in table 5, there was no statistically significant association between the presence of dental caries or periapical lesions and low MUAC. Nevertheless, there was a statistically significant association between caries and high MUAC and a stronger significant association between periapical lesions and high MUAC. The insignificant odds ratio of having low MUAC, over having normal MUAC, was 1.1 for participants with dental caries, relative to those who do not have caries. In addition, the insignificant odds ratio of having low MUAC, over having normal MUAC, was 1.0 for participants who had periapical lesions, relative to those who do not have them. However, the significant odds ratio of having high MUAC, over having normal MUAC, was 1.3 for participants with dental caries, relative to those who have caries (95% CI 1.0 -1.7,  $p=0.046$ ). The significant odds ratio of having high MUAC, over having normal MUAC, was 1.6 for participants who had periapical lesions, relative to those who do not have them (95% CI 1.2 – 2.2,  $p=0.002$ ).

Table 4. The odds ratio for having a low or high BMI, compared to those who have normal BMI, by dental diseases status (dental caries and periapical lesions)

	Low BMI			High BMI		
	N (%)	OR (95% CI)	P-value	N (%)	RR (95% CI)	P-value
Presence of dental caries	31 (5.3%)	1.1 (0.6-1.9)	0.831	77 (13.3%)	1.5 (1.0- 2.2)	0.056
Absence of dental caries	23 (5.2%)	Reference category		41 (9.4%)	Reference category	
Presence of periapical lesions	15 (6.3%)	1.3 (0.7-2.4)	0.396	33 (13.8%)	1.3 (0.9- 2.0)	0.211
Absence of dental caries	39 (5.0%)	Reference category		85 (11.0%)	Reference category	

- Generated by unadjusted multinomial logistic regression

Table 5. The odds ratio for having a low or high MUAC, compared to those who have normal MUAC, by dental diseases status (dental caries and periapical lesions)

	Low MUAC			High MUAC		
	N (%)	OR (95% CI)	P-value	N (%)	RR (95% CI)	P-value
Presence of dental caries	40 (6.9%)	1.1 (0.7-1.8)	0.796	210 (36.2%)	1.3 (1.0- 1.7)	0.046
Absence of dental caries	31 (7.1%)	Reference category		132 (30.3%)	Reference category	
Presence of periapical lesions	15 (6.3%)	1.0 ( 0-6-1.9)	0.912	101 (42.1%)	1.6 (1.2-2.2)	0.002
Absence of periapical lesions	56 (7.3%)	Reference category		241 (31.1%)	Reference category	

- Generated by unadjusted multinomial logistic regression

## **6. DISCUSSION**

### **6.1. Main results of the study**

The study investigated the association of dental caries and periapical lesions with anthropometric measurements (BMI and MUAC) among postpartum women in rural Malawi. The study did not find any statically significant association of either dental caries or periapical lesions with BMI or low MUAC. However, the study found a statistically significant association between dental caries and high MUAC and a stronger significant association between periapical lesions and high MUAC. Therefore, the study results do not support the hypothesis that dental caries and periapical lesions are associated with low anthropometric measurements (BMI and MUAC).

The hypothesis was formulated based on the characteristics, lifestyle, dietary habits, oral hygiene and healthcare access of the study participants, who live in a rural context. People living in a similar context usually ate unrefined, coarse and hard-to-chew food which made the chewing and mastication process painful, especially if dental caries or periapical lesions are present. That painful process and discomfort could have led to less food intake and less frequent meals, which might influence the weight, BMI, and MUAC to be lower. (Benzian et al. 2011).

The study results may be attributed to the possible urbanization, discrepancies among the study population, the change in the dietary pattern and eating behaviors that introduced softer, sugary and calorie-dense food to the rural contexts, in addition to the better oral hygiene practices and access to oral health care services.

## **6.2.The association of dental caries and periapical lesions with low anthropometrics**

The significant association of dental caries and periapical lesions with low anthropometric was mainly investigated among children, not adults. For example, a cross-sectional study (n=1951) found a significant association between caries-related odontogenic infections and low BMI in 12-year-old children in the Philippines (Benzian et al. 2011). Also, rampant caries was associated with being underweight and having low growth rate among 3-5 years children in a case-control study (Ayhan et al. 1996).

The previously mentioned studies investigated the association in deciduous dentition or mixed deciduous and permanent dentition, which is different in nature and composition than the adult permanent dentition. The increased growth hormone secretion among children and adolescents might influence the enamel composition, making the teeth more susceptible to dental caries (Li et al. 2015). There were no published studies about this association among adults or pregnant women.

## **6.3.The association of dental caries and periapical lesions with high anthropometrics**

The increased prevalence of dental caries and periapical lesions was usually associated with increased food intake and consumption of sugary and refined food. These are the same risk factors associated with increased weight and high BMI. (Alswat et al. 2016). Caries and periapical infections could be worsened by the limited dental care in rural areas, expensive associated cost and poor oral hygiene practices. However, this study did not find a significant association of dental caries or periapical lesions with the high BMI.

The previously mentioned studies are contradicting with other studies that found a positive association of dental caries or periapical lesions with high BMI. Among children, a case-

control study (n=235 participants) found a significant association between early childhood caries and high BMI among preschool children (Davidson et al. 2016).

This study found a significant association between high MUAC and caries and a stronger association between High MUAC and periapical lesions. This association was not investigated in any published article.

Contradicting studies have been published where no association was found between dental diseases and anthropometric measurements among children (Mojarad et al. 2011, Alves et al. 2013, Kurian et al. 2016, and Chakravarthy et al. 2016). The previous results were attributed to the common risk factors, for example, dietary habits, socioeconomic status, the level of education and urbanization.

#### **6.4. Multifactorialism of dental diseases and anthropometrics**

The inconsistent findings on the association of dental caries and periapical lesions with anthropometric measurements suggested the investigation of factors that could be influencing both dental diseases and anthropometric measurements. These factors included diet, age, socio-economic status, race, culture, education, urbanism, hygiene habits and study settings (Hooley et al. 2012).

The role of diet and socioeconomic status as possible risk factors or confounders is interlinked, complex and different based on study population, urbanization and development status. For example, a study in India linked high socioeconomic status with increased risk of caries prevalence because of increased food intake, meal frequency, lifestyle, consumption of calories dense food and food variety (Chopra et al. 2015). Another conflicting study in Sweden, a developed country, associated high socioeconomic status with less caries prevalence (Gerdin et al. 2008) and that was attributed to the better hygiene habits, better dental care, and lifestyle.

Previous studies found age as one of the important risk factors in both dental disease and anthropometric measurements (Gerdin et al. 2008). Dental diseases usually take years to be developed and usually remain neglected or untreated in rural underserved contexts (Selwitz et al. 2007). That is also aligning with the increase in weight among older people (Seidell et al. 2000). Therefore, further studies are recommended in this area.

For the socioeconomic status of the study population, data on this variable was not collected when this study analysis started. Therefore, the data analysis was not adjusted for socioeconomic status.

It is important to clarify that dental caries and periapical infections are not separate diseases, as they always happen in the same affected teeth. The periapical lesions usually develop from deep caries (Leggiadro 2009).

### **6.5.Strengths of the study**

The study is the first of its scale to investigate the association of dental diseases and periapical lesions with anthropometrics (BMI and MUAC) among this population of postpartum women in a rural context of Malawi, sub-Saharan Africa.

The enrolment of participants, data collection, and data management have taken all the required measures to minimize bias through strict quality assurance in data collection, combining clinical examination with radiographic examination, measurement equipment calibration, the clearly defined inclusion and exclusion criteria.

There was no previous baseline oral health data in Mangochi, rural Malawi. This study, along with the other iLiNS-DYAD-M studies, serve as a coherent reliable source of information about the oral health status in this population.

## **6.6.Limitations of the study**

A study limitation is that the data was not collected at the same time as the anthropometric measures were collected at study enrollment, where participants were in the early pregnancy ( $\leq 20$  weeks of gestational age). The dental data was collected after delivery ( $\leq 6$  weeks postnatal). Dental data collection during pregnancy was not possible because of the iLiNS study nature as a clinical trial. The detailed description of the iLiNS limitations is mentioned elsewhere (Ashorn et al. 2015). However, the different timing of data collection is not regarded as a concerning limitation, because caries and periapical lesions are chronic diseases that take a very long time that can be years, to be developed and were expected to be present already at the beginning of the pregnancy (Selwitz et al. 2007). Therefore the results are believed to consistent and reliable.

The study data was nested from a randomized, controlled trial (iLiNS-M-DYAD), not specifically collected for this study. In addition, the study participant received interventions that were associated with increased cariogenic activity. Study participants who had multiple micronutrient supplements or lipid-based nutrient supplement as the nutrient intervention of the study had higher caries prevalence and lesions (Harjunmaa et al. 2015). The higher caries prevalence among the study population might thus be slightly accelerated compared to the mean caries prevalence of participants who did not participant in the trial, in the study area.

## 7. CONCLUSION

The study did not find any statically significant association between dental caries or periapical lesion with low or high BMI or low MUAC, among postpartum women in rural Malawi. However, dental caries and periapical lesions were associated with high MUAC. Therefore, the study outcomes reject the hypothesis that dental caries and periapical lesions were associated with low anthropometric measurements (BMI and MUAC). That association is probably not causal, but due to the multifactorial nature of both dental diseases and anthropometrics, and the common risk factors.

Obesity, dental caries, and malnutrition are among the most common global health burdens. Therefore, further studies are recommended for in-depth investigation and understanding of the nature of the association between dental diseases and anthropometrics, whether it is a causal association or they share the same risk factors. Some previous studies found positive associations, some found negative associations and others found no association at all (Mojarad et al. 2011, Alves et al. 2013, Kurian et al. 2016, and Chakravarthy et al. 2016).

MUAC is more sensitive and a better anthropometric measurement to capture the malnutrition among pregnant and postpartum women (Singh et al. 2015, Ververs et al. 2013). It is recommended to use MUAC as a reliable indicator among postpartum women in further studies in similar contexts.

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I would like to dedicate this thesis to my late mother Mrs. Samia El-Shabasy.

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