

Sweet Taste Perception in Relation to Oral and General Health

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To Anna and Jaddi...

ABSTRACT

Oral health is today considered as an integral part of general health and as being essential to the overall well-being. Several oral and general health conditions share similar predisposing factors. Among these are dental caries and obesity where both are dietary-related diseases, with sugar as one of the key elements.

Objectives: The aims of this thesis were to study the difference in sweet taste perception, dental caries and BMI between three different geographical areas (Italy, Mexico and Saudi Arabia) and to elucidate the relationship of sweet taste perception with caries and BMI. Dietary habits were also assessed in relation to sweet taste perception in Saudi Arabia. In addition, the differences in sweet taste perception and plaque acidogenicity between pregnant and non-pregnant Saudi Arabian women were assessed.

Materials and methods: For papers I, II and III, 669 schoolchildren, 13-15 years-old (220 Italian, 224 Mexican and 225 Saudi Arabian) were included, while in paper IV the study subjects were a total of 121 Saudi Arabian women (41 non-pregnant, 40 early pregnant and 40 late pregnant). Sweet taste perception was determined by evaluating the sweet taste threshold (TT) and sweet taste preference (TP). For caries registration, DMFS, DMFT and ICDAS indices were used. The BMI-for-age scale was used for anthropometric assessments of the schoolchildren in paper II. In paper III, Saudi schoolchildren dietary habits were assessed via an estimated three-day dietary record and questionnaire. Plaque acidogenicity was determined for Saudi Arabian women in paper IV using the strip method. Statistical analysis for the different variables were conducted using different parametric and non-parametric tests.

Results: Differences were found when comparing the three countries in terms of sweet taste perception (TT and TP). When assessing differences between the countries regarding the dental caries variables, a significant difference was found for DMFS and initial caries, with the highest mean value found among the Saudi Arabian schoolchildren. Sweet taste perception (TT and TP) was found to be related to DMFS and manifest caries in the three countries (Italy, Mexico and Saudi Arabia). A statistically significant difference was found between the three countries in terms of BMI value. No correlation was found between sweet taste perception (TT and TP) and BMI. In Saudi Arabia, sweet taste perception was found to be related to different dietary habits. Sweet taste perception differed significantly between non-pregnant, early pregnant and late pregnant women. In addition, significant differences were reported for plaque acidogenicity, with a lower pH value among the pregnant group.

Conclusion: The existing differences observed in schoolchildren between the countries in terms of sweet taste perception, dental caries and BMI are believed to be due to cultural and environmental factors. The sweet taste perception level was found to have an effect on dental health while no such relationship was found with BMI. In addition, findings also suggest a higher risk of developing dental caries among pregnant women. Thus, they should be addressed as a high risk group.

Keywords: BMI, Caries prevalence, Children, Dental caries, Dietary habits, Italy, Mexico, Obesity, Plaque pH, Pregnancy, Saudi Arabia, Sweet taste perception

SAMMANFATTNING PÅ SVENSKA

Oral hälsa anses idag utgöra en del av allmänhälsan och ha stor betydelse för en individs välbefinnande. Flera orala och medicinska sjukdomstillstånd delar gemensamma riskfaktorer. Detta gäller exempelvis för karies och fetma som båda är kostrelaterade sjukdomar med socker som en av de huvudsakliga faktorerna vid uppkomst av sjukdom.

Syfte: Målsättningen med denna avhandling var att studera skillnader i söthetsupplevelse, karies och BMI mellan skolbarn i tre länder (Italien, Mexiko och Saudarabien) samt att studera sambanden mellan söthetsupplevelse och karies respektive BMI. För ungdomar från Saudarabien utvärderades även kostvanor i relation till deras söthetsupplevelse. I en delstudie jämfördes skillnaden i upplevelse av söt smak och det dentala plackets syrabildande förmåga mellan gravida och icke gravida kvinnor i Saudarabien.

Material och metod: I delarbete I, II och III deltog 669 barn (220 Italien, 224 Mexiko och 225 Saudarabien) i åldern 13-15 år och i delarbete IV 121 kvinnor från Saudarabien (41 icke gravida, 40 under tidig graviditet och 40 under sen graviditet). Söthetsupplevelsen bestämdes genom att fastställa i) den nivå då den söta smaken först noterades och ii) den nivå då smaken ansågs optimal. Vad gäller karies registrerades DMFS, DMFT, ICDAS samt antal initiala och manifesta kariesskador. För bedömning av fetma beräknades BMI (vikt/m²). För skolbarnen i Saudarabien insamlades information om deras kostvanor genom en 3-dagars matdagbok och ett frågeformulär. Plackets syrabildade förmåga bestämdes för kvinnorna i delstudie IV med hjälp av den s.k. "Stripmetoden".

Resultat: Skillnader i söthetsupplevelse sågs mellan skolbarnen i de tre länderna. Vad gäller DMFS och initial karies sågs signifikanta skillnader mellan de tre länderna med de högsta värdena för Saudarabien. Smakupplevelsen var relaterad till DMFS och förekomsten av manifest karies för barnen i samtliga tre länder. För BMI registrerades en signifikant skillnad mellan Italien, Mexiko och Saudarabien. Inget samband kunde ses mellan smakupplevelse och BMI. För skolbarnen i Saudarabien var söthetsupplevelsen relaterad till deras kostvanor. För kvinnorna sågs skillnad i upplevelse av den söta smaken mellan icke gravida, tidig graviditet och sen graviditet. Vidare sågs signifikanta skillnader mellan de tre grupperna avseende plack-pH med ett mer uttalat pH-fall för de gravida kvinnorna.

Slutsatser: Smakupplevelse, karies och BMI skilde sig åt mellan skolbarnen i de tre länderna. Detta bedöms bero på variationer i kultur och kostvanor. Samband sågs mellan söthetsupplevelse vid jämförelse med både DMFS och förekomst av manifest karies. Upplevelsen av söt smak var relaterad till individens kostvanor, vilket bedöms ha betydelse både för den orala och generella hälsan. Vad gäller inverkan av graviditet visade data att gravida kvinnor har ett högre söthetsbehov och deras biofilm en högre syrabildande förmåga, vilket indikerar en högre kariesrisk.

LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

- I. Ashi H, Lara-Capi C, Campus G, Klingberg G, Lingström P. Sweet taste perception and dental caries in 13- to 15-year-olds: A multicenter cross-sectional study. *Caries Res* 2017; 51: 443-450.
- II. Ashi H, Campus G, Lara-Capi C, Klingberg G, Bertéus Forslund H, Lingström P. Childhood obesity in relation to sweet taste perception and dental caries - a cross-sectional multicenter study. 2017 (Submitted).
- III. Ashi H, Campus G, Bertéus Forslund H, Hafiz W, Ahmed N, Lingström P. The influence of sweet taste perception on dietary intake in relation to dental caries and BMI in Saudi Arabian schoolchildren. *Int J Dent* 2017. <https://doi.org/10.1155/2017/4262053>
- IV. Sonbul H, Ashi H, Aljahdali E, Campus G, Lingström P. The influence of pregnancy on sweet taste perception and plaque acidogenicity. *Matern Child Health J* 2017; 21: 1037-1046.

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ABBREVIATIONS

AUC _{5.7}	Area under the curve at pH value of 5.7
AUC _{6.2}	Area under the curve at pH value of 6.2
BMI	Body Mass Index
BS	Beverage sweet intake score
DMFS	Number of decayed, missed and filled tooth surfaces
DMFT	Number of decayed, missed, filled tooth
ICDAS	International Caries Detection and Assessment System
SS	Snack sweet intake score
TP	Sweet taste preference
TT	Sweet taste threshold

INTRODUCTION

Taste is one of the five senses in humans. It plays an important role in the human body and may affect the quality of life. The taste sensation allows us to recognise different flavours from the diet we consume. It is induced by a series of signals transmitted via certain proteins and receptors to the central nervous system [Joseph et al., 2016]. Those receptors, are located throughout the entire mouth but they are mainly concentrated on the tongue and presented with different shapes and anatomical structure.

Five types of taste are known: bitter, salty, sour, sweet and umami (savory). All the varieties of flavour that humans experience are a combination of one or more of these tastes. Since the beginning of time, taste sense have played a role in the well-being of an individual by assisting in deciding whether ingested food is harmful or safe [Drewnowski, 2000; Mennella and Bobowski, 2015]. In particular, the perception of sweetness is usually associated with pleasantness, while bitterness is a warning sign indicating that ingested food may be poisonous.

Sweet preference is an instinct that starts at an early age and can be altered throughout life [Drewnowski, 2000; Mennella, 2014; Mennella and Bobowski, 2015]. This preference for sweets becomes less pronounced with increasing age, with the highest preference among children. However, sweet preference and subsequent dietary choices differ from one person to another. Therefore, ways of modifying sweet preference have been the subject of discussion for years and efforts have constantly been made to try to control the sugar content in our diet. The attention devoted to sweetness or taste in general may be due to the fact that many oral and general conditions have some association with sugars and diet in one way or another. These diseases include dental caries, obesity as well as diabetes, heart diseases and other obesity-related diseases [Reilly et al., 2003; Peres et al., 2016; WHO, 2016a].

In the past, oral health was often looked upon as a separate entity than general health. However, following advances in health care and medicine, oral health is now regarded as an integral part of general health and as being essential to the overall well-being of an individual. Several oral and general health conditions share similar predisposing or etiological factors. Two conditions that fit this description are dental caries and obesity where both are dietary-related diseases, with sugar as one of the key elements [Modeer et al., 2010; Robino et al., 2015; Moynihan, 2016; Proserpio et al., 2016].

Therefore, a healthy balanced diet is essential for the well-being of an individual from early life and care should therefore begin by addressing the parents, particularly the mothers. Information should be given to mothers about the etiology of dietary-related diseases and how to prevent them by introducing healthy diets to their children. It is important that this education starts even as early as pregnancy.

Dental Caries

Nature and etiology

Dental caries is the tooth destruction, which develops as a result of the interaction between host-related factors, cariogenic microorganisms and diet [Fejerskov, 2004; Marshall et al., 2007; Selwitz et al., 2007]. The host-related factors include the dental biofilm, salivary factors and oral hygiene [Selwitz et al., 2007]. Caries is subject to several environmental and social factors which affect its development, progress and outcome [Moynihan and Petersen, 2004; Yildiz et al., 2016]. These factors include cultural, sociodemographic and socioeconomic situations, preventive strategies and access to treatment [Moynihan and Petersen, 2004; Marshall et al., 2007; Modeer et al., 2010; Masood et al., 2012; Kramer et al., 2016]. Genetics also play an important role in the personal variation in caries susceptibility [Opal et al., 2015].

All the above variables contribute to the complex multifactorial nature of dental caries. Thus, susceptibility to caries and subsequent outcomes may differ greatly from one person to another.

Prevalence

Dental caries in both deciduous and permanent teeth is the most prevalent chronic disease affecting millions of subjects worldwide [Petersen, 2003; Kassebaum et al., 2015]. A high prevalence is still reported in several countries, as well as in special population groups. From an international perspective, in particular the developing countries such as countries in the Middle East, have a high disease prevalence [Moynihan and Petersen, 2004; Khan, 2014; Abid et al., 2015; Farooqi et al., 2015].

A decline in caries prevalence has been observed during the past three decades due to the implementation of caries-prevention strategies [Moynihan and Petersen, 2004]. However, that decline has now reached a plateau phase, especially in younger age groups and developing countries [Moynihan and Petersen, 2004]. Thus, it remains a public oral health concern, since a high

percentage of the population is affected by caries worldwide and particularly in children [Petersen, 2003; Petersen and Lennon, 2004].

Sugars and dental caries

Due to the metabolism of the sugars in our diet in the oral cavity, the plaque bacteria produce acids that cause demineralisation of the tooth structure [Featherstone, 2000]. Among the types of sugars, sucrose is regarded as the main etiological factor in the caries process [Zero, 2004; Paes Leme et al., 2006; Anderson et al., 2009; Alm et al., 2012]. This is related to the accumulation of polysaccharides from the excess sugar and the pronounced decrease in pH following the metabolism of sugar by bacteria [Guggenheim, 1970; Paes Leme et al., 2006].

Conventionally, the frequency of sugar consumption has been regarded as important; however, the amount has recently been found to be of importance as well [Sheiham and James, 2014; Bernabe et al., 2016; Moynihan, 2016; Peres et al., 2016]. The frequency and amount of sugar are mutually dependent and thus have a parallel effect on the caries development process [Moynihan and Petersen, 2004]. Though sugars and bacteria are factors in the caries causal line, but the outcome is determined by the susceptibility of the tooth, bacterial profile, saliva properties and diet [Moynihan and Petersen, 2004]. Therefore, research has shown that sugar intake should be limited [Anderson et al., 2009; Moynihan and Kelly, 2014; Sheiham and James, 2014].

Plaque acidogenicity and dental caries

Plaque acidogenicity refers to the process of ecological shift that occurs in the dental biofilm due to the effect of bacteria after exposure to sugar [Stephan, 1940; Stephan, 1944; Bowen, 2013]. Studies then focused on the effect of the sucrose on plaque acidogenicity and reported its relationship to the risk of caries [Lingström et al., 2000; Paes Leme et al., 2006; Aranibar Quiroz et al., 2014].

Plaque pH decreases as a response to the formation of acid by the oral bacteria and demineralisation occurs in particular due to the loss of the calcium compound in the tooth tissue as it becomes highly soluble [Moynihan and Petersen, 2004]. Low plaque pH is an ideal environment for colonisation by cariogenic microorganisms [Moynihan and Petersen, 2004]. Therefore, to prevent dental caries, a pH neutral environment is desirable and it can be created by shifting the plaque ecology and neutralising the sugar-

induced decrease in its pH [Featherstone, 2000]. In addition, the process can also be reversed through salivary properties [Moynihan and Petersen, 2004].

Caries prevention

Dental caries can affect any of the tooth surfaces and may also extend beyond the crown to the root surface. Caries can have a major influence on quality of life and nutrition. Where the esthetic part of the tooth can affect the subject's self-esteem and the masticatory function can affect the ability to obtain good nutrition [Moynihan and Petersen, 2004; Peres et al., 2016]. Disease prevention is therefore always of great importance and it is known to have an effect on the outcome of diseases. It is well known that prevention is always preferable in comparison to treatment in terms of time, cost and the minimally invasive perspective in preserving a sound tooth structure.

Three levels of caries prevention were previously mentioned by Longbottom et al. [2009]. First, there is primary prevention prior to disease initiation, which aims to prevent its occurrence. Second, there is secondary prevention after the clinical signs of caries have manifested in order to help arrest the lesion. Third, tertiary prevention involves removing the irreversibly damaged dental tissue to prevent caries progression [Longbottom et al., 2009].

Over the years, different strategies have been suggested to prevent caries. They include fluoride application, sealant and adopting healthy dietary and oral hygiene habits. The introduction of fluoride, where the introduction of fluoridated toothpaste in particular has played an important role, is considered the major factor [Moynihan and Petersen, 2004; Arola et al., 2009; Mannaa et al., 2014a; Mannaa et al., 2014b].

In addition, particularly regarding diet, part of the strategy to be adopted can be defined as health promotion by preventing the occurrence of the disease rather than treatment [WHO, 2016b]. Integrating a healthy dietary regimen into the daily routine can have a real influence on oral health and can be regarded as a primary step towards caries prevention. Moreover, several food items such as cheese, grains and milk have been found to have preventive properties in relation to caries.

A caries risk assessment is also necessary to identify the appropriate method of treatment and prevention. Several caries risk assessment strategies and methods have been developed, all of which can improve the caries outcome and help control the disease. Commonly used methods today are the Cariogram and CAMBRA systems, where several caries-related variables are

evaluated in order to predict the subject's future susceptibility to caries and the chance of avoiding it [Featherstone et al., 2003; Featherstone, 2004; Bratthall and Hänsel Petersson, 2005].

Individuals with an increased risk of dental caries

Due to the multifactorial nature of dental caries, the individual's vulnerability may differ from one another where some may be more susceptible to a higher risk of developing the disease.

Adolescence is a period in life in which there is an increased risk of caries development. This is particularly related to the eruption of new tooth surfaces at this age, which have greater susceptibility to caries [Moynihan and Petersen, 2004]. Parental influence also plays a role in the caries development and Alanzi et al. [2013] reported that the mothers' taste perception may be an important predictor of caries experience in children.

In addition, children's dietary habits largely influence their risk of developing caries. Children are thought to like sweets more than adults and a high preference of sugar among children has been reported [Drewnowski, 2000; Liem and de Graaf, 2004; Mennella and Bobowski, 2015]. In addition, elderly nowadays are also at a high risk to develop caries as they are currently retaining an increased number of their own teeth in high age [Norderyd et al., 2015]. Thus, they still face the same dietary challenges as other age groups.

Another vulnerable group to develop dental caries are pregnant women. It has been found that pregnancy may increase the tendency to develop caries [Martinez-Beneyto et al., 2011; Vergnes et al., 2012]. Several oral changes occur during pregnancy and they can therefore affect the oral health among pregnant women [Barak et al., 2003].

Among other factors or changes, research has shown that pregnant women experience reduced saliva production and salivary pH [Rockenbach et al., 2006]. These salivary changes can lead to a decrease in plaque pH, resulting in an increased accumulation of dietary carbohydrates on the tooth surface [Lingström and Birkhed, 1993; Aranibar Quiroz et al., 2003]. Dietary alterations may also occur in pregnancy such as cravings for sweets [Belzer et al., 2010; Saluja et al., 2014]. Which in turn affects the susceptibility of pregnant women to dental caries. These changes may be attributed to pregnancy-induced hormonal imbalances [Silk et al., 2008].

Moreover, other factors affecting pregnant women oral health includes the fear of harming the unborn child by having frequent regular dental check-ups [Ressler-Maerlender et al., 2005]. For example, fear of exposure to X-rays or oral hygiene measures such as scaling and the use of anesthesia in conjunction with restorations.

Obesity

Obesity is defined as a condition in which excess body fat accumulates from an energy imbalance that may affects the subject's health [WHO, 2016a]. It may lead to different medical conditions and is related to oral health. Obesity shares several etiological factors with dental caries, namely diet and, in particular, sugar intake [Costacurta et al., 2014]. Similar to dental caries, obesity is a multifactorial disease that is spreading globally.

Prevalence

There is a growing global concern regarding obesity, especially in low and middle income countries [Ng et al., 2014; Farpour-Lambert et al., 2015; Apovian, 2016]. Over 42 million overweight children were reported by the World Health Organisation in 2014 [WHO, 2016a]. Childhood obesity threatens the lives of many children around the world and may persist in adulthood, leading to serious implications in relation to general health [Reilly et al., 2003].

Etiology

Different genetic, cultural, sociodemographic and environmental factors may affect the susceptibility to obesity [Marshall et al., 2007; Qi and Cho, 2008; Modeer et al., 2010; Apovian, 2016; Kyle et al., 2016; Winkvist et al., 2016]. There also appears to be a geographical pattern to this tendency [Winkvist et al., 2016]. For example, living in a rural area has been found to be linked to a higher risk of obesity than living in an urban areas [Winkvist et al., 2016].

In addition, a high level of sucrose and energy in the diet is regarded as one of the main environmental factors responsible for obesity [Winkvist et al., 2016]. Snacks with a high fat and sugar content have also been found to be associated with both overweight and obesity [Washi and Ageib, 2010; Murakami and Livingstone, 2016]. Therefore, diet constitutes a principal factor in the etiology of obesity [Gutierrez-Pliego et al., 2016; Proserpio et al., 2016].

Since dental caries and body weight are considered dietary-related health outcomes, an association between the two may be found. This supposed association has been mainly studied in adolescents from industrialized countries through Body Mass Index (BMI) [WHO, 2006; Hayden et al., 2013]. Conflicting findings has been described in the literature on the relationship between caries disease and bodyweight; where no associations, positive or negative, have been reported [Hooley et al., 2012].

Diet and health

Diet is a basic foundation of living and survival of humankind. It is essential to obtain proper nourishment in order to thrive and develop in a healthy manner. As previously mentioned, several conditions are affected by the nature and type of diet consumed. The adopted dietary habits can be either harmful or beneficial and may even prevent from diseases. A healthy diet that is beneficial to oral health has the same influence on general health. People may have control over what they eat or drink, but still there are other factors that can alter their dietary choices and determine what is finally consumed.

Different cultural, environmental, socioeconomic factors and personal preferences can predict the nature and quality of food intake [Washi and Ageib, 2010; Hall et al., 2017]. The geographical situation may also have an influence on the type of dietary intake [Winkvist et al., 2016]. Several recent studies have reported that genetic factors may also play a role in dietary choices and sweet intake [Negri et al., 2012; Opal et al., 2015]. In contrast, Drewnowski et al. [2007] found no relationship between genetics sensitivity and dietary or sweet intake.

The sense of taste is another important factor that influences dietary intake. It is considered as one of the main motives in determining food choices and preferences [Negri et al., 2012; Fogel and Blissett, 2014; Kourouniotis et al., 2016; Mennella et al., 2016; Proserpio et al., 2016].

The influence of taste on diet begins early in life. When it comes to the maternal influence on diet, this may start as early as in the womb. Food and a noticeable preference for sweets can be transmitted from mother to baby through the amniotic fluid and mother's milk [Drewnowski et al., 2012; Wahlqvist et al., 2015]. In addition, a recent study has suggested that smell also plays an important role in dietary choices [Monnery-Patris et al., 2015].

Dietary habits in pregnancy

Pregnancy is a period in which women experience hormonal changes that may cause different dietary cravings [Faas et al., 2010; Choo and Dando, 2017]. These dietary changes have been found to occur during the early stages of pregnancy and they decline towards the end [Nordin et al., 2004; Choo and Dando, 2017]. This is due to the sudden rush and fluctuation of hormones early in pregnancy [Choo and Dando, 2017]. An increased appetite for sweet dietary items is one of the common cravings and dietary changes seen during pregnancy [Saluja et al., 2014; Orloff et al., 2016].

Attention to a pregnant woman's diet is therefore important and it is also vital in ensuring the health of the unborn child [Meyer et al., 2010; Meyer et al., 2014]. As previously mentioned, taste or flavour can be transmitted from a mother to her unborn baby and new-born [Drewnowski et al., 2012; Wahlqvist et al., 2015]. Therefore, maternal food choices can have a great effect on their children [Wahlqvist et al., 2015].

Dietary habits in children

Childhood is characterised by a period of growth spurts demanding the right nutrition. However, unhealthy dietary habits in children have been reported worldwide [Andrade et al., 2016; Handeland et al., 2016; Saulle et al., 2016]. This observation holds true for both general nutrition and specific intakes. A high intake of sugar and fat has previously been reported among adolescents [Al-Hazzaa et al., 2011; Allafi et al., 2014].

An increase in sweet consumption by children may be due to parental influence and to the association of growth with an increased need for energy [Drewnowski, 2000; Coldwell et al., 2009; Lanfer et al., 2012]. In addition, the educational level of the mother has been found to be a major influence on her children's diet [Pawellek et al., 2017]. Other factors influencing diet in children were reported by Pawellek et al. [2017], where the country of residence and the child's order in the family were linked to increased sugar intake in diet.

It is innate in the biology of a child to be drawn to sweet taste. More efforts are therefore required to achieve a healthy shift and to resist the surrounding temptations of sweet foods [Mennella et al., 2014]. Such a shift can be facilitated if the desired lifestyle changes are first applied to the children's social environment including home. The food that is served to a child could modify that child's taste preference and consequently its dietary choices. It is

therefore important to focus on healthy habits from childhood through parents education [Mennella, 2014].

Children have different motives for adopting healthy lifestyles. It has been found that around 11.3% of children have been reported to adopt a healthy lifestyle due to its beneficial effect on their wellbeing, while the large remainder are concerned about the way it may affect their appearance [Washi and Ageib, 2010].

Sweet taste perception

As previously mentioned, different taste senses are known to mankind and sweet taste was found of an interest in relation to different conditions. Worldwide, sweet food is easily accessible and there is a common belief that it has a good taste and when added makes other types of food pleasant [Mennella and Bobowski, 2015]. Sugar also serve other functions, such as being used for food preservation, and it symbolises something positive and is particularly consumed at different celebrations. This preference for sweet taste is not believed to be solely a culturally acquired trait, but rather a natural instinct from childhood [Mennella, 2014; Mennella and Bobowski, 2015]. Furthermore, repeated exposure to certain sweetened food items can also alter taste perception and increase the preference for these products [Jamel et al., 1997; Keller et al., 2014; Kourouniotis et al., 2016].

Taste perception is known to be influenced by cultural, environmental and genetic factors [Mennella et al., 2005; Haznedaroglu et al., 2015; Opal et al., 2015]. Ageing has also been found to be a factor that affects taste and the liking for sweet food [Mennella et al., 2014; Guido et al., 2016; Joseph et al., 2016]. The preference for sweet taste undergoes specific changes throughout life, as it decreases with age and appears less distinct in adulthood [Drewnowski, 2000; Liem and de Graaf, 2004; Mennella and Bobowski, 2015; Mennella et al., 2015]. A possible explanation for this, as stated previously, is that childhood is a period of growth that requires energy which can be provided by sugar intake [Drewnowski, 2000; Coldwell et al., 2009]. In addition, gender has been shown to influence the sucrose detection threshold, which appears to be higher in boys than in girls [Joseph et al., 2016].

Other factors that may affect taste and help identify food choices are hormonal factors [Loper et al., 2015]. For example and as previously mentioned, pregnancy is found to be stage when women can experience taste alterations due to hormonal fluctuation [Choo and Dando, 2017]. In addition,

the sweet taste perception has been found to be influenced by the taste receptor genes [Mennella et al., 2005; Guido et al., 2016; Joseph et al., 2016].

Many studies have linked sweet preference with the sensitivity to the bitter compounds [Verma et al., 2006; Furquim et al., 2010; Keller et al., 2014; Joseph et al., 2016]. In addition, sensitivity to the bitter compound, PROP, may influence different taste sensations, which can in turn have an effect on food preferences and intake [Keller et al., 2002; Dinehart et al., 2006; Verma et al., 2006; Keller et al., 2014].

Sweet taste perception in relation to dental caries and obesity

The level of perception to sweet taste has been found to affect oral and general health by altering the sweet intake. General health is dependent on healthy nutrition, which is in turn dependent on oral status and health.

Reports from different countries have found that dental caries is associated with sweetness preference and thereby a high sugar intake [Jamel et al., 1997; Robino et al., 2015]. Other studies have linked the sweet taste genetic factors with the role of liking sweets as a predisposing factor for caries [Haznedaroglu et al., 2015; Robino et al., 2015].

Regarding obesity, the BMI and sweet threshold have been found to be positively related and, the higher the BMI, the higher the threshold [Guido et al., 2016]. Obese subjects were found to prefer high energy diet with sweet and fatty taste, which contributes to an increase in weight [Lanfer et al., 2012; Proserpio et al., 2016]. Other studies have reported that children with normal weight have a better sensitivity to the taste threshold than those who are obese [Overberg et al., 2012; Park et al., 2015]. Therefore, smaller amount of sweet in the previous group of children needs to be consumed in order to sense the presence of the sweet taste.

Although the reason why the obese individuals have higher taste thresholds than the normal weight group is not fully understood, one of the suggestions that have been considered is that obese subjects show less sensitivity to the sensory based termination signals leading to an increase in energy intake [Park et al., 2015]. Other explanations presented by Park et al. [2015] are the difference in the brain tissue or taste buds between the two groups.

From what can be concluded, both dental caries and obesity are dietary-related diseases and sugars are the main factors in their etiology. The sweet

taste perception is known to influence the subject's dietary habits and so, when focusing on the sweet taste perception, it is of interest to assess its relationship to dental caries and obesity in different populations. In addition, in terms of factors altering taste perception, pregnancy is a period in which it is well known that women experience taste changes and further oral alterations that can affect their oral health. However, its influence on caries risk is still unknown.

AIM

The overall aim of this thesis was to focus on the relationship between sweet taste perception and different oral and general health conditions in schoolchildren 13-15 years of age and pregnant women.

The specific aims of this thesis were:

- to study the differences in sweet taste perception between Italian, Mexican and Saudi schoolchildren (Paper I),
- to study the dental caries experience in Italian, Mexican and Saudi schoolchildren and elucidate the relationship between sweet taste perception and dental caries (Paper I),
- to study the differences in BMI between Italian, Mexican and Saudi schoolchildren and its relation to sweet taste perception (Paper II),
- to evaluate the relationship between sweet taste perception and several dietary habits among Saudi schoolchildren and its relationship to dental caries and BMI (Paper III),
- to study sweet taste perception and plaque pH alteration in pregnant and non-pregnant Saudi Arabian women (Paper IV).

The aims are based on the following hypotheses:

- differences exist between children in the three countries in terms of sweet taste perception level, dental caries and BMI,
- sweet taste perception has an influence on dental caries experience and BMI value,
- sweet taste perception has an influence on children's dietary choices which result in increased susceptibility to caries and obesity,
- pregnant women experience alterations in plaque acidogenicity and taste sense. The later may influence sweet taste preference and subsequently dietary patterns affecting oral health.

PATIENTS AND METHODS

This thesis consists of two main studies on schoolchildren and pregnant women, and the results are presented as four different papers. First, data from the study on schoolchildren are presented in papers I, II, and III. Second, the results from the study on pregnant women are presented in paper IV. The papers will be referred to in this thesis as studies I, II, III, and IV. The main focus of the four studies is sweet taste perception in association with caries, BMI, dietary habits, and plaque acidogenicity.

Ethical considerations

For studies I, II, and III on schoolchildren, the study protocol was submitted to the accountable institute in the three countries (Italy, Mexico, and Saudi Arabia) and ethical approval was obtained:

- Italy: Ethics Committee at the University of Sassari (no. 1073/L 23/07/2012)
- Mexico: Secretary of Education of Veracruz (S.E.V. 30FIS0030Z)
- Saudi Arabia: Ethical Committee at King Abdul-Aziz University, Jeddah (no. 029-12)

A letter describing the study's aims and data collection process was sent to the school's head teachers and parents of participating children. The children were informed about the nature and process of the study. A signature for the consent forms was obtained from the children's parents. At the start of the study, each participant was given a code for use in all data processing.

For study IV on pregnant women, the study protocol was submitted and approved by the ethical committee at King Abdul-Aziz University, Jeddah, Saudi Arabia (no. 003-12). Signed consent forms were obtained from the participants prior to the start of the data collection phase.

Study design

Studies I, II, and III were cross-sectional observational multicenter studies on schoolchildren of the same age from Italy, Mexico, and Saudi Arabia (Table 1). In studies I and II, the children were assessed for their sweet taste perception in relation to dental caries and BMI. In study III, only children from Saudi Arabia were included, and the focus was on dietary habits in relation to different variables (Table 1). Study IV was a cross-sectional study of pregnant women. Their socioeconomic status was determined using two questions on educational level and yearly income.

Table 1. Study subjects, design and main focus of the four included studies.

Study	Sample size	Main topic	Population
I	669	Sweet taste perception in relation to dental caries	Schoolchildren:
			220 Italian
II		Sweet taste perception in relation to BMI	224 Mexican
			225 Saudi Arabian
III	225	Sweet taste perception in relation to dietary habits	Schoolchildren: 225 Saudi Arabian
IV	121	Sweet taste perception and plaque acidogenicity in pregnancy	Saudi Arabian women:
			41 non-pregnant
			80 early and late pregnant

Multicenter study

All the tests, examination forms, and charts were standardized for the three countries. All the examiners participating in the data collection in those countries collaborated and were in constant contact during the duration of the study. Before the start of the study, the steps to be taken at each center were written out in detail, including the materials needed for preparation of sucrose solutions.

Data collection in Saudi Arabia was performed at the selected schools mainly by the main author (HA). In Italy and Mexico, co-author of the papers I and II (CLC) was responsible for collecting data. The data collection took place in the students' classrooms or in the main auditorium of the schools with the subjects seated on their school chairs and under natural light. The main author and co-author met for calibration sessions to coordinate the caries registration and sweet taste perception tests. Additional sessions were completed before the start of the study between the main author and co-authors as well as with the dentists who participated in the data collection in each country.

The children's data were obtained in two visits. The first visit was an introductory visit and involved the collection of demographic data and medical information. The sweet taste perception test, caries registration, and BMI data were collected during the second visit.

Pregnant women study

The data collection process took place at the Obstetrics and Gynecology Clinic, King Abdul-Aziz University Hospital. The subjects were visiting the clinic for examinations or regular check-ups. All the tests were performed during that visit when possible or at the next one.

Study subjects

The inclusion criteria for the study subjects were as follows: i) free from medical diseases; ii) not taking any regular medication; iii) ≥ 20 teeth present; iv) not taking any antibiotics during the previous month; and v) willingness to participate in the study. Additional inclusion criteria concerning the children was that the children had lived in their country of residence since the age of 6 years. Subjects with medical conditions, fixed orthodontic appliances, or with any kind of illness at the time of examination that could affect their taste judgement were excluded.

As illustrated in Fig. 1, the studies I and II were of a total of 669 schoolchildren aged 13-15 in the three countries (Italy, Mexico, and Saudi Arabia): 51.3% were boys and 48.7% girls. A similar sample size for each area ($n = 200$) was chosen during the study design phase. A post hoc power analysis was performed after the survey, with a non-centrality parameter of 18, a critical χ^2 of 7.81 and a power ($1-\beta$ -err prob) of 0.96.

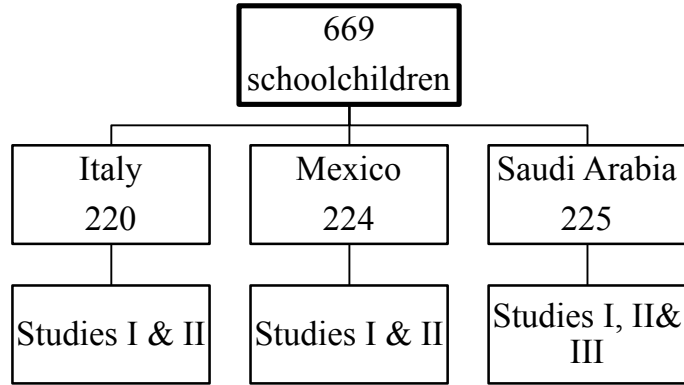


Figure 1. Distribution of population in Studies I, II and III.

In study IV, 121 participants (80 pregnant and 41 non-pregnant women [controls]) were randomly selected from patients visiting the Obstetrics and Gynecology Clinic, King Abdul-Aziz University Hospital, Jeddah, Saudi Arabia (Fig. 2). Every other patient visiting the clinic (nos. 1, 3, 5, etc.) was included. Pregnant women were categorized as being in early or late pregnancy. The early pregnant group comprised women who were in 1-20 weeks of pregnancy; the late pregnant group were those in 20-40 weeks or term. The sample size was determined following the results of previous studies. pH measurements were made with an estimated difference in pH reduction of 0.4, standard deviation of 0.5, significance level of 5%, and 80% power.

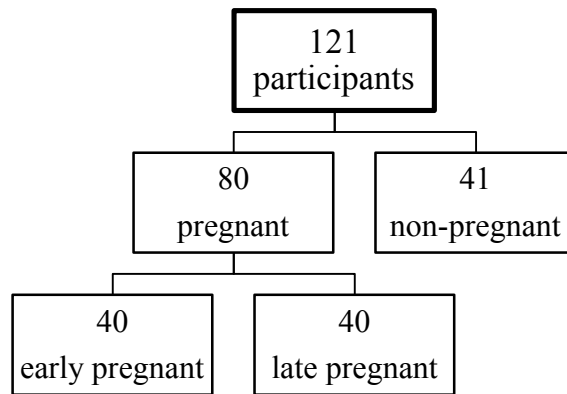


Figure 2. The population in Study IV.

Clinical variables

A number of variables were assessed and are shown in Table 2.

Table 2. Variables presented in studies I, II, III and IV¹.

Data	Study			
	I	II	III	IV
Sweet taste threshold (TT)	✓	✓	✓	✓
Sweet taste preference (TP)	✓	✓	✓	✓
ICDAS	✓	✓	✓	
DMFS	✓	✓	✓	
DMFT				✓
Body Mass Index (BMI)		✓	✓	
Dietary record			✓	
Questionnaire			✓	
Saliva sample				✓
Bacterial count				✓
Plaque pH				✓

¹ Some of the data are only presented in the respective paper.

Sweet taste perception (Studies I - IV)

In standardization sessions, the solutions were prepared and tested on a number of volunteers by way of a pilot test. The participants were asked not to eat, drink, or brush their teeth for one hour prior to the test.

The sweet taste perception level was assessed using a modified version of the method of Nilsson and Holm [1983]. All the concentrations were used in a single series when testing [Nilsson and Holm, 1983; Furquim et al., 2010]. Two variables were determined in this test: *sweet taste threshold (TT)*, i.e. the level at which the subject was able to identify the presence of sucrose in the

solution and differentiate it from water; and *sweet taste preference (TP)*, i.e. the chosen preferred sucrose solution (the solution number that reflected the participants' preferred sucrose concentration). After the pilot test, it was agreed that the TT and TP test should be combined and evaluated simultaneously.

Ten sucrose solutions, ranging from 1.63 g/L (0.0047 M/L) to 821.52 g/L (2.40 M/L), were offered to the participants in order of increasing concentration and served in 10 ml disposable plastic medicine cups (Table 3). The participants rinsed between each tasting with filtered water and a maximum of 2 minutes was allowed between tasting. The participants were asked to mark the chosen solution number for TT and TP on a sheet.

Table 3. Concentration of sucrose solution (in M/L and gm/L) used for assessment of taste preference (TP) and taste threshold (TT).

Sucrose solution number	M/L	g/L
1	0.0047	1.63
2	0.0095	3.25
3	0.019	6.50
4	0.0375	12.84
5	0.075	25.67
6	0.15	51.35
7	0.30	102.69
8	0.60	205.38
9	1.20	410.76
10	2.40	821.52

Caries registration (Studies I - IV)

The DMFS index was used for permanent teeth caries registration according to WHO criteria [WHO, 1997]. The total number of decayed (D), missed (M), and filled (F) tooth surfaces was calculated for the total DMFS score. The International Caries Detection and Assessment System (ICDAS) index was used for caries prevalence assessment.

The ICDAS system consists of a two-digit number: the first digit represents the restoration status of the tooth: the second digit represents tooth surface status. The second digit code was used, and tooth surface status was assigned a code from 1 to 6. Carious lesions were then categorized as ICDAS 1, 2, or 3 (initial caries affecting the enamel) or ICDAS 4, 5, or 6 (manifest caries affecting the dentine). Any visible tooth change in enamel, including enamel breakdown due to caries, was defined as initial caries; any lesion extending to the dentine was registered as manifest.

In study IV, The DMFT index was used according to the WHO criteria with the third molars excluded from the calculation [WHO, 1997]. No radiographs were taken for any of the study populations.

Anthropometric measurements (Studies II and III)

Data on the height (cm) and weight (kg) of the children were collected using portable scales. Before measurements, the children were instructed to remove socks, shoes, jackets, and any loose clothing. In addition, the BMI (body weight divided by height squared) of each subject was calculated.

In study II, for further data processing, the participants were divided into four groups (underweight, normal, overweight, and obese) based on their BMI value for age and gender as indicated on the WHO chart [WHO, 2007].

Estimated food record and questionnaire (Study III)

These data were assessed among the Saudi Arabian schoolchildren. The number of main meals (structured eating events), snack intake (unstructured eating events and usually uncooked), and total intake occasions of both main meal and snacks were determined using a 3-day food diary showing daily variations in intake. Two weekdays and a weekend day were included. The sweet intake frequency was additionally evaluated from the diary by counting all sweet containing items.

Furthermore, nine sweetness containing beverages and snacks (five beverages and four snacks) were used for further data processing after the initial analysis of 19 items presented in the self-administered beverage and snack questionnaire [Neuhouser et al., 2009; Losasso et al., 2015]. Responses to the questions ranged from never (zero intake) to more than four times a day. A score was then given to each option presented in the beverage and snack questionnaire (i.e. never or zero intake = 0, once a week = 1, etc.). The scores for the nine sweet items were then calculated for each participant and summed as the beverage sweet intake score (BS) and snack sweet intake score (SS).

Plaque acidogenicity measurements (Study IV)

Plaque acidogenicity (4.0-7.0) in the pregnant and non-pregnant women was assessed using the strip method [Carlén et al., 2010]. A pH indicator strip (Spezialindikator, Merck, Darmstadt, Germany) was inserted interproximally into the left and right sides of the upper premolar/molar region after a 1-minute mouth rinse with 10 ml of a 10% sucrose solution. The colour that appeared on the strip was then compared with the manufacturer's index at five time points as follows: before (0 min) and after 2, 5, 10, and 20 minutes.

Saliva buffer capacity (Study IV)

Saliva samples were collected for buffer capacity measurement using CRT[®] Buffer (Ivoclar-Vivadent, Schaan, Liechtenstein). The CRT Buffer kit consisted of a buffer strip that was soaked into the saliva collected to indicate buffer capacity as low, medium and high.

Statistical analysis

Descriptive and statistical analysis were performed using IBM[®] SPSS[®] (PASW version 23.0 IBM[®] Chicago, Ill, USA) in studies I, II and III. In study IV, (PASW version 21.0 IBM[®] Chicago, Ill, USA) was used. The p-value for statistical significance was set at < 0.05.

A one-way ANOVA (analysis of variance applied) test was used to compare the following data variables: i) TT, TP, caries variables and BMI between the three countries (Italy, Mexico and Saudi Arabia), ii) TT, TP, DMFT, and plaque acidogenicity between the two pregnant groups and the non-pregnant group. The independent t-test was used to determine the differences between genders in terms of dietary habits in study III. Chi square test was used for saliva buffer capacity differences between study groups in study IV.

In terms of the correlation analysis, Spearman’s rank correlation was used for variables in studies I, II and III, while, for study IV, Pearson’s correlation was used. The regression analysis test was applied in studies III and IV. The dependent variables in study III were the BS and SS. In addition, the impact of the different study variables on the two different groups (non-pregnant and pregnant) and the three different groups (non-pregnant, early pregnant, late pregnant) was evaluated in study IV. The area under the curve at pH 5.7 (AUC_{5.7}) and at pH 6.2 (AUC_{6.2}) was calculated using a computer program [Larsen and Pearce, 1997].

Table 4. Statistical analysis performed for studies I, II, III and IV.

Statistical analysis	I	II	III	IV
Descriptive statistics	✓	✓	✓	✓
One-way ANOVA	✓	✓	✓	✓
Post-hoc LSD analysis	✓			
Independent t-test			✓	✓
Correlation analysis	✓	✓	✓	✓
Chi square test				✓
Regression analysis			✓	✓

RESULTS

Sweet taste perception (Studies I - IV)

The sweet taste perception level was identified as the sweet taste threshold (TT) and preference level (TP). When comparing the three countries (Italy, Mexico and Saudi Arabia) in terms of sweet taste perception in study I, the Italian schoolchildren had the highest sweet taste threshold level (65.0 gm/L), while Saudi Arabian children had the highest sweet taste preference level (319.7 gm/L) (Table 5). The differences between the three countries with regard to sweet taste threshold and sweet taste preference were statistically significant ($p < 0.001$ and $p < 0.001$ respectively) (Table 5). In addition, the post-hoc analysis showed a statistically significant differences between Italy-Mexico, Italy-Saudi and Mexico-Saudi ($p < 0.001$).

Table 5. The mean and standard deviation (SD) for sweet taste threshold (TT) and sweet taste preference (TP) presented for schoolchildren (Italy, Mexico and Saudi Arabia) and Saudi Arabian women (non-pregnant, early pregnant and late pregnant).

Study subjects	TT	p-value ¹	TP	p-value ¹
Schoolchildren	Italy	65.0±82.6	231.9±315.1	
	Mexico	7.5±4.4	25.5±16.4	< 0.001
	Saudi Arabia	37.3±47.5	319.7±302.1	
Women	Non-pregnant	12.5±11.4	45.9±38.4	
	Early pregnant	24.1±20.6	108.6±106.0	< 0.001
	Late pregnant	14.1±10.4	46.9±35.6	

¹p-value: One-way ANOVA

As illustrated in Fig. 3, the highest tested solution (821.52 gm/L) for taste preference was preferred by the largest proportion of children in Italy (20.0%) and Saudi Arabia (22.7%). A much lower concentration (25.67 gm/L) was preferred by the largest percentage (33.5%) of the Mexican

children. The highest preferred concentration among the Mexican schoolchildren was (51.35 gm/L), which was chosen by 24.6% (Fig. 3).

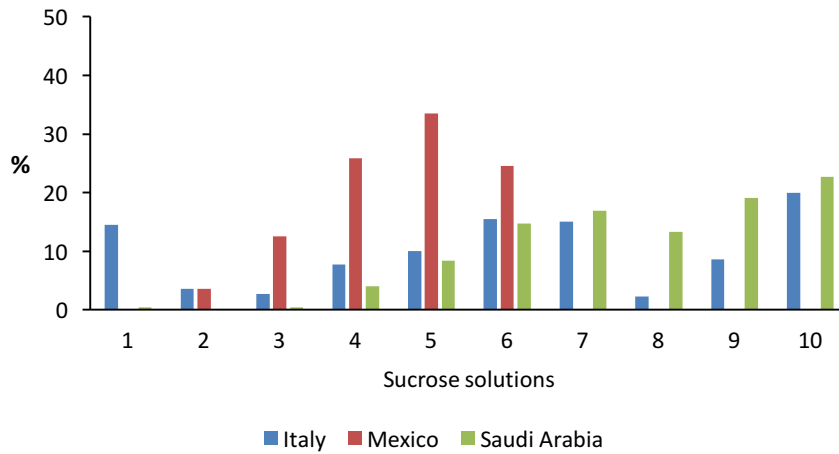


Figure 3. Percentage (%) of children preferring the different sucrose solutions offered in the sweet taste preference test (TP) for Italy, Mexico and Saudi Arabia. X-axis represents the different sucrose solutions where 1 is the lowest sucrose concentrations and 10 is the highest. (For further information regarding sucrose solutions, refer to table 3).

In regards of the pregnant women study (IV), the sweet taste threshold and preference level for the non-pregnant, early pregnant (0-20 weeks) and late pregnant (20 weeks-term) women is shown in Table 5. A statistically significant difference was found between the three groups (Table 5). The variation in the TT and TP level can be clearly seen as the early pregnant group stands out with the higher TT and TP mean value (24.1 gm/L and 108.6 gm/L respectively) in comparison to the late pregnant and non-pregnant groups (Table 5).

The early pregnant group was the only group reporting a higher concentration (102.70 gm/L) for their sweet taste threshold (Fig. 4). A similar pattern was also seen for the sweet taste preference and the highest preferred sucrose solution (410.76 gm/L) was only chosen by the early pregnant women (Fig. 4). Regarding the late pregnant and non-pregnant women the highest chosen solutions were 102.69 gm/L and 205.38 gm/L respectively (Fig. 4).

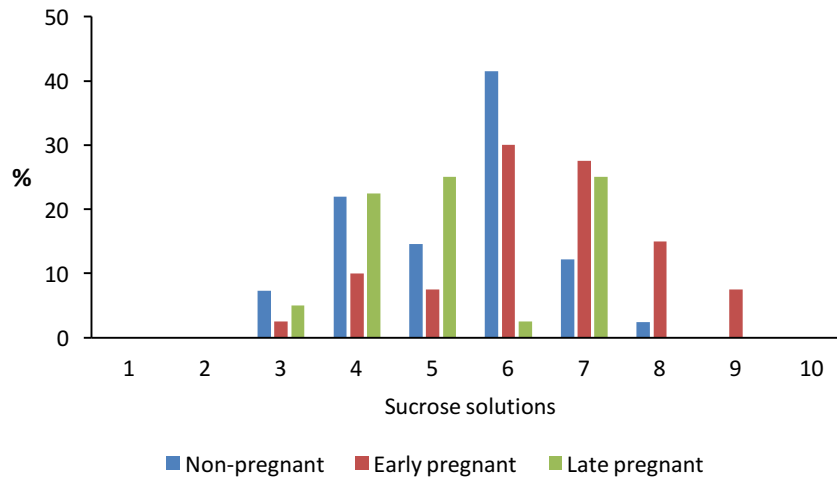


Figure 4. Percentage (%) of taste preference for the different sucrose solutions chosen by the non-pregnant, early pregnant and late pregnant women. X-axis represents the different sucrose solutions where 1 is the lowest sucrose concentrations and 10 is the highest. (For further information regarding sucrose solutions, refer to table 3).

Caries experience (Studies I - IV)

The caries experience in schoolchildren and pregnant women is presented as DMFS and DMFT and the caries prevalence among schoolchildren is presented as initial and manifest caries. As illustrated in Fig. 5, Saudi schoolchildren were found to have the highest DMFS mean value (2.99 ± 4.03), followed by Italy (1.67 ± 2.39) and Mexico (1.22 ± 1.57) ($p < 0.01$) (Fig. 5). The highest mean value for initial lesions was found among the Saudi schoolchildren (6.74 ± 7.84) compared with (0.83 ± 1.34) in Mexico and (0.19 ± 0.58) in Italy ($p < 0.01$). However, in regards to the manifest lesions, similar values were found for the Italian (1.34 ± 2.09), Saudi Arabian (1.32 ± 2.82) and Mexican children (1.16 ± 1.48) (ns) (Fig. 5). In terms of prevalence of caries, the values were 45.5% in Italy, 52.2% in Mexico and 66.6% in Saudi Arabia.

None of the caries parameters showed any statistically significant differences when comparing Italy and Mexico. However, differences were found for both DMFS and initial caries when comparing Saudi Arabia with Italy and Mexico respectively ($p < 0.001$; $p < 0.001$) (Table 6).

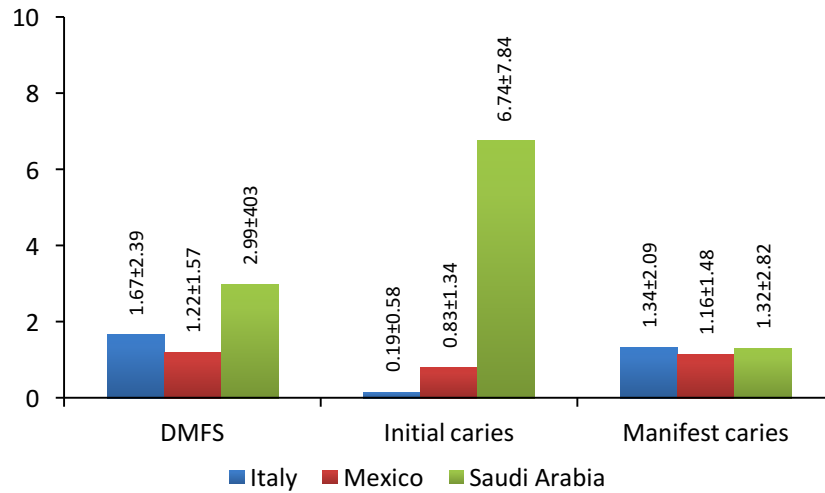


Figure 5. The mean and standard deviation (SD) for DMFS, initial and manifest caries presented for children from Italy, Mexico and Saudi Arabia.

Table 6. Significant differences for caries variables (DMFS, initial and manifest) between countries (post-hoc analysis).

Variable	Saudi-Mexico	Saudi-Italy	Mexico-Italy
DMFS	$P < 0.001$	$P < 0.001$	ns
Initial	$P < 0.001$	$P < 0.001$	ns
Manifest	ns	ns	ns

Regarding study IV of pregnant women, no statically significant differences were found when comparing the mean DMFT between any of the study groups.

Sweet taste perception in relation to dental caries (Study I)

The correlation between the caries variables and sweet taste perception (TT and TP) are presented in Table 7. A significant correlation was found between sweet taste perception (TT and TP) and both DMFS and manifest caries for all three countries (Table 7).

Table 7. Correlation (Spearman's rank correlation) between sweet taste threshold (TT), sweet taste preference (TP) and DMFS, initial caries and manifest caries for children from Italy, Mexico and Saudi Arabia.

Variable	TT		TP	
	r	p-value	r	p-value
<i>Italy</i>				
DMFS	0.248	<0.01	0.137	<0.05
Initial	-0.064	0.347	-0.010	0.881
Manifest	0.313	<0.01	0.147	<0.05
<i>Mexico</i>				
DMFS	0.246	<0.01	0.258	<0.01
Initial	0.186	<0.01	0.149	<0.05
Manifest	0.247	<0.01	0.260	<0.01
<i>Saudi Arabia</i>				
DMFS	0.172	<0.01	0.268	<0.01
Initial	0.044	0.516	0.064	0.342
Manifest	0.204	<0.01	0.218	<0.01

BMI score (Study II)

The majority of the Italian schoolchildren were within the normal weight (76.4%), compared to 58.5% in Mexico and half the Saudi Arabian schoolchildren (50.2%) (Fig. 6). In addition, the percentage of obese schoolchildren was found to be highest in children in Saudi Arabia (32.4%) in comparison with Mexico (20.5%) and Italy (6.8%) (Fig. 6). No children in Mexico were found to be underweight.

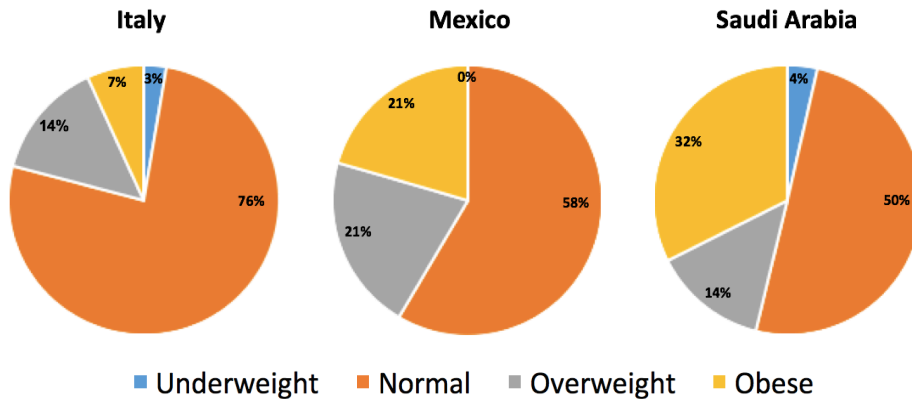


Figure 6. Percentage (%) of underweight, normal weight, overweight and obese schoolchildren in Italy, Mexico, and Saudi Arabia.

The highest mean BMI value was found among Saudi schoolchildren (23.9 ± 6.1), followed by Mexican and Italian schoolchildren (22.0 ± 3.4 and 20.6 ± 2.2 respectively) ($p < 0.001$). No statistically significant correlations were found for BMI versus caries and sweet taste perception variables.

When comparing the BMI groups (underweight, normal, overweight and obese), a statistically significant difference was only found among the Saudi Arabian children in terms of sweet taste threshold (Table 8). However, numerical differences are shown below in Table 8. The overweight group reported the highest TT and TP mean value in Italy while in Mexico and Saudi Arabia they reported the lowest (Table 8).

Table 8. The mean and standard deviation (SD) for sweet taste threshold (TT) and sweet taste preference (TP) in children from Italy, Mexico and Saudi Arabia according to BMI groups (underweight, normal, overweight and obese).

Variables	Underweight	Normal	Overweight	Obese	p-value ¹
<i>Italy</i>					
TT	55.6±25.2	64.8±69.3	88.1±146.2	23.8±18.6	0.100
TP	172.0±322.0	213.5±304.2	313.8±353.2	291.9±347.1	0.332
<i>Mexico</i>					
TT	-	7.6±4.5	7.2±4.8	7.4±3.7	0.837
TP	-	26.6±16.6	23.5±17.1	24.2±15.3	0.436
<i>Saudi Arabia</i>					
TT	116.3±145.2	33.5±40.5	27.3±23.4	40.1±37.9	<0.01
TP	388.3±378.7	308.8±297.1	262.5±281.0	353.3±310.7	0.465

¹p-value: One-way ANOVA

Dietary habits in Saudi schoolchildren (Study III)

Of the total daily intake (4.2 ± 0.9), the Saudi schoolchildren reported a larger number of main meal intake occasions (2.3 ± 0.7) compared with the snack intake occasions (1.9 ± 0.8) (Fig. 7). In terms of sweet intake occasions for Saudi schoolchildren, the mean was 2.4 ± 1.3 and ranged from 0 to 6 intakes a day.

In overall terms, the boys reported a higher number of total intake occasions compared with the girls (4.4 ± 0.9 and 4.1 ± 0.8 respectively) ($p < 0.05$) (Fig. 8). The main meal and snack intake occasions were equal (2.2 ± 0.7 and 2.2 ± 0.8 respectively) among the boys, while the number of main meal occasions for the girls was higher (2.5 ± 0.6) than the snack intake (1.7 ± 0.7) (Fig. 8). Statistically significant differences were found when comparing the boys and girls in terms of the main meal ($p < 0.01$) and snacking events respectively (p

< 0.001) (Fig. 8). In terms of the sweet intake occasions, a higher intake was found among the boys (2.8 ± 1.1) compared with the girls (2.1 ± 1.4) ($p < 0.001$) (Fig. 8).

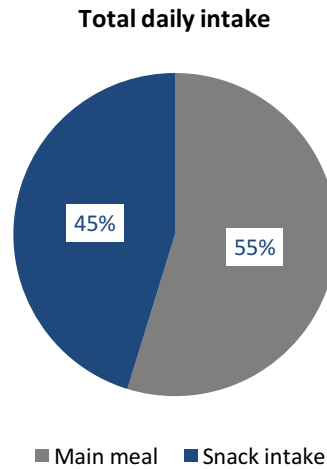


Figure 7. The distribution of main meal and snack intake of the total daily intake for schoolchildren in Saudi Arabia.

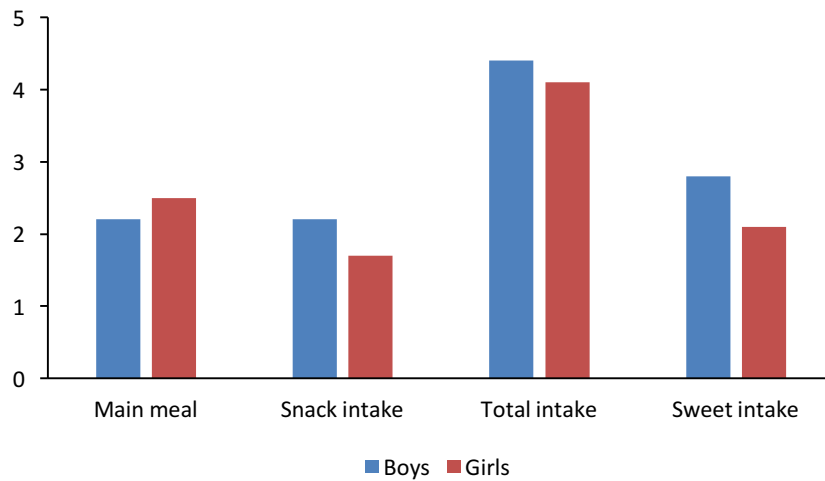


Figure 8. The mean values for main meal, snack intake, total food intake and sweet intake in Saudi schoolchildren (boys and girls).

The influence of sweet taste perception on dietary habits (Study III)

The correlation between sweet taste perception and different dietary intakes is shown in Table 9 and a significant negative correlation was found between the number of main meals and sweet taste perception (TT and TP). In addition, a significant positive correlation was found between both the sweet and snack intake occasions in relation to the sweet taste perception (TT and TP). The caries and BMI mean value showed no correlation with any of the three intake variables (number of main meals, snack events and sweet intake events).

A significant association between BS and gender and sweet intake occasions was found in regression analysis with BS as dependent variable. With SS as a dependent variable gender showed borderline significance ($p = 0.059$, 95%CI = -0.044-2.34) but no significant association seen for the other variables (data not shown).

Table 9. Sweet taste perception (TT and TP) in relation to main meal, snack intake, total intake and sweet intake occasions in schoolchildren from Saudi Arabia (Spearman's rank correlation).

Variable	Main meal		Snack		Total intake		Sweet intake	
	r	p-value	r	p-value	r	p-value	r	p-value
TT	-0.228	<0.001	0.169	<0.05	-0.005	0.587	0.276	<0.001
TP	-0.480	<0.001	0.286	<0.001	-0.106	0.473	0.288	<0.001

Plaque acidogenicity (Study IV)

The figure illustrates the mean pH value for non-pregnant, early pregnant and late pregnant women at different time points after a sucrose rinse. The highest pH fall was seen for the pregnant groups compared with the non-pregnant one. In addition, a difference can be seen between the early and late pregnant group at baseline (0 minutes) ($p < 0.05$) (Fig. 9).

The mean minimum pH value was 5.5 in the early pregnant women, 5.6 in the late pregnant women and 5.9 in the non-pregnant women ($p < 0.01$). Similarly, for the maximum pH fall, the respective values were 1.2 pH units

in the early pregnancy group compared with 0.8 pH units in both the late and non-pregnant groups ($p < 0.01$).

The largest area under the curve (AUC) for pH values of 5.7 and 6.2 was noticeable among the pregnant groups. The value for the $AUC_{5.7}$ were 2.3 in the early pregnant group, 2.0 in the late pregnant group and 0.6 in the non-pregnant group (ns). The corresponding values for $AUC_{6.2}$ were 6.1 for the early pregnant group, 5.6 for the late pregnant group and 2.5 for the non-pregnant group ($p < 0.05$). No correlation was found when comparing the sweet taste threshold or sweet taste preference with any of the pH variables (ns).

However, a positive significant correlation was found for buffer capacity in relation to $AUC_{5.7}$ and $AUC_{6.2}$ ($p < 0.01$ and $p < 0.05$ respectively). In addition, the saliva buffer capacity differed significantly between the early, late pregnant and non-pregnant groups where the largest proportion of high buffer capacity found among the non-pregnant group ($p < 0.01$).

A statistically positive Relative Risk Reduction (RRR) was found for buffer capacity, $AUC_{6.2}$, DMFT and taste threshold in pregnancy when compared with non-pregnancy. In early pregnancy, the buffer capacity (RRR=2.49) and $AUC_{6.2}$ (RRR=1.13) differed significantly compared with the base outcome (non-pregnancy). Several variables (buffer capacity, $AUC_{6.2}$, DMFT, taste threshold) showed a statistically positive RRR during late pregnancy in comparison with the values for non-pregnant women.

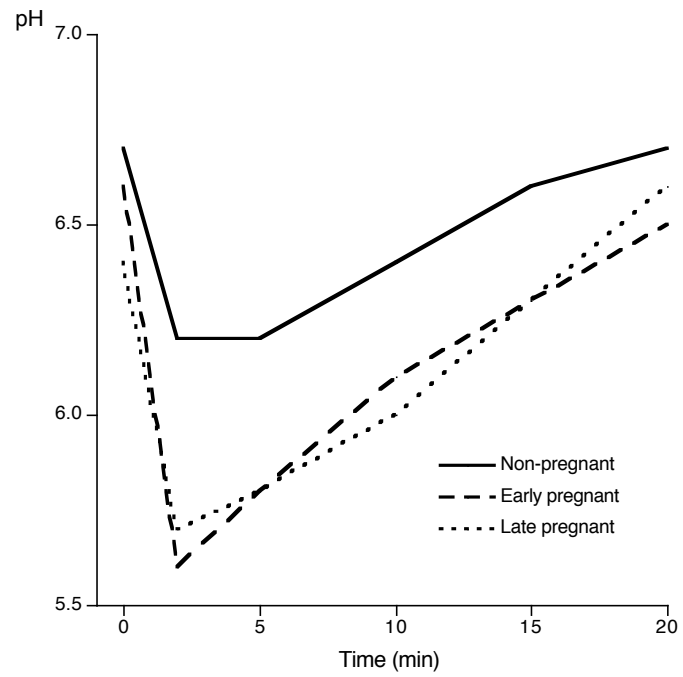


Figure 9. Changes in plaque pH after a mouthrinse with 10 ml of 10% sucrose in the non-pregnant, early pregnant and late pregnant women.

DISCUSSION

The present thesis focused on studying the sweet taste perception level (sweet taste threshold and sweet taste preference), dental caries and BMI in schoolchildren from Italy, Mexico and Saudi Arabia. In addition, the relationship between sweet taste perception and both dental caries and BMI was assessed in the same children. The dietary habits in relation to sweet taste perception were also studied in Saudi schoolchildren. Furthermore, the effect of pregnancy on sweet taste perception and plaque acidogenicity was assessed.

Interpretation of results

General discussion

With regard to the schoolchildren in studies I and II, the main findings were the observed differences between the Italian, Mexican and Saudi Arabian children. These differences are related to their sweet taste perception level (TT and TP), dental caries prevalence and anthropometric measurements. Furthermore, a significant relationship was found in all three countries between sweet taste perception and dental caries, when expressed as DMFS and the number of manifest lesions. However, no association was observed between sweet taste perception and BMI. With regards to study III focusing on the Saudi schoolchildren, a relationship was found between sweet taste perception and dietary habits.

The hypothesised relationship between sweet taste perception, dental caries and BMI was thought to be attributable to the effect of sweet taste perception on the subject's dietary choices. Furthermore, it was anticipated that, when the sweet taste perception level is high, it may consequently have an effect on dietary choices, leading to an increase in the sweet intake. An increase in the consumption of sweets will accordingly result in a greater predisposition to develop both dental caries and obesity. Previous studies have linked diet with both dental caries and obesity [Washi and Ageib, 2010; Costacurta et al., 2014; Moynihan, 2016]. In addition, an association between obesity and dental caries has been reported, with similar factors associated with both conditions [Hooley et al., 2012; Hayden et al., 2013; Caudillo-Joya et al., 2014; Costacurta et al., 2014]. However, this association was not supported in this thesis.

The present findings among Saudi schoolchildren revealed no direct relationship between their actual sweet intake and caries. This finding is contrary to reports in the literature regarding the relationship between sugars and caries [Sheiham and James, 2014; Bernabe et al., 2016; Moynihan, 2016; Peres et al., 2016]. In terms of anthropometric measurements, a relationship between the number of meals and being overweight has been reported by Washi and Ageib [2010]. Though, no similar relationship was observed in the work presented in this thesis for any of the countries.

In regards to the pregnant women study, differences were found between groups in terms of sweet taste perception and plaque acidogenicity. However, a relation between these variables could not be confirmed.

Variations in sweet taste perception, caries and BMI among countries (Studies I and II)

There are only a few studies with focus on sweet taste perception level and particularly at country level. At the present time, this may be the first study to compare sweet taste perception among different nationalities.

Differences were found between Italian, Mexican and Saudi Arabian schoolchildren regarding their mean values for sweet taste perception, dental caries and BMI. Italian children had the highest sweet taste threshold and Saudi children had the highest sweet preference level. Mexican children showed the lowest sweet taste threshold and preference level.

These differences can be attributed to variations between the three countries in terms of lifestyle, genetics, cultural and environmental factors [Mennella et al., 2005; Qi and Cho, 2008; Haznedaroglu et al., 2015; Opal et al., 2015]. The influence of cultural factors and their effect on sweet taste perception may be observed in the thesis. This was apparent from the preference of Italian and Saudi Arabian schoolchildren for the sweetest solution offered and the Mexican schoolchildren's preference for a much less sweet solution. The low preference for sweet dietary items among the Mexican children could be explained by the salty and sour nature of Mexican cuisine.

The higher preference for sweet taste reported in Saudi Arabia is in agreement with the finding of other studies, which have reported high sweet consumption and poor dietary habits among Saudi schoolchildren [Collison et al., 2010; Quadri et al., 2015]. The Saudi diet is well known for its high sugar content and preference for sweet food. In Italy, it has previously been reported that more than 64% of Italian children do not follow healthy dietary

recommendations [Saulle et al., 2016]. Poor dietary habits usually reflect diet that is high in sugar and fat and a sugar preference among Italian children may therefore be concluded.

Regarding the differences in caries experience between the three countries, the highest mean value for the DMFS was found for the Saudi schoolchildren, followed by the Italian and then the Mexican schoolchildren. However, the mean number of manifest lesions was almost identical for the three countries. DMFT values were not calculated in this study and it was therefore not possible to compare the results with the WHO's 2020 goals for DMFT at 12 years of age, with the value of 1.5 [Hobdell et al., 2003].

An interesting finding with regard to caries results was the large difference observed for initial lesions among the three countries. The lowest number was found for Italy and the highest for Saudi Arabia. The difference between the mean number of initial lesions for Saudi Arabia and both Italy and Mexico is distinctive and worth considering. The value reported for Saudi schoolchildren could be the result of inadequate preventive measures [Masood et al., 2012]. In addition, a study by Abid et al. [2015] reported an increase in prevalence of dental caries in the Middle Eastern countries and attributed this increase to the lack of available treatment. However, despite the well-known importance of preventive measures using fluoride, the recommendations still focus on reducing sugar consumption to a minimum [Anderson et al., 2009; Moynihan and Kelly, 2014; Sheiham and James, 2014]. To a large extent, the initial lesions are believed to reflect caries activity. However, it is anticipated that the number of initial caries lesions may be higher if intra oral radiographs were used.

The caries prevalence found in the present thesis among schoolchildren from Italy, Mexico and Saudi Arabia was 45.5%, 52.2%, and 66.6% respectively. This varies from other recent studies of caries prevalence in the same age group. In Italy, the value reported in the present thesis is higher than that found by Ferrazzano et al. [2016] (36%). The thesis finding for Mexico was similar to that reported by Pontigo-Loyola et al. [2007] (49%), but higher than the finding by Guizar et al. [2016] (36%). In Saudi Arabia, the caries prevalence reported in this thesis is similar to that presented by Farooqi et al. [2015] (68%), while Quadri et al. [2015] reported a higher value (91%). Possible explanations for the differences in the prevalence compared with other studies in the literature may be the examination setting, given that data were collected in school and under natural light. That in addition to the lack of radiographic assessment for carious lesions. Moreover, sociodemographic factors may have had an influence on the results outcome.

In terms of BMI, Saudi schoolchildren had the highest BMI mean value (23.9), followed by the Mexican (22.0) and then the Italian schoolchildren (20.6). Different ways of calculating BMI for children are presented in the literature [Cole et al., 2000; Butte et al., 2007; WHO, 2007; de Onis and Lobstein, 2010]. The present BMI data have been processed using the WHO BMI-for-age in children, which takes account of age and gender when categorising the children as underweight, normal, overweight and obese [WHO, 2007]. Therefore, making a direct comparison of BMI mean values is challenging. However, when taking a closer look at the present data, it appears that Italian children may fall into the normal range, while children from Mexico and Saudi Arabia may be considered to be overweight.

The number of obese schoolchildren in Saudi was the highest compared with Italy and Mexico, in addition to a smaller number of normal weight subjects. This may have been due to the culture and lifestyle differences, in addition to the dominant diet in the area. The lack of physical and outdoor activity due to the climate, in Saudi Arabia, particularly among females, could be an explanation for the high numbers [Al-Hazzaa et al., 2014a; Al-Hazzaa et al., 2014b]. As reported from Europe, the lack of physical activity combined with social factors can be a predisposing factor to develop obesity [Contaldo et al., 2015].

In Italy, data presented for a similar age group showed a similar proportion for the normal, overweight and obese groups [Lazzeri et al., 2008]. In addition, Lazzeri et al. [2015] reported a decrease in overweight and obesity prevalence among Italian children. However, the proportion reported in the present thesis has been found to be low compared to what has previously been reported in the literature for Italy [OECD, 2014].

For Mexico, a study by Gutierrez-Pliego et al. [2016] reported similar number for overweight subjects, smaller number of obese and a higher number of normal weight individuals among Mexican children aged 14 to 16. Interestingly in the findings for Mexico in this thesis, none of the schoolchildren was found to be underweight which is in agreement with Gutierrez-Pliego et al. [2016], who found that only 0.02% were underweight. Conversely, among 6-12 year olds, Caudillo-Joya et al. [2014] reported that 10.5% of the children were underweight and a smaller percentage were obese and normal weight compared to thesis findings. However, the percentage presented by Caudillo-Joya et al. [2014] with regard to overweight was similar to the findings in this thesis.

A study conducted in Saudi by Farsi and Elkhodary [2017] reported a percentage of schoolchildren in the individual BMI categorisation groups which was almost similar to that presented in this thesis with exception to the obese group. In addition, Quadri et al. [2017] found the normal weight group in Saudi Arabia to be 60.6%, which is about 10% higher than the finding in this thesis. However, the obese group percentage was much lower (4.7%) than that reported in thesis [Quadri et al., 2017].

It is only possible to speculate about the reason for the differences between the thesis findings and what previously been reported in the literature. It can be assumed that the age, number of participants and adopted habits are among the responsible factors. However, the influence of numerous genetic, cultural and environmental factors on the thesis results should be considered.

Sweet taste perception in relation to caries and BMI (Studies I and II)

The comparison between sweet taste perception (sweet taste threshold and sweet taste preference) and dental caries (DMFS and manifest caries) revealed a positive significant relationship. As mentioned previously, the highest DMFS, initial caries and sweet taste preference were found among the Saudi schoolchildren and the lowest values for these variables were found among the Mexican children.

In comparison of Saudi and Italian schoolchildren, almost equivalent values for manifest lesions were noted, along with a preference for the sweetest test solutions. However, when the two countries were compared in terms of DMFS values, the values differed significantly. A lower mean DMFS value for DMFS was seen in the Italian schoolchildren. Since manifest caries is presented as decayed (D) in the DMFS score, this may suggest a higher value for the missed (M) and filled (F) component of the DMFS among the Saudi schoolchildren.

Similarly, differences were found between Mexico and Italy in terms of sweet taste perception, but no differences were found for any of the caries-related variables. All of which supports the hypothesis that dental caries is a multifactorial disease and sweet taste preference is one of many factors that should be considered.

The previous comparison indicated that other factors, such as access to treatment, preventive measures and sociodemographic background, should be considered when evaluating the relationship between sweet taste perception

and dental caries. However, the present findings are in agreement with those presented by Robino et al. [2015] and Jamel et al. [1997], who found a relationship between sweet taste preference and caries. As discussed by Jamel et al. [1997], sweet taste preference has a stepwise relationship with sugar consumption. When sugar consumption is high, the sweet taste threshold level rise due to this increase in consumption. This increase in sugar consumption and sweet taste threshold will in turn result in an increase in susceptibility to dental caries [Jamel et al., 1997].

Conversely, no direct relationship between sweet taste preference and dental caries has been found in previous studies [Bretz et al., 2006; Furquim et al., 2010]. However, the studies by Verma et al. [2006] and Furquim et al. [2010] reported a higher susceptibility for caries among the bitter non-tasters who were found to be sweet likers. In addition, Verma et al. [2006] found a higher bacterial number among the bitter non tasters.

In terms of BMI, no correlation was found in the present data between sweet taste preference and BMI, which is in agreement to previous results by Hill et al. [2009]. In contrast, Lanfer et al. [2012] reported a relationship between sweet preference and obesity. Similarly, taste has been found to be distinct in normal weight subjects, with the reporting of a higher threshold level for sweets among obese subjects [Overberg et al., 2012; Park et al., 2015].

Sweet taste perception in relation to dietary habits in Saudi Arabian children (Study III)

The relationship between the sweet taste perception level and dietary habits was only assessed in Saudi schoolchildren for practical reasons and due to language barriers. Dietary habits were assessed as main meal, snack intake, total intake and sweet intake occasions. This in order to assess the hypothesis that sweet taste perception may influence the dietary habits of the schoolchildren. This may result in a greater susceptibility to develop caries and obesity. Several studies in the literature have reported that schoolchildren are known to be more prone to develop poor dietary habits [Coldwell et al., 2009; Washi and Ageib, 2010; Allafi et al., 2014].

The present findings identified a relationship between sweet taste perception versus snack and sweet intake occasions. In addition, a negative relationship was found between sweet taste perception and main meal occasions. As reported by Kourouniotis et al. [2016], subjects regarding taste as an important factor for their food choice tend to have a higher consumption of sweets and snacks. Moreover, Kourouniotis et al. [2016] stated that “taste

perception can result from a cumulative effect of lifetime exposure to certain food and taste". As a result, poor dietary choices may be a consequence of acquired habits developed over a period of time.

No relationship was found between the actual sweet intake and DMFS values among Saudi schoolchildren, despite the relationship that was found between sweet taste perception and both sweet intake or DMFS. Similar findings were seen for adult by Robino et al. [2015].

For further data analysis, a beverage sweet-intake score (BS) was calculated as a measurement of sweet intake. The regression analysis revealed an association between the beverage sweet-intake score (BS) and gender and sweet intake occasions respectively. These associations may be due to the difference in gender related dietary habits. This is also supported by the result for the sweet intake occasions extracted from the dietary records.

The results showed that boys reported a higher sweet intake than girls. The gender related differences found in the Saudi population can be attributed to cultural and environmental factors [Al-Hazzaa et al., 2011; Al-Hazzaa et al., 2013; Al-Nakeeb et al., 2015; Al-Sobayel et al., 2015]. In addition, females reported that taste was of importance when selecting food and this was found to be related to poor dietary choices [Kourouniotis et al., 2016]. However, a study by Allafi et al. [2014] in the Kuwaiti population found no differences between boys and girls regarding sweet intake.

The effect of pregnancy on sweet taste perception and plaque pH (Study IV)

Results from the pregnant Saudi women study showed differences in taste, in addition to more attenuated plaque acidogenicity, among pregnant women. This may contribute to an increased risk of oral diseases, especially dental caries. In addition, a lower resting pH was reported in the pregnant group. Both these factors may have an effect on the oral health of pregnant women and their dietary choices.

Finding a relationship between sweet taste perception and both caries and plaque acidogenicity could have been expected. However, no relation was found. This may be explained by the small number of participants in each group. Other explanations could be the fact that caries progresses over time, and the study had a cross-sectional design. In addition, no follow-up on caries status was performed. The taste changes observed in pregnant women

therefore lacked the time required to develop caries or alter plaque acidogenicity as a result.

When comparing the women in different stages of pregnancy, sweet taste preference was more pronounced in the early pregnancy group (0-20 weeks) than in the late pregnancy group (20 weeks-term). This may indicate a greater tendency towards dietary modification earlier in pregnancy. In accordance with the findings presented in this thesis, several studies have shown that changes in the taste of pregnant women are more distinct during the early pregnancy period [Duffy et al., 1998; Nordin et al., 2004; Choo and Dando, 2017]. In contrary, Belzer et al. [2010] reported the taste changes occur later in pregnancy (24-28 weeks). The present study found that more than half the early pregnant women chose the solutions of ≥ 25.67 gm/L when tested for their sweet taste threshold and they were also the only group that chose the highest recorded sucrose concentration (102.70 gm/L). The same finding applied when it came to the sweet taste preference, with half of the early pregnant group preferring the highest reported solution.

The reasons for these changes are subject to discussion. Hook [1978] stated that changes in taste preference may be due to the taste, smell or metabolic changes that occur during pregnancy. In addition, it has been stated that the increasing need for nutrition to the foetus and instability in sex hormones during pregnancy could contribute to such dietary changes observed in pregnant women [Faas et al., 2010].

To present knowledge, the increased plaque acidogenicity among pregnant women has not previously been discussed. In addition to the more pronounced plaque acidogenicity and lower resting pH, a greater pH fall was also seen between the groups when evaluating the results as the area under the curve ($AUC_{5,7}$ and $AUC_{6,2}$), with elevated areas for the pregnant women. Consequently, the ability for remineralisation may be reduced in pregnant women. This may lead to an increased risk of tooth solubility due to the prolonged pH fall [Aranibar Quiroz et al., 2014].

The increased pH drop seen in the pregnant women after the sugar challenge indicates a more acidogenic biofilm compared with the non-pregnant women, while the lower resting pH reflects an overall more acidogenic environment. This is believed to be a result of both changes in taste preference and potential changes induced by pregnancy, such as variations in plaque and saliva composition, oral hygiene and behavioural habits [Ressler-Maerlender et al., 2005; Rockenbach et al., 2006; Belzer et al., 2010], all of which can influence the susceptibility to dental caries, as stated by Aranibar Quiroz et

al. [2014]. Pregnant women should therefore pay special attention to oral hygiene and diet and be regarded as a high caries risk group.

Methodology

The present study focused on two population groups to examine the sweet taste perception level of participants. The first group consisted of 13 to 15 year-old schoolchildren from Italy, Mexico, and Saudi Arabia, who were assessed for their sweet taste perception level, dental caries, BMI, and dietary habits. Pregnant women from Saudi Arabia constituted the second study group, and they were investigated for their taste changes and plaque acidogenicity. To minimize the effect of ageing or disease, data was collected from healthy subjects as it is difficult to include all the variables associated with taste sensitivity. The socioeconomic group recruited for this study was from the middle income level. The possibility of obtaining different results from other socioeconomic level can't be excluded.

Data from the first study group were included in studies I and II, which had a multicenter approach. It is well known that setting up a multicenter study poses a number of challenges, including the identification of comparable test subjects. However, though this approach does present difficulties, it offers the potential to build a stronger scientific basis for the conclusions. Multisite clinical trials require comprehensive planning, including standardisation, training and calibration.

Organization and calibration can be a challenge in a multicenter study; thus, all the study tests and forms were standardised, and examiners were calibrated. Despite the above mentioned limitations, it is still interesting to present the effects of cultural and environmental factors on dietary-related conditions. Therefore, measurements were taken to ensure that the children were comparable as possible from both an age perspective and socioeconomically. However, the impact of other cultural and environmental differences cannot be excluded. Each country has its own distinctive dietary habits and preventive routines that may potentially influence a study's results and outcome.

The cross-sectional design used for the studies imposes several limitations since it shows only the situation at a particular point in time. In addition, what applies to a certain subject at the time of data collection does not necessarily remain true throughout their life. As a result, a definitive cause of or explanation for a complete causal relationship between taste perception and caries or diet cannot be concluded.

Regarding to the sweet taste perception test method, a standardised test protocol was followed in the four studies. The sweet taste threshold and preference tests were combined and steps were decided upon during the study design phase. We can therefore rely on the results of the tests to indicate the actual level of sweet taste perception at that time, despite the minor modification applied to the original method developed by Nilsson and Holm [1983].

Due to the wide interest in the literature regarding bitter taste, it is possible to speculate about why interest has focused on sweet taste, not bitter taste. However, it has previously been found that a high preference for sweets among children usually occurs in combination with a low preference for bitter foods and that they reflect the opposite of each other [Mennella and Bobowski, 2015]. In addition, the relationship between bitter sensitivity and sweet preference has been addressed [Verma et al., 2006; Furquim et al., 2010; Keller et al., 2014; Mennella, 2014; Joseph et al., 2016]. Therefore, in the present study, it was sufficient to examine only sweet taste. The method was based on a subjective judgement regarding taste. However, even though determination by a sweet taste perception gene has been found [Mennella et al., 2005; Guido et al., 2016], no information was collected in this thesis.

Regarding caries registration, as previously mentioned data was not collected in a dental clinic setting and therefore an anticipated difference in prevalence based on the data collection settings can't be ruled out. When it came to the dietary record in study III, it is difficult to estimate the accurate quantity or quality of intake, especially when taking the children's young age into account and personal variations in reporting and writing down the consumed food or beverages should be considered, in spite of the fact that clear instructions on how to report the intake had been given.

Ethics

At the start of the study, ethical approval was obtained to collect all personal and clinical data, and the data were accessed only by the authors. This study involved two study populations: children and pregnant women. Both groups can be regarded as vulnerable and requiring particular attention and precautions. To a certain extent, dealing with these groups can involve some risks. For example, pregnant women are known to experience general discomfort or may experience hypotension from prolonged sitting [Barak et al., 2003]. Therefore, effort was made to reduce the examination time to a minimum. Exposing schoolchildren to sweet solutions when some of them may never have tried such sweet items before is an ethical concern. However,

the solutions were not actually swallowed by the children and they were tasted only for seconds, so no risks were expected as a result.

The age of the children was also an ethical concern, and consent forms were obtained from their parents. However, once the entire process and purpose of the study was explained to them, the children had the right to decide whether or not they wished to participate. In addition, the children were found old enough to be able to answer the questions addressed to them.

CONCLUSION

- Differences in terms of sweet taste perception (sweet taste threshold and sweet taste preference) were found between schoolchildren from Italy, Mexico and Saudi Arabia.
- Differences were found between Italian, Mexican and Saudi Arabian schoolchildren in terms of dental caries and they were found to be related to the sweet taste perception level.
- BMI differed between the schoolchildren from the three different countries, but no relationship to sweet taste perception was found.
- A relationship was found between sweet taste perception and dietary habits. No relationship was found between dietary habits and dental caries and BMI respectively.
- Pregnant Saudi Arabian women showed a change in sweet taste perception compared with non-pregnant women. This was accompanied by an increase in plaque acidogenicity.

FUTURE PERSPECTIVES

Various taste and dietary related habits acquired at a certain point in life may persist long afterwards or even throughout life. It is important to focus on those aspects during different stages of life. It is therefore of great importance to try to establish good dietary habits early in life. Dietary habits should be regarded when the risk of adopting new, less favourable dietary habits may increase, such as adolescent and during pregnancy.

Dietary habits and sweet taste perception differ among different countries, and they are influenced by such factors as cultural variations. The differences among countries may have a number of possible causes and identifying the exact cause will always be challenging. In addition, particular attention should be paid to identifying dietary risk factors that increase the likelihood of developing dietary-related diseases, such as caries or obesity. Both conditions may lead to further negative complications and affect quality of life. For example, obesity may result in other medical conditions, such as cardiovascular disease and diabetes [WHO, 2016a].

The results of the thesis may suggest new perspectives in terms of identifying individuals at risk, i.e. the high risk caries and obesity groups. Attempts are being made to realize the goal of identifying a new, straightforward sweet taste perception test that can be used in dental clinics. It would be beneficial to adapt such a test as a chairside examination for subjects at risk of developing caries not just for schoolchildren and pregnant women, but for other individuals at increased risk.

The complex social and living situation nowadays may easily affect the dietary habits positively and negatively. Therefore, attention should be given and in particular to schoolchildren's social and cultural aspects. This should not be limited to the home but also includes preschools, schools and any other environment children may be exposed to. This will not exclude the role of the mothers and the importance of adopting proper dietary habits at home. It is important that future research should also focus on the relationship with sweet taste perception from a genetic perspective.

In regards of caries, the present study has addressed only a limited number of factors related to caries. With respect to the multifactorial aspects of the disease, other important factors to be considered are fluoride exposure, oral hygiene measures, and educational level [Anderson et al., 2009; Arola et al., 2009].

The finding of a more acidogenic biofilm suggests that pregnant women should be given extra attention from an oral health perspective. Studies have shown that despite the knowledge that pregnancy may increase the risk of caries, only 20% of French doctors refer pregnant women for dental check-ups [Boutigny et al., 2016]. Increased collaboration between dentists and both obstetricians and gynecologists is therefore recommended. It would be desirable if regular medical check-ups included questions on oral health or had screening examinations that would offer the opportunity to refer the patient to a dentist or dental hygienist in the event of negative findings.

Only sweet taste perception was assessed for the pregnant women, but no assessment was made of the potential influence on dietary habits during pregnancy. It would therefore be interesting to assess dietary intake habits and patterns during that period. It would have been preferable to follow the oral condition of the women longitudinally, with examinations more than once over a period of time before, during, and after pregnancy. However, difficulties identifying the women prior to pregnancy were encountered at an early stage and the cross-sectional design was therefore chosen.

To prevent oral and general diseases, it is important to have clear dietary recommendations. They include keeping sugar consumption to a minimum, consuming sugars with meals and not between meals, and recommendations for frequent fluoride exposure, correct oral hygiene measures, and dental check-ups conducted on a regular basis. Diet plays a central role for humans from pre-birth throughout life. This is a very complex matter, and the present study has focused only on some aspects related to dietary intake and its consequences for oral and general health.

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