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Risk factors for adolescent caries incidence in the Iowa Fluoride Study

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RISK FACTORS FOR ADOLESCENT CARIES INCIDENCE IN THE IOWA FLUORIDE STUDY

by

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of the requirements for the Master of
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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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has been approved by the Examining Committee for the thesis requirement for the Master of Science in Dental Public Health at the May 2015 graduation.

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To

Mr. N. R. Shette, Mr. Sainath

Mr. S.N. and Mrs. Parvatidevi Yaduwanshi, Mr. K.L. and Mrs. Ramadevi Yadav (Grandparents)

My parents,

Vaibhav and Vaidehi

The more I read, the more I meditate; and the more I acquire, the more certain I am that I know nothing.

-Voltaire

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ABSTRACT

Objective: To determine risk factors for cavitated caries incidence and extent of cavitated caries among adolescents.

Methods: Three hundred and three Iowa Fluoride Study (IFS) subjects met inclusion criteria for interval between dental examination and the responses from the IFS (ages 13.5 to 17.0) and the Block Kids Food Frequency (ages 13.0 to 17.0) questionnaires, respectively. The analyses focused on the outcome variables of net cavitated caries incidence and net cavitated caries increment counts, respectively. The independent IFS questionnaire variables related to demographics, fluorides, oral hygiene, beverage intakes, dental visits, sealants and previous caries incidence variables, respectively, whereas, Block's questionnaire variables related to intakes of solid foods and beverages, respectively. Two sets of analyses, logistic and negative binomial regression analyses, were conducted to assess the associations between risk factors and net cavitated caries incidence and increment counts from 13 to 17, respectively.

Results: In multivariable logistic regression analyses, significant ($p<0.05$) negative associations were found between age 13 to 17 net cavitated caries incidence and greater frequency of consumption of vegetables, greater brushing frequency and greater frequency of sugar-free beverage consumption. Additionally, significant ($p<0.05$) positive associations were found between age 13 to 17 net cavitated caries incidence and both net cavitated caries incidence from 9 to 13 and frequency of consumption of solid-foods in the combined category of presumed moderate cariogenicity. The significant interaction effect showed that the effect of the presence/ absence of sealants varied for girls vs. boys.

In multivariable negative binomial analyses assessing the association between net cavitated caries increment count from 13 to 17 and risk factors, significant ($p<0.05$) positive associations were found with greater intake of foods predominant in starch, presence of sealants, greater baseline age, cavitated caries increment count from 9 to 13, and greater frequency of consumption of foods predominant in added sugar, respectively. Significant ($p<0.05$) negative associations were found between net cavitated caries incidence and greater frequency of consumption of foods predominant in fiber and natural sugar and greater daily fluoride intake from water. However, daily fluoride intake from water was not statistically significant with the significant interaction effect included between baseline age and net cavitated caries increment count from 9 to 13 (dichotomized as Y/N).

Conclusion: Presence of sealants, frequency of consumption of vegetables and previous cavitated caries incidence from 9 to 13 were associated with outcomes of incidence and extent of cavitated caries observed among IFS adolescents. The differences in findings for risk factors for incidence and extent of cavitated caries are due in part to the nature of the outcome variables (count vs. dichotomous), emphasizing the need to consider both outcomes in future studies of adolescent caries.

PUBLIC ABSTRACT

Dental decay is a common chronic disease affecting much of the adolescent population in the U.S. and affecting their quality of life and overall health. The death of a twelve-year old boy in Maryland from the consequences of dental decay is testimony to this fact. A few studies have sought to identify factors associated with dental decay in adolescents, but as these were mostly cross-sectional studies, cause and effect relationships between factors and disease could not be determined.

This study aimed to determine the factors associated with occurrence of dental decay among adolescents participating from about ages 13 to 17 years in both the Iowa Fluoride Study (IFS) and the Iowa Bone Development Study (IBDS). The associations of demographic, dietary, fluoride intake, oral hygiene, sealant and dental visit variables on the occurrence of dental decay and extent of tooth decay observed from age 13 to 17 were assessed using logistic and negative binomial analyses, respectively.

Adolescents with more frequent intake of foods with added sugar and processed starch were more likely to have higher rates of dental decay, whereas those with more frequent intake of sugar-free beverages and vegetables, and more frequent daily toothbrushing with fluoride toothpaste, were more likely to have lower rates of dental decay. Having had new decay and more new decay from 9 to 13 years were associated with the occurrence of and more cavitated decay among the adolescents from age 13 to 17. The findings also support the Dietary Guidelines for Americans, 2010, for systemic health, issued by the U.S. Department of Agriculture and U.S. of Department Health and Human Services.

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CHAPTER 1

INTRODUCTION

According to the World Health Organization (WHO), dental caries is a pandemic oral disease prevalent among the world population. It is reported as one of the major public health challenges (Peterson, 2005), with five billion people affected worldwide (WHO, 2004). The distribution of dental caries is uneven in various populations, with the highest rates of decay in young children. In the United States, dental caries is categorized as the most common chronic disease in children, reported to be five times more common than asthma and seven times more common than hay fever (Surgeon General Report, 2000).

Dental disease in adolescents is a critical issue in the United States. According to the National Health and Nutrition Examination Survey (NHANES) data from the U.S. Department of Health and Human Services (2007), 59% of adolescents aged 12 to 19 years had experienced dental caries in the permanent dentition from 1999-2004. During the same time period, 20% of the adolescent population was reported to have untreated decay due to the increasing cost of dental treatment (U.S. DHHS, 2007). Furthermore, the national oral health objectives in Healthy People 2020 have placed emphasis on the problem of dental caries. One of the main oral objectives is to reduce the proportion of adolescents aged 13 to 15 years with dental decay from 53.7% to 48.3%. The effects of dental decay in adolescents have impacted not only their oral health, but also negatively influenced quality of life and systemic health. Of note, the severe consequences of dental caries resulted in the death of an adolescent in Maryland (Huffington Post, 2011).

According to the American Academy of Child and Adolescent Psychiatry, the adolescent period ranging from 11 to 19 years of age is a period when substantial physical and cognitive development occurs (HHS, 2007). According to the American Academy of Pediatric Dentistry (2010), this age is also accompanied by substantial changes in the oral environment, including an increase in the number of tooth surfaces susceptible to caries, enhanced caries activity, gingival and periodontal problems. These changes are accompanied by increased intake of cariogenic substances, both in the form of solids and beverages, and greater desire for independent lifestyle preferences leading to inclination toward poor oral hygiene. These adolescent age-related effects are further magnified when accompanied by social and economic gradients. In order to understand and better prevent dental caries in adolescents, it is essential to determine the magnitude of effects of selected behavioral and psychological factors that contribute to the risk and occurrence of disease.

Current scientific understanding states that knowledge of the disease mechanism, as moderated by the protective and risk factors, is critical in order to avert disease occurrence (Featherstone, 2004). According to a WHO report (1962), dental caries is defined as “a localized post-eruptive pathological process of external origin involving softening of the hard tissue of the teeth and proceeding to the formation of a cavity” (pg.9). The multifactorial disease of dental caries begins with sub-surface changes and slowly progresses to involve dentin (Selwitz et al, 2007). The pathogenesis of the disease is governed by acidogenic bacteria, fermentable carbohydrates and absence of sub-optimum levels of protective factors leading to changes in the equilibrium of tooth minerals and oral biofilms. This change in equilibrium results in demineralization of tooth structure and formation of carious lesions. Thus, dental caries is known to result when the deleterious effects of pathological factors are greater than the beneficial effects of protective factors (Featherstone et al, 2000). In the broad scheme of things, the interplay of protective and pathological factors can be assessed by determining the associations between exposure to risk factors and the incidence of the disease.

Epidemiological studies that determine the nature of disease in large populations use the term ‘risk’ to express the probability that a specific outcome will occur (Last, 2001& Burt, 2001). In medicine, the term ‘risk factor’ was used for the first time by Dr. William Kannel in a paper based on the Framingham Heart Study (1961). It has since been defined and interpreted in many ways (Last, 2001). A common definition of risk factor, as given by Burt (1998), is the “environmental, behavioral factor confirmed by temporal sequence, usually in longitudinal studies, which if present increases the probability of a disease occurring and if absent or removed reduces the probability. Risk factors are a part of the causal chain, or expose the host to the causal chain. “Once disease occurs, removal of a risk factor may not result in cure” (pg. 5). An exposure studied in cross-sectional data, however, is called a risk indicator (Burt, 1998).

There are a few studies reporting evidence on risk factors and indicators related to caries in adolescents. Findings of these studies are focused on two types of risk factors: modifiable and non-modifiable. Modifiable factors are defined as “determinants that can be modified by intervention” (Burt, 1998, pg. 5).These include concurrent exposures to beverages, intake of fluoride supplements, other fluoride exposures through water and topical fluorides, exposures to cariogenic foods, oral hygiene-related factors, etc. Research on the associations of modifiable risk factors with adolescent caries has been done in a few longitudinal studies (Haugejorden and Birkeland, 2006; Chankanka et al, 2011). Risk indicators associated with caries in adolescents have been documented in cross-sectional studies including those from Ditmyer et al, 2008, and Ditmyer et al, 2010. On the other hand, non-modifiable risk factors are those that cannot be modified by an intervention and include variables such as previous caries experience, early childhood dietary behaviors, demographic factors such as age, sex etc. A few longitudinal studies have been done on non-modifiable risk factors such as previous caries experience and/or previous dietary exposures (Alm et al, 2012, Rise et al, 1982). Overall, the evidence based on longitudinal data for both modifiable and non-modifiable risk factors for caries in adolescents are sparse and provide inconsistent results, likely due to differences in analytical designs, study populations, age distributions, and risk factor definitions.

There is a great need to conduct additional research to assess the associations of both modifiable and non-modifiable risk factors with incidence of caries in adolescents in the United States. Thus, the aim of this study is to determine the risk factors for caries in adolescents by conducting secondary analysis of data from the Iowa Fluoride Study (IFS). The results obtained will help in determining the strength of associations between both modifiable and non-modifiable risk factors and incidence of caries in adolescent subjects of IFS, with hopes that the results would ultimately lead to improved design of caries prevention efforts.

CHAPTER 2

LITERATURE REVIEW

Introduction

This chapter consists of four sections. First section provides a brief overview of the dental caries process and epidemiology of caries in adolescents. Second section includes a detailed description of studies of risk factors for caries in adolescents followed by summaries of important findings by category of risk factors. Third section includes an overall summary of gaps and limitations. Finally the fourth section summarizes the need to conduct this study.

The Dental Caries Process

Dental caries is a chronic, infectious, multifactorial disease of calcified tissues of teeth characterized by demineralization of the inorganic portion of teeth and followed by destruction of organic substance leading to cavitation (Schaeffer, Hine and Levy, 2009). The caries process begins when there is a physiologic imbalance between the demineralization and remineralization of hard tissues of teeth. The demineralization process is governed by microbiological shifts within the complex biofilm, and occurs when acids produced by endogenous microbes diffuse into tooth structure and dissolve the hydroxyapatite crystals. Remineralization, on the other hand, occurs when minerals and the pH of the biofilm are restored by salivary buffers. Many episodes of demineralization and remineralization determine the stage of a carious lesion. When the physiologic imbalance of demineralization and remineralization is restored, it leads to arresting and sometimes reversal of the caries process.

The coronal lesion begins with involvement of the enamel, followed by dentin and progresses to involve the pulp; unless moderated by a control or treatment measure. Clinically, the early decay process is likely to be seen on an intact enamel surface with white opacities, and is called non-cavitated caries or a white spot lesion. This lesion results when there is sub-surface demineralization of enamel under the dental plaque. As the disease progresses in severity, the clinical manifestation of a carious lesion becomes obvious cavitation. Both, the caries process and the carious lesion are characterized as dental caries.

The time-dependent caries process results from interactions among cariogenic bacteria, fermentable carbohydrate that acts as a substrate and host factors, e.g., teeth and saliva. The multifactorial nature of the disease is attributed to the biological, physical, oral environmental, behavioral, lifestyle-related and personal factors (Selwitz et al, 2007). Fejerskov and Manji (1990) illustrated the factors involved in caries development and reported that tooth, diet and bacteria in the biofilm and their interactions over time were the factors directly contributing to caries. Factors like fluoride, dental sealants, antibacterial agents, protein, sugar clearance rate, mineral ions, plaque pH and microbiological species in the oral cavity were described as oral environmental factors or factors contributing to host response. Factors like socioeconomic status, income, dental insurance, knowledge, attitudes, education, personal behavior and oral health literacy can be categorized as lifestyle-related factors.

Epidemiology of Caries in Adolescents

A major emphasis of research in dentistry is to find ways for effective prevention and treatment of dental diseases in order to decrease the morbidity and mortality from the disease. Primarily, researchers aim to conduct descriptive research to measure the occurrence of disease in the population. Incidence and prevalence are common measures of disease in epidemiology and are considered as the most important measures of morbidity (Hill, 1961). While prevalence constitutes the total number of individuals with the disease at a specific time point in a given population, incidence is defined as the number of new cases of disease within a specific time. The measure of disease prevalence gives a snapshot of the disease status and disease burden in the population, whereas incidence generally measures the transition from non-diseased to diseased state. In the case of dental caries, incidence rates can be described as transitions seen from: non-cavitated to cavitated lesions, sound surface to cavitated lesions and sound surface to non-cavitated lesions. In order to quantify the burden of disease, to identify populations at risk and to plan effective dental public health programs to decrease the disease burden, incidence and prevalence of dental caries have been recorded and assessed globally.

The prevalence of dental caries in the United States has been recorded in the National Health and Nutrition Examination Survey (NHANES) from a representative sample population since 1971. The NHANES survey was designed by the National Center for Health Statistics with the aim to obtain information on the health and nutritional status of the U.S. population including oral health as one of its components. The results of this survey are based on data collected from a nationally representative sample population. The NHANES were preceded by the Health Examination Surveys which were conducted from 1959 to 1970. After this, the series of NHANES surveys that has been published were for the years 1971-75, 1976-80, 1988-94, 1999-04, and 2005-10.

A detailed comparison of findings and oral health trends from 1988-1994 and 1999-2004 have been published by Dye et al (2007). It was found that 57.3% and 78.2% of adolescents aged 12 to 15 years and 16 to 19 years, respectively, had dental caries experience in 1988-1994. These levels declined to 50.7% and 67.5% in adolescents aged 12 to 15 years and 16 to 19 years, respectively, in 1999-2004 (Dye et al, 2007). However, the prevalence in females aged 12 to 19 years was 62.7% and in males was 55.7% in 1999-2004. These figures seem alarmingly high, considering that caries is a preventable disease. In the United States, as reported by Dye et al (2007), the prevalence of caries among 12 to 19 year old adolescents was highest for Mexican-Americans (64.5%), followed by Non-Hispanic Whites (58.0%) and Non-Hispanic Blacks (54.4%) (Dye et al, 2007). In reference to poverty status, 65.6%, 64.4% and 54.0% caries prevalence were reported for those in groups less than 100% of the Federal Poverty Level (FPL), 100-199% of the FPL and greater than 200% of FPL, respectively, for adolescents aged 12 to 19 years (Dye et al, 2007). A net prevalence of 59.1% for dental caries experience in American adolescents aged 12 to 19 years was also reported from 1999-2004 (Dye et al, 2007).

The World Health Organization estimated dental caries globally and reported that among the 12 year old adolescents of 188 countries 200,335,280 teeth were either decayed, missing or filled (Bratthall, 2004; Bagramian et al, 2009). The World Health Assembly in 1979 had declared that, by the year 2000, the global average goal for dental caries was not to exceed 3 DMFT in 12-year-olds adolescents (WHO report, 2010). Subsequently, the World Health Organization report on the global oral health data bank (WHO, 2001) reported the data for countries that did not achieve this goal. Bosnia and

Herzegovina were the countries with highest mean DMFT (8.6). Based on post 1995 data, Bulgaria, Croatia, Czech Republic, Hungary, Latvia, The Former Yugoslav Republic of Macedonia, Poland, Russia, and Slovakia were reported to have 12-years-olds with mean DMFT of 4.2, 3.5, 3.4, 3.8, 4.2, 3.6, 4.1, 3.7, and 4.3, respectively. Among the Mediterranean countries, Jordan was reported to have a mean DMFT of 3.3. The countries that did not achieve the WHO global average goal from the Americas included Bolivia, Brazil, Chile, Costa Rica, Dominican Republic, Honduras, and Panama, they were reported to have 12-year-olds with mean DMFT of 4.7, 3.1, 4.1, 4.8, 4.4, 3.7 and 3.6, respectively. The countries of the Western Pacific that did not reach the average global goal were the Republic of Korea, Philippines and Tokelau, and they were reported to have 12-year-olds with mean DMFT of 3.1, 4.6, and 4.8, respectively (Bagramian et al, 2009).

In China, the weighted prevalence of dental caries (DMFT) was 42% among the 12-year-old adolescents (Wong et al, 2001). The prevalence of dental caries among 12-year-old adolescents of Brazil was reported to be 53.6%. In the United Kingdom, the percentage prevalence of caries in 12 and 15 year old adolescents was reported to be 55.2% and 72.4%, respectively, in children attending deprived schools (i.e., schools with mostly deprived children). In comparison, the prevalence of caries was 42.0% and 55.0% in children aged 12 and 15, respectively, who were attending non-deprived schools (United Kingdom National Technical Reports, 2001). In India, 53.8 % and 63.1% of 12- and 15-year-olds, respectively, were reported to have experienced dental caries (National Oral Health Survey and Fluoride Mapping Report, 2004).

The high prevalence of dental caries, across the globe can be limited by effective prevention approaches. Prevention can be targeted in populations with greater exposure to risk factors by adequate dental public health prevention programs so as to reduce the incidence and prevalence of dental caries and its effects on quality of life. Hence, it is necessary to understand the influence of risk factors so that dental public health programs can be effectively designed to address the exposures to different risk factors in various populations.

Risk Factors for Caries in Adolescents

This section first presents a review of key studies of risk factors for caries in adolescents, followed by brief summaries of findings by risk factor, and finally an overall summary of gaps found in the literature on risk factors for dental caries in adolescents.

Detailed Review of Key Studies on Risk Factors for Caries in Adolescents

This section is divided into two main parts:

- Studies from the United States, and
- Studies from outside the United States.

Studies from the United States:

Ditmyer et al (2008, 2010) conducted two studies published in 2008 and 2010. The basic methodology of collecting information was the same for both studies. Hence, some of the common aspects of both the studies are discussed here. The two studies by Ditmyer et al (2008, 2010) used data from the statewide Oral Health Screening Initiative in Nevada that began in 2001 and retrospectively analyzed data on cohorts from 2005-

2006 (Ditmyer et al, 2008) and 2008-2009 (Ditmyer et al, 2010), respectively. Visual assessments in both studies were done by using NHANES criteria (Ditmyer et al, 2008, 2010), while compressed air and explorers were not used in this survey. In both the studies, the DMFT index score was used to assess cavitated caries prevalence and severity, and no assessments were made of non-cavitated lesions.

Ditmyer et al (2008) recorded the prevalence of caries cross-sectionally in 13 to 18 year olds, and was compared with NHANES data reported for 1999-2004 for the same age group (Ditmyer et al, 2008). Independent variables were self-reported by subjects and included sex, age, race-ethnicity, SES, locale, family history of diabetes, dental insurance status, environmental smoke exposure, tobacco status, presence of sealants and overweight status (which calculated from weight of children. In addition, residence in Clark County or outside Clark County was also considered as an indicator of fluoridation (Clark County is the only county in Nevada that was fluoridated). This population based study, examined a group of 9,202 adolescent volunteers. The group was considered to be representative of moderate and high SES children based on information about eligibility status for free and reduced cost school lunch programs. Multiple regression analyses were used to study the risk indicators of prevalence and severity of caries, as continuous and categorical variables, respectively. Based on the DMFT WHO scoring criteria, the children were categorized into low, moderate and high caries categories which were defined as those with DMFT ≤ 2.6, DMFT = 2.7-4.4 and DMFT ≥ 4.5, respectively.

Study participants had a mean DMFT of 2.79 with a higher prevalence of untreated decay and greater mean DMFT scores when compared to NHANES 1999-2004, survey results (Ditmyer et al, 2008). Residence in Clark County (fluoridated) and presence of sealants was negatively associated with caries prevalence and severity ($p \leq 0.001$). In linear regression analyses, water fluoridation, exposure to environmental smoke, age, race and living in rural or urban areas were the strongest predictors of caries prevalence and severity in the model ($p \leq 0.001$). In the logistic regression analyses, variables such as exposure to non-fluoridated water, environmental smoke, tobacco use in adolescents were associated with higher odds of severity and prevalence of caries. In addition, higher prevalence and severity of caries was also positively associated with children who were Native American and Pacific Islanders, or who had higher body mass indices and residence in rural areas. The final model excluded variables of ethnicity, SES and family history of diabetes and had a 40% predictive ability.

One of the biggest strengths of the study was that it assessed the association of several variables along with the prevalence and severity of caries in a large study population. However, as this was a cross-sectional study, causality could not be determined. Socioeconomic status was not associated with prevalence and severity because the study had poor representation of low SES population, where the risk of caries prevalence is highest. In addition, the study focused on analyses of distal determinants, and proximal risk factors such as dietary behaviors, and cariogenic bacteria were not assessed in the study. Furthermore, fluoride exposure from different sources was not analyzed in the study. The participating schools in the study comprised of only one-fourth of all schools in Nevada. Hence, the population studied was not likely representative of the state of Nevada.

On the other hand, in a second study, Ditmyer et al (2010) divided adolescents into two age groups for study purposes 12-15 years and 16-19 years, and determined the association between eight independent variables and caries prevalence as the outcome (Ditmyer et al, 2010). As referred to earlier, the data from 2008-09 Oral Health Screening Initiative in Nevada (that began in 2001), including 4,169 adolescents were analyzed retrospectively to determine the factors associated with prevalence and severity of caries in a group with highest caries. The data were collected using oral health screening and face-to-face interviews as stated earlier in detail. Sex, age, dental insurance status, race, environmental smoke exposure, smoking habits, living in an area with fluoridated water (residence in Clark County) and presence of dental sealants were assessed as the predictor variables in these analyses. In addition, the study group was divided into three sub-groups depending on the DMFT scores. Adolescents in the highest tertile of caries prevalence and those without caries were labeled as cases (N=2,124) and controls (N=2,045), respectively, in this study

According to the multiple logistic regression analyses, the strongest predictors of severe caries prevalence included race, higher age, living in area without community water fluoridation and presence of sealants ($p<0.001$) (Ditmyer et al, 2010). The results showed that Hispanic adolescents, and individuals aged 16-19 years of age, those living in areas with no fluoridated drinking water and those without sealants were more likely to have the highest reported mean DMFT scores. The odds ratio reported for these variables were 2.1, 2.04, 1.98, and 1.52 respectively ($p<0.001$). In addition, R^2 value indicated that the model had 40% predictive ability. As stated earlier, the study compared caries prevalence in Nevada youth to the prevalence and severity of caries for the same population reported in the NHANES data from 1999-2004. It was found that prevalence and mean DMFT scores among children with highest caries in the study population were more when compared to the national average reported in NHANES 1999-04 for the 12-19 year old adolescent population.

Ditmyer et al (2010) did not report the number of schools selected and did not clarify whether the target population was representative of the Nevada adolescent population. In addition, the authors did not assess snacking and beverage drinking behaviors. Diet is a proximal risk factor for caries, and in adolescents dietary behaviors can be more critical. In addition, the methodology did not focus on analyses of ethnicity and daily fluoride exposure from different sources, e.g., topical, systemic and total, etc., as predictors of caries.

An article published in Morbidity and Mortality Weekly Report (Klejka et al, 2011) examined the association between prevalence and severity of dental caries in rural Alaskan native children (4-5 and 12-15 years old) cross-sectionally and soda pop intake and fluoridation status (Klejka et al, 2011). In this study, the sample included 348 children aged 4-15 years old, from five selected villages, whose parents gave consent to participate. Parental consent was obtained and they were asked questions regarding themselves and the children. The questions on parents were focused on their self-reported tooth-brushing behaviors, access to care and status of water fluoridation. The questions about children focused on child related independent variables- children’s tooth brushing, use of dental floss and soda pop consumption. The only socio-demographic information asked was the sex of the child. Data on prevalence and severity of caries was obtained from intra-oral exams conducted by a single examiner and were determined for children by age groups 4-5, 6-8, 9-11, and 12 -15 years, using oral health survey method that was matched to NHANES protocol (Dye et al, 2007). Age adjusted bivariate analyses were initially performed to examine the association between each risk factor and dental caries. This was followed by multivariable logistic regression where the variables were eliminated from the model by a backward selection procedure. The alpha level for the analyses ≤ 0.25 was used for inclusion in multivariate modelling. The multivariate models presented associations between variables after adjusting for age and sex.

Prevalence of dental caries was greater among 12-15 year old adolescents in comparison to prevalence among 4-5 year old children in the study population (Klejka et al, 2011). However, the mean dft values of dental caries were higher in children aged 4-5 years (7.3) in comparison to the mean DMFT values in children aged 12-15 years (5.0) and were also substantially higher than caries reported in national sample of same age group of U.S. children (Dye et al, 2007). Among 4-11 year olds, a minimum of 71% of the children were reported to have caries on at least one tooth in areas without fluoridated water and this proportion was greater than children in fluoridated areas (67%).

Prevalence and severity of caries were reported separately by dentition (primary vs. permanent) and age group (Klejka et al, 2011). The mean dft in primary teeth was 2.7-9.8 in non-fluoridated villages which was much higher than those in fluoridated villages (2.2-3.7). Similarly, in permanent teeth, the mean DMFT in the non-fluoridated areas ranged from 1.6-5.6 in comparison to the mean DMFT score in the fluoridated area which was relatively low (0.5-2.7). Out of the 76 children examined, the proportion of children aged 12-15 years having % DMFT > 0 and % DT > 0 were 91% and 68%, respectively. The odds of caries prevalence were higher in children aged 4-5 years living in non-fluoridated areas (OR=3.5) when compared to those staying in fluoridated areas. Similarly, the odds of caries prevalence in 12 to 15 year olds living in non-fluoridated areas (OR=1.7) were higher when compared to those staying in fluoridated areas. . Higher odds of cavitated caries prevalence were found in children who consumed soda pop more than three times per day, followed by those who consumed soda pop twice and once per day when compared to children who did not consume soda-pop at all. It was suggestive of a significant association between dental caries and greater frequency of soda-pop consumption for all children aged 5 to 13 years.

The results compared prevalence and severity of caries in children in fluoridated and non-fluoridated areas (Klejka et al, 2011). Although the authors reported fluoridation status, the time of exposure or the years of residence in a fluoridated area were not assessed. In addition, intra-examiner reliability was not reported and it was unclear whether the examiner was trained or calibrated. Although frequency of soda pop-consumption was defined as a risk indicator, the authors did not assess the different times (e.g. between meals/after meals and night time drinking) at which the children were more likely to have soda pop and whether these times differed with age. Authors determined the caries in both primary and permanent dentition, for children aged 4-5 years and 12-15 years, and so could compare the prevalence of caries in these groups, to some extent. The study lacked focus on other potential risk indicators like frequency of dental visits, topical fluoride application and dietary intake (solid foods) or even frequency of intake of other sugar sweetened beverages. In addition, as this was a cross-sectional study, the analyses were not sufficient to determine any causal associations between the few risk indicators and caries in Alaskan Native children.

Burt et al (1988) conducted a longitudinal study of 499 South Central Michigan (U.S.) based adolescents aged 11-15 at baseline, to study the associations of three-year caries increments and average daily sugar consumption from all sources (Burt et al, 1988). The main independent variables were, average amount of sugar consumed, average daily number of eating occasions, average daily number of between meal sugar consumption and average daily number of high sugar snacks. The study had a voluntary sample from schools of rural and non-fluoridated communities. The children enrolled in the study reported data on dietary intake by means of a 24-hour recall interview and food frequency questionnaire, four times during the 3-year study period. The dietary recall interviews were adopted from NHANES data of 1976-80 while the caries examinations were based on NIDCR's criteria (Burt et al, 1988). Depending on the average daily consumption of sugars, the authors divided the children into percentile groups. The children who had 109 g of sugar intake daily and those who had 175 gm of sugar intake daily were defined in the 25th and 75th percentiles, respectively. The study sample was divided into two groups, i.e., low caries children (zero increment) and high caries children (greater than two approximal caries).

The associations between dependent and independent variables for low and high caries children and for low sugar and high sugar consumers were determined by using independent t-test and fisher's exact test (Burt et al, 1988). The confounding effects of variables like past fluoridation status, frequency of topical fluoride applications, tooth brushing frequency, antibiotic use, educational level of parents, and demographic variables was assessed with regards to sugar and caries relationships, by linear and logistic regression analyses, but actual results were not reported.

New lesions comprised of mainly pit and fissure caries (81%) and the average consumption of sugars from all sources was more in males (156 gm/day) than in females

(127 gm/day) (Burt et al, 1988). For all children, sugars constituted one quarter of total calorie intake. However, there was no significant association between pit and fissure caries increment and average daily consumption of sugars from all sources, average number of daily eating occasions, average number of between meal snacks of high sugar foods or average daily consumption of sugar between meals. In contrast, significant positive association was found between approximal caries increments and total energy intake from sugar and average consumption of sugars between meals ($p<0.05$).

The authors reported that during the interview process children were probed to recall everything eaten on the previous day (Burt et al, 1988). This may have led to response bias. It is not known whether the examiners or the interviewers were blinded to the purpose of the study or were able to influence children's responses in any manner. In this study, information on calibration of examiners and inter-examiner reliability was not assessed. It is also necessary to understand that the authors had only 4 interviews during the three year study period, which may not be sufficient to map the variation in patterns of sugar consumption. Though the authors tried to assess the diets in different days and seasons; previous day measure of diet may not be a true measure of daily dietary intake over a three year span. These factors are likely to affect the internal validity of the study. In addition, the authors did not clarify if the dietary measures taken were from a specific time or distributed throughout the three-year period and if the periods were uniform for all subjects. The findings on the target population cannot be generalized as the sample was likely not representative.

Fontana et al (2011) assessed caries progression and its association with predictors in two models, including and excluding dental caries at baseline (Fontana et al, 2011). The main aim of the study was to design a risk assessment model assessed by the area under the receiver operating characteristic (ROC) curve and to determine the sensitivity and specificity of the models designed for dental and non-dental settings.

The authors aimed to assess the risk factors for caries progression in 408 Hispanic children aged 5 to 13 years in a longitudinal study (Fontana et al, 2011). The children were enrolled in three rural schools of Puerto Rico Children with medical problems or medical conditions were excluded from the study. The caregivers recorded information about themselves and children in a 25-item questionnaire. The questionnaires were completed by the caregivers at the 12- and 24-month-follow-up visits and included variables (i.e., demographics, medical and dental history, access to care, dental habits, dietary habits and fluoride-related variables) related to caregivers and children.

The dental examinations were done at baseline, 12-month and 24-month follow-up visits and dental caries was scored using International Caries Detection and Assessment System (ICDAS) (Fontana et al, 2011). Caries progression was analyzed as the outcome variable using two types of primary outcomes for predictive modeling that included any caries progression (caries if ICDAS ≥ 1). Any caries progression was also reported if the ICDAS score progressed from baseline ICDAS score 1-2 to 3 or progressed from a baseline ICDAS score of 3-4 to 5 or higher, or if there was one new filling observed between the two examinations. Caries progression to cavitation was observed (caries if ICDAS ≥ 3) from baseline to 12-month follow-up visits and baseline to 24-month follow-up visits. Progression to cavitation was reported if presence of at least one new filling or lesion ICDAS ≥ 3 was observed. Progression to cavitation was also reported if the ICDAS score progressed from a baseline ICDAS score of 1 or 2 to 3 or higher or when lesions progressed from a score of 3 or 4 to 5 or higher between the two examinations. Inter-examiner and intra-examiner reliability was assessed re-examining 10% children at initial, 12-month follow-up and 24-month follow-up dental exams, respectively.

This study determined separately the associations of each predictor variable with progression of caries from baseline to the 12-month and baseline to 24-month follow-up exams, respectively, using logistic regression (Fontana et al, 2011). Baseline ICDAS scores were added initially to the model when the risk assessment model was targeted for a dental setting. However, when the risk assessment model was targeted toward a non-dental setting, the baseline ICDAS scores were added only after the assessment of predictors collected using questionnaires. The area-under-the-curve was calculated to determine the overall predictive ability of the final models. In both cases, the multivariable models were developed using backward elimination procedures considering $p<0.05$ to be statistically significant.

At the 12-month follow-up examination, 348 (89%) children had at least one surface with any progression and 239 (61%) of children had progression to cavitation (Fontana et al, 2011). The mean ICDAS dmfs/DMFS for ICDAS ≥ 1 and ICDAS ≥ 3 at the 12-month follow-up examination were 17.9 and 8.3, respectively. At the 24-month follow-up examination, the ICDAS dmfs/DMFS for ICDAS ≥ 1 and ICADS ≥ 3 were 16.8 and 8.4, respectively. Additionally, at the 24-month follow-up examination, 358 (91%) children had one surface with any progression and 268 (68%) with a progression to cavitation from 12-month follow-up to 24-month follow-up.

Children with progression to cavitation at the 12 month follow-up were more likely to have the extracted teeth (OR=2.56), restored teeth (OR= 2.08), a longer time elapsed since past dental visit (OR=2.22) and to have a caregiver who does not consider child's oral health to be very good (OR=2.68) (Fontana et al, 2011). The sensitivity and specificity of this model were 80% and 58%, respectively, without including previous caries experience as the predictor variable. Children with any progression at the 12-month follow-up visit were more likely to have a tooth extracted (OR=3.97) and to have a caregiver who does not consider child's oral health to be very good (OR=5.43). The sensitivity and specificity of this model when previous caries experience was excluded were 73% and 61%, respectively. However, when previous caries experience was included, the sensitivity and specificity were 79% and 58%, respectively.

Children with progression to cavitation from baseline to 24-month follow up visit were more likely to have a restored tooth (OR=2.38), to have longer time elapsed since last dental visit (OR=1.93) and were more likely to have caregivers who did not consider the children's oral health to be very good (OR=2.80) (Fontana et al, 2011). The sensitivity and specificity of this model were 73% and 61%, respectively, irrespective of inclusion and exclusion of previous caries experience in the model. Children with any caries progression at 24-month follow-up were more likely to have past restored teeth (OR=2.31), caregivers with current caries (OR=2.62), caregivers who received a referral for the child (OR=2.43), and caregivers who did not consider child's oral health to be very good (OR=2.33). The sensitivity and specificity of this model were 82% and 59%, respectively, without including previous caries experience but changed to the the value of 75% and 61%, respectively, when previous caries experience was included at the start.

The study's target population was Hispanic children from rural Puerto Rico that constituted 91% of the sample (Fontana et al, 2011). The authors did not clarify the number of children with primary, mixed and permanent dentitions. It was not explicitly stated by the authors as to which exposure period was considered in the questionnaires. In addition, the questionnaires were not modified for different age groups, and caries progression was analyzed collectively for all three dentition stages in which the oral environment and habit patterns are likely to undergo many changes. Hence, caries progression in this case cannot be defined for a particular age group and the risk factors for caries progression for primary, mixed and permanent dentition cannot be evaluated separately. The most proximal risk factors for caries were not strongly associated with caries progression. This might be because data on the exposure variables such as dietary behaviors, beverage and snack intakes were not collected. The authors had a novel approach in terms of defining caries risk assessment models in dental and non-dental settings. However, as observed, the high sensitivity of the models was obtained at the cost of low specificity.

In a longitudinal study by Chankanka et al (2011), the authors examined the associations between modifiable risk factors and cavitated and non-cavitated caries during the primary, mixed and permanent dentitions exams conducted among Iowa Fluoride Study children at ages 5, 9 and 13 years (Chankanka et al, 2011). The criteria used for the dental examination were those given by Warren et al (2002) with the outcome variables classified as d1/D1 (non-cavitated caries) and d2+f /D2+F (cavitated caries). The outcome variables were calculated as person level counts of caries increments. The transition of diagnosis from sound surface to non-cavitated caries were counted as new non-cavitated caries and from sound surface to cavitated caries or filled lesions were counted as new cavitated caries. Increments observed from 0 to 5 years were considered as increment at exam 1, age 5 to 9 were considered as increments at exam 2 while increments observed from age 9 to 13 were considered as increments at exam 3. The study sample comprised of 156 of the total children recruited in Iowa Fluoride Study from 1992-1995. It was a convenience sample comprised primarily of non-Hispanic white children from mostly high and moderate SES backgrounds. The authors collected dietary information from dietary diaries till age 8.5 years. Beginning at 9 years, the information on dietary variables was collected in the form of a detailed questionnaire sent to children's parents.

The dietary variables assessed the intake of milk, water by itself, reconstituted sugared beverages made from powder, sugared soda pop, 100 percent juice, and juice drinks with added sugars (Chankanka et al, 2011). For every child, the frequencies of intake were averaged across three different time points, i.e., 3-5 years, 6-8 years and 11-13 years, respectively. The weighted average of fluoride levels from main sources of water were used to determine a composite water fluoride level. Information for public water without filtration was obtained from Iowa State Health Department. Fluoride assays using ion-specific electrode were used to determine fluoride levels from non-public individual sources. The total fluoride intake was averaged for each period for every child. Individual tooth brushing frequency was also reported from questionnaires used prior to and after 9 years of age.

The associations between the predictor and the outcome variables were assessed by using generalized linear mixed models based on negative binomial distribution

(Chankanka et al, 2011). Here, the generalized linear mixed models were used to model the proportion of new non-cavitated or cavitated caries surfaces to surfaces at risk. Since the data were longitudinal, repeated measures modeling framework was done to account for the correlated data. Moderate to high correlation pairs found from the univariable analyses were included in the multivariable regression analyses. The final model was developed using backward elimination procedures. All variables included in the analyses were those that had p<0.15 in the univariable analyses. However, the predictors such as exam time, exam age, and dentition type were included in the regression models even if the p-values in the bivariate analyses were not significant at 0.15 levels.

The highest non-cavitated caries incidence was seen at age 9 (39.10%) for exam-II in comparison to increments at age 5 (21.15%) for exam-I and to increments at age 13 for exam-III (35.90%) (Chankanka et al, 2011). However, the mean values for non-cavitated caries increments for exams-I were just slightly greater than exam-II and exam-III. The highest cavitated caries increment were also reported at age 9 for exam-II (54%) when compared to increment at age 5 (26%) and at age 13 (28%). It was found that higher proportion of new cavitated caries surfaces to surfaces at risk and lower SES level were significantly associated with more non-cavitated caries increments, while factors like tooth brushing frequency were negatively and significantly associated with non-cavitated caries increments. They also found that greater proportion of new non-cavitated caries to surfaces at risk, increment at exam-II and exam-III were significantly associated with cavitated caries. In separate analyses where dietary variables were included, higher levels of 100% juice intake were negatively and significantly associated with new non-cavitated caries (p<0.041) and cavitated caries (p<0.02), respectively.

Because the study had a longitudinal design, it was able to record and analyze risk factors preceding the outcome of interest, thus, having the ability to determine causal relationships (Chankanka et al, 2011). The study design also had some unique approaches such as using both fixed and random effects models along with repeated outcomes for individual subjects. Additionally, it was a novel approach to observe the associations of risk factors for caries from birth to age 13 years. The study however, did not have a diverse sample of United States adolescent population so the generalizability was limited. Furthermore, the association between risk factors and caries was limited to higher income children and the sample size was very modest. The study did not assess the risk factors for caries beyond age 13, which presents an opportunity for future research.

Studies from outside the United States

In an article by Haugejorden and Birkeland (2006), data were collected during oral examination of several consecutive cohorts of 12-year-olds, born between 1973 and 1986 (Haugejorden and Birkeland, 2006). These oral examinations were conducted at 103 dental health districts in Norway from 1985-2004 and the data were used in two different ways.

The first way assessed the incidence of cavitated caries (D3MFT) in 12-year-old children for 20 consecutive years (1985-2004) (Haugejorden and Birkeland, 2006). The population size varied with time and for 12-year-olds ranged from 51,452 in 1995 to 63,213 in 2003. The percentage of 12-year-old children examined nationwide also varied from 94.7% in the year 1986 to 76.2% in 2004. The second part of the study assessed cavitated caries incidence for fourteen birth cohorts from 1973 to 1986. Each birth cohort was followed from age 12 to age 18 years. At the national level, the proportion of 18-year-old children examined ranged from 71.4% (1999) to 83.4% (1993).

In the study, caries prevalence at 5 years and average of the mean D3MFT at 12 and 18 years were defined as the dental variables (Haugejorden and Birkeland, 2006). The background variables consisted of the year when children were 15 years old, the percentage of the population who completed a university or college degree, the average income in Norwegian kroner, mortality in children aged less than a year per 1,000 live births, and proportion receiving income support. The other background variables included in these analyses were net-mobility, i.e., net population mobility by county, Haugejorden and Birkeland, 2006) considered per year and proportion of population of 0-17 year old subjects who were immigrants of first and second generation. The fluoride exposure was recorded as two separate variables: “Fluorexp” and “Fluorexp1-10”. Fluorexp was described as the total sale of fluoride tablets expressed as the mean daily dose/per person under 15 years of age per year, while Fluorexp1-10 was defined as the average sale of fluoride tablets during the first nine years of life, for each respective cohort. Dental care variables included the percentage of subjects 12-18 years of age examined or treated and the proportion of vacant positions for dentists and dental hygienists in the Dental Service System.

Haugejorden and Birkeland (2006) assessed the relationships for two outcome variables: cavitated caries D3MFT experience at age 12 years and cavitated caries D3MFT incidence from age 12-18 years in this study (Haugejorden and Birkeland, 2006). Caries prevalence at age 12 years and caries incidence from age 12 to age 18 years were related to predictor variables using chi-square tests to compare frequency distributions and students t-test to compare paired observations. Bivariate tests (Spearman's rank correlation) were performed and variables that were significant in the bivariate analyses were included in the multiple linear regression analyses. Four different models were developed considering the repeated measures taken for the birth cohort, whereas model fit was assessed by ANOVA.

Results described the overall trend in caries from 1985 to 2004 and a mean reduction in caries of about 3% per annum through 2000 was reported (Haugejorden and Birkeland, 2006). However, caries rates increased from 2001 to 2004 at the rate of 3.3% per annum. The mean D3MFT score showed a gradual decrease from 3.4 (1985) to 1.5 (2000), but then increased slightly to 1.7 (2004).

The mean D3MFT score and prevalence of caries was associated positively with percent caries prevalence of the cohort at age 5 (Pearson's r=0.65 to 0.83) (Haugejorden and Birkeland, 2006). However, the same outcome was negatively associated with sales of fluoride tablets in 10 of the 16 analyses. The r value for the 10 analyses ranged between -0.38 to -0.61. Caries prevalence was positively and significantly associated with infant mortality. Among the independent variables: later year, college or university degree, higher income, social support at the level of 1000 Norwegian kroner and lower net mobility in counties were negatively correlated with mean D3MFT prevalence at 12 years. When the four predictors were included in linear multiple regression analyses, the mean caries prevalence at age 5 was significant ($p<0.05$).

Among the children followed from 12 to 18 years of age, the highest mean D3MFT increment was reported for birth cohort in 1976 (4.1) while the lowest mean was reported (3.2) for the years 1982 and 1983, respectively (Haugejorden and Birkeland, 2006). Due to issues of multicollinearity, only two variables were included in the multiple linear regression analyses, along with two interaction variables defined as “year + income” and “year + education”. Significant positive associations between 12 to 18 years D3MFT incidence and income support, income and baseline D3MFT were identified in multiple linear regression analyses. In addition, caries increment rates were positively and significantly associated with the percent caries prevalence of the cohort at age 5 years. At the county level, D3MFT increments in children observed between 12 to 18 years of age were significantly and negatively associated with sales of fluoride tablets ($r = -0.38$ to -0.61, $p<0.05$). When compared to other predictors, previous caries experience as measured by caries at baseline (the mean D3MFT score at 12 and 18 years), was a stronger predictor of caries incidence from age 12-18 years explained 91% of the variability of the models. When the variable baseline D3MFT was not considered, there was significant positive association between 12-18 year increment and education, whereas; a significant negative association between social support, mobility across counties, infant mortality and percentage examined and the additive interaction terms of “year + income” and “year + support” and 12-18 year.

The study assessed the causal associations between the selected independent variables and caries increments from age 12-18 years and caries prevalence at age 12 years (Haugejorden and Birkeland, 2006). The authors assessed cavitated caries incidence as mean D3MFT in both analyses, but results were not specifically related to categories of family income. Another a drawback of the study was that incomes for the years 1988 and 1992 were missing. Apart from the demographic and fluoride-related variables, the authors did not consider potentially important variables such as oral hygiene and dietary variables in the analyses. The reported fluoride exposure was not recorded at any individual level and there was no measure of cumulative fluoride exposures from different sources. Moreover, the data were not equally representative of all the regional/county level populations as missing information were not evaluated from all counties and regions and, therefore the findings cannot be generalized specifically to any part or whole of the 103 dental districts. In addition, as the the findings were not based on individual level data, interpretation of the findings should be made cautiously considering ecological fallacy.

Clancy et al (1977) assessed relationship between one-year caries increments and dietary variables of study subjects from upstate New York (U.S.) (Clancy et al, 1977). The final sample size consisted of 143 mother-child dyads. The main independent variables were snack food intake and money spent on purchasing snack food. The information on explanatory variables was collected using structured interview. Mothers reported demographic information comprising of family income, education of both parents, and number of family members in the household while both mothers and children reported dietary variable information.

The children and mothers were asked to give information on 18 types of food, amount of money spent by them on the purchase of snack foods and frequency of snack intake between meals for child and themselves, while information on other dietary behaviors were collected from children (Clancy et al, 1977). There were two scores assigned for snack intake at child level i.e., individual score and composite score. Individual score for snack intake of each child was derived by adding the frequencies of intake of nine of the eighteen food items while the composite snack score was defined as the correlation between a particular snack intake and the total snack intake. The associations between one-year caries increment in children and the dietary behaviors of both mothers and children were assessed by Pearson r correlation, partial correlations and t-tests (Clancy et al, 1977). The baseline caries score and the caries increment was significantly positively associated with those who ate chocolate candy ($p=0.007$) and was negatively and significantly associated with intake of apples, fruit juice and sugarless gum ($p<0.05$). Among the mothers score, a weak correlation was found between mothers' snack food score and child's dental caries increment score ($r=0.05$; $p=0.04$).

Although it is clear that interviewers were trained, it was not clear whether the interviewers were tested to ensure consistent methods of interviewing (Clancy et al, 1977). As the sample selection process was not clear and the sample comprised of relatively high SES children, the results could not be generalizable to a target population. In addition, from the details of the study, it could not be determined whether the examiners and dieticians were blinded from the purpose of the study.

Even with the longitudinal design, it is a study that was conducted over 35 years ago (Clancy et al, 1977). Also, independent variables were based on dietary information of both mother and child. The authors hypothesized that mother's dietary habits will be significantly associated with caries in the child, but the study reported a very weak relationship of mother's snack consumption and caries increment in children. Additionally, there was a very weak relationship between self-reported snack intake by the child and snack intake by the mother. Moreover, other factors such as fluoride exposures and oral hygiene habits were not considered even when the non-fluoridated areas are likely to encounter the benefits of fluoride due to the halo effect. Furthermore, factors such as dental visit variables and home or office use of other preventive agents were also not assessed.

Beighton et al (1996) conducted a study on a sample of 328 children aged 12 years from seven volunteer middle schools in the south area of Northumberland, United Kingdom (Beighton et al, 1996). The information on dietary variables was obtained using three-day diet diaries completed every three months for each child from a private interview process conducted by a single dietician. Any eating event was considered separate from others if the time of consumption was 30 minutes in the case of a meal or 15 minutes in the case of a snack, after the previous event. In this way, each of the separate events was based on snack and meal intakes. In addition, events/day were assessed for both solid food and drinks containing high proportions of sugar (sugar events), all food and drinks (total events), confectionary only events, foods containing a high proportion of starch events. The authors also assessed total carbohydrate, total starch, and total sugar in grams per day, along with the mean per day intake which was calculated for each of these food groups. Caries was assessed in December 1989, using criteria by Rugg and Gunn (Rugg-Gunn et al, 1984) without radiographs, while the dietary diaries were completed beginning in January 1990.

The authors also assessed salivary micro-organism levels from each child in April/May 1990 at school one hour after the last recorded food intake (Beighton et al, 1996). The counts of mutans streptococci, lactobacilli and yeasts were recorded using these samples. The microbiological counts were detected at a threshold of 10 colony forming units per ml (Beighton et al, 1996). For statistical analysis, the authors used $\log_{10}$

counts to assure a normal distribution. The authors conducted step-wise multivariate regression analyses to determine the associations between independent variables (diet, bacteria, plaque measures and age) and caries prevalence including and excluding pre-cavitated lesions along with cavitated lesions.

Caries experience was recorded as DMFT, DMFS, DFS (pits), and DFS (smooth), as well as non-cavitated lesions (Beighton et al, 1996). Smooth surface DFS was significantly positively associated with total eating events and confectionary events. Sugar-containing events were more likely associated with smooth surface caries than the pit and fissure caries. A significant positive association between caries experience scores (DMFT and DMFS), and the total number of eating events, number of events for food containing high proportion of sugars, and the number of confectionary events, were reported. However, the association between caries DMFS/DMFT was not associated with number of starch events, i.e., frequency of starch intake. Except for amount of starch consumed, the quantity of other daily dietary food categories was not associated with caries experience in 12-year-old English children. The mean (std. deviation) DMFS were 3.05 (± 3.85) and 5.72 (± 5.00) when, non-cavitated lesions were excluded and included, respectively. Mean number of sugar-containing events was significantly positively associated with higher caries, both including and excluding non-cavitated lesions ($p<0.05$).

In the multivariate analyses, the variables such as number of eating events per day and frequency of sugar containing or confectionary events were significantly and positively associated with non-cavitated caries and cavitated caries lesions (Beighton et al, 1996). Mean values for higher caries was significantly positively associated with confectionery eating events. For pits and fissure caries in posterior teeth, the confectionary eating events were positively correlated with lactobacillus levels. There was also a positive significant association between gingival index, salivary concentration of bacteria along with frequency of ingestion of confectionary/sugary foods and caries experience.

As this study was cross-sectional, the causal relationship between dietary variables and caries experience could not be established (Beighton et al, 1996). In addition, as evident from the dates in the collection of the study data, the exposure to different dietary variables was assessed after caries assessment. It is not clear if the dietician was blinded to the purpose of the study. Bacterial levels and frequency of consumption of sugary and confectionary foods were correlated. This finding is indicative of the strong association of sugar intake and bacterial counts, which in turn were related positively to caries. Although the authors stated that the sample was a representative cross-section of social groups, it is not clear how social groups (ethnicity, economic etc.) were assessed and hence the representativeness of the sample may be limited.

In a study by Bruno-Ambrosius et al (2005) conducted in Sweden among 185 female teenagers aged 12 years at baseline, the authors assessed the relationships between three year caries increment and dietary behaviors, tooth brushing behaviors, and smoking behaviors (Bruno-Ambrosius et al, 2005). The information on dietary variables was assessed using a 15-item questionnaire that was completed by the subjects every four months throughout the study period. The dietary variables assessed were omitting breakfast, omitting school lunch, omitting dinner, irregular meals, and intakes of snack and sweets, soft drinks and juice, respectively. The frequency of intake was recorded as never, seldom, several times a week, daily or several times a day. The questionnaire recorded information on smoking, tooth brushing regimen and use of fluoride toothpaste. Caries experience was recorded using DMFT/DMFS/DFSa (decayed and filled proximal surfaces)/proximal enamel lesions (ECa) scores obtained from intra-oral exam (WHO criteria, 1987) and by use of radiographs. The associations between smoking, dietary, and tooth brushing variables and caries increment over the three year period were evaluated by two tailed chi-square tests with Yates correction factor for continuity. In addition, the comparison of caries increments in children with different habits was assessed by two-tailed t-test.

It was reported that omission of breakfast and irregular meals at home were positively and significantly related to greater caries increment (DMFS) at age 15 years ($p<0.05$) (Bruno-Ambrosius et al, 2005). However, it was also found that caries increment at age 15 was not statistically significantly associated with frequent daily snacking, intake of sweets and intake of sugar containing beverages such as soft drinks/juice (p-values were not reported). The authors admitted that assessment of the increase in dietary intake per year could not be done using the questions from the questionnaire. Among eight grades, odds (C.I.) for caries increment were higher for smokers than the non-smokers [OR= 4.1(1.0, 18.9)] ($p=0.05$). The mean DMFS (SD) increment was higher for the smokers [7.7(4.7)] vs. non-smokers [1.9(2.7)] ($p<0.001$).

The broad conclusions of the study suggest association between dietary behaviors and caries increment, but highlight the need for more comprehensive research (Bruno-Ambrosius et al, 2005). The questionnaire information was filled in groups and there was a chance that the children had biased responses due to peer pressure. The authors defined a single dietary group comprising of both, juice and soft drinks, which could have affected the relationships given the nature of sugars in each. Moreover, in the current era of changing dietary behaviors (e.g., intake of energy drinks and sports drinks) the association between dietary habits in adolescents and dental caries demands further research.

A study conducted by Kallestal and Fjelddahl (2007) assessed the relationships between preventive factors and risk factors in adolescents and caries for those at high and low risk, respectively (Kallestal and Fjelddahl, 2007). The four-year longitudinal study was conducted in Sweden and a cohort of 3,373 adolescents who agreed to participate in the study was recruited. The study sample comprised of subjects from multiple sources, i.e., towns, large cities and rural areas and was representative of the Swedish population. The data were collected from records obtained from the Swedish Dental Services for 12-year-old children in 26 dental clinics. Dentists were trained in diagnosis and assessments of caries based on the C.K. assessment standard (Kallestal and Fjelddahl, 2007) and were calibrated twice before the study. Inter-examiner reliability was tested twice each year. Radiographs were also used to detect caries. The authors calculated caries experience using the DMFS score and enamel caries was reported as DeMFS scores.

At baseline, the presence of one decayed proximal surface, any active enamel or dentine caries, a filled proximal surface or a missing tooth because of caries, placed the child in the high-risk group which also included children with a mental or physical disability or chronic disease (Kallestal and Fjelddahl, 2007). In addition, when the bacterial testing report found the lactobacilli CFU $>10^5$, patients were included in the high risk group. These high-risk children were randomly assigned to one of four preventive programs that included tooth-brushing, fluoride lozenges, fluoride varnish and individual programs. In the tooth brushing program, children were advised to brush teeth using a technique in which toothpaste foam was kept in the mouth and not rinsed away. In the fluoride lozenges group, children were prescribed to take fluoride lozenges 0.25 mg, three times daily (up to 16 years of age) and thereafter were instructed to take the lozenges 4-6 times daily. At each subsequent dental examination, the subjects were asked about the compliance. In the fluoride varnish program, after cleaning teeth, fluoride varnishes were applied three times per week at 6-month intervals. In the individualized program, the children were instructed about their oral hygiene status, and the association of diet and dental caries which was followed by professional cleaning and fluoride varnish applications. The oral hygiene and diet was checked and fluoride varnish was applied at each of these visits at three-month intervals.

The independent variables that were part of the risk factor analyses included sex, ethnicity, socio-economic level, fluoride in drinking water, self–administered fluoride, use of sealants, consumption of candy and soft drinks, tooth-brushing habits and participation in earlier preventive programs (Kallestal and Fjelddahl, 2007). The relationship between the four-year incidence rate and its association with the risk factors was assessed using univariable and multivariable Poisson regression models.

It was reported that the two and four year increment in DMFS and DeMFS scores were not very different between low and high-risk groups (Kallestal and Fjelddahl, 2007). Overall, the mean dentine caries increment (assessed every second year) was lower for 12-14 years (0.98) and higher for 14-16 year period (1.04). More than one-third of dentinal caries increment and two-thirds of the enamel caries increment was due to proximal caries. Over the four-year period, there were 21% of subjects without any caries increment. Highest compliance was for the fluoride varnish program (62%), followed by the fluoride mouth rinsing program, and only 8% had continued in the tooth brushing programs or in taking fluoride lozenges program. Relative risk for dentine caries increment was higher in children whose parents were working class and for those who came from outside of Western Europe. Less than 0.1 ppm of fluoride in the drinking water was significantly and positively associated with a higher risk of caries increment. The children who did not their brush teeth twice daily and who ate candy had increased risk of developing caries. All the findings for total study group were applicable to the high-risk group. Girls had an increased risk, and children who had at least one sealant and who were part of the fluoride varnish program had a lower risk of dentine caries increment. However, the preventive effects of sealants and fluoride varnish were higher for enamel lesions than for dentinal lesions. Fluoride levels in drinking water were significantly and negatively associated with dentinal caries increment, but not with enamel caries increment.

Kallestal and Fjelddahl (2007) made an ambitious effort to study the association of caries increments over a four-year period with risk factors and the effect of different prevention programs (Kallestal and Fjelddahl, 2007). The study was strong in defining the association of risk factors for enamel and dentinal caries separately. The details of the information recorded for fluoride levels in drinking water along with cumulative fluoride exposures were not assessed. Furthermore, the long-term exposure of fluoride was neither defined nor assessed based on years of residence in a fluoridated area. The study also faced problems with loss to follow-up. Although the initial study population was representative of the Swedish population aged 12 years, it is not clear whether the final population after loss to follow-up in the study was still representative of the Swedish adolescent population. In addition, it was not clear why the authors had prescribed application of fluoride varnish three times in one week in the preventive program. The authors report that the clinicians were not blinded with regard to the treatment group and the questionnaire data may be subject to recall bias.

Alm et al (2012) assessed the relationships between caries prevalence in adolescents and early childhood factors (Alm et al, 2012). The study was a prospective longitudinal study, where the samples of 671 children were recruited from four districts including town, suburbs and rural areas from Jonkoping in Norway. Independent variables included caries experience at age 3 and 6 years, snacking habits at 1 and 3 years, tooth brushing habits at 3 years, and dental avoidance behavior at age 1. Information on these variables was obtained from examinations, interviews and questionnaires completed when the children were 1, 3 and 6 years old. In addition, child and parent related variables analyzed in a previous study were also included. The outcome variable in the study was approximal caries experience at 15 years of age and was defined as the mean total of approximal caries experience including fillings and was called ‘DFa’. According to caries experience at 15 years of age, children were grouped into four categories: DFa=0, DFa>0, DFa ≥4, DFa ≥8. The relationships between independent and dependent variables were analyzed by t-test for continuous variables and logistic regression for the dichotomous outcomes of caries incidence.

It was reported that the overall mean number of DFa was 3.2 and the mean DFa was higher in girls than in boys (3.9 vs. 3.0, $p<0.01$) (Alm et al, 2012). The independent variables- caries at age 3 and 6 years were divided into initial and manifest caries. Initial caries was defined as proximal caries in which radiolucency in enamel had not passed the dentinal junction or did not include the dentinal portion, whereas manifest caries was defined as radiolucency that passed the dentino-enamel junction and included a part of the dentinal portion. The initial and manifest caries at 3 and 6 years, respectively, were statistically significantly related to caries experience at age 15 years for the groups with DFa scores greater than zero ($p=0.001$) in univariable analyses, but remained significant for initial and manifest 6 years, in the multivariable analyses. In addition, consumption of sweets at 1 years age was positively and significantly associated with caries experience at age 15 years for the groups with DFa ≥4 ($p<0.004$), DFa ≥8 ($p<0.001$), respectively.

Tooth brushing sometimes/never versus twice daily or more at 3 years of age was positively and significantly associated with caries experience of DFa ≥4 [OR=3.0, (CI=1.3-7.0)] and DFa ≥8 [OR=8.5(1.3-7.0)] at 15 years (Alm et al, 2012). Dental avoidance behavior at 1 year was significantly and positively associated with caries experience DFa ≥ 4 [OR=3.8(1.3-13.8)] and DFa ≥ 8 [OR=5.5(1.6-22.4)]. Unfavorable behaviors such as omitting breakfast and dinner, irregular main meal consumption were significantly and positively associated with caries experience at age 15. Out of the parental variables considered, the mother's self-estimation of oral health status was negatively associated with caries experience in children at age 15 years. According to the final multivariable analyses, the authors concluded that girls who consumed sweets more than once a week at 1 year, had manifest caries at age 6 years, had mother who estimated her oral health as less good/poor was more likely to have a score of DFa ≥8 when compared to boys who did not consume sweets, did not have manifest caries at age 6 years and had mothers who did not estimate her oral health as less good/poor (OR=21).

The study by Alm et al (2012) focused on determining the prevalence of caries at age 15 years and its association with previous caries experience and high risk caries behaviors at ages 1, 3 and 6 years (Alm et al, 2012). Although the authors reported a significant association between the analyzed dependent and independent variables, there was no analysis of concurrent risk factors in determining the caries experience at age 15 years. It was not clear whether the low and high-risk behaviors at early ages also had high-risk dietary behaviors at age 15 years. This is essential in understanding whether previous dietary and caries experiences are more critical than proximal modifiable factors. Thus, in addition to previous caries experience and exposure to risk factors at an early age, associations between cavitated caries and factors such as dietary intake, oral hygiene and topical fluoride application were critical especially for determination of caries.

Campain et al (2003) conducted a two-year longitudinal study to determine the cariogenic effect of sugar- and starch-containing food and to assess the effects of starch at low sugar levels and at high sugar levels, respectively, and the effects of sugar at low, medium and high starch levels, respectively, on caries in adolescents with mean age 12.5 years (Campain et al, 2003). The authors also aimed to study the caries increment and the dietary intake and composition in terms of sugar and starch, among this group. The adolescents were recruited from 25 secondary schools from northwestern region in Melbourne (Australia) which had high ethnic diversity and socioeconomically disadvantaged population. The authors defined them as low risk individuals as they lived in communities with fluoridated water. The sample consisted of 504 subjects who volunteered to participate and gave consent for the study and provided both dental and dietary information. The independent variables included solid foods and beverages with different sugar and starch combinations and comprised six categories. These categories included high sugar-low starch, medium sugar-medium starch, medium sugar-low starch, low sugar-low starch, low sugar-medium starch, and low sugar-high starch.

The categories were grouped into clusters and non-hierarchical methods of clustering were used, which was in turn derived by k-means and partitioning around Medoids algorithm (Campain et al, 2003). Each cluster was representative of its own homogeneous type of food item. The process of data collection of food was based on 4-day records of food intake and assessed food intake in portion sizes. The data collection protocol was such that it enabled the recording of dietary intake for 8-16 days. The authors claimed that the information was suggestive of the dietary intake on weekends, weekdays and for different seasons. It was, however, not clear as to how many times and at what different time intervals the dietary information was assessed.

Efforts were made to ensure subject retention by making reminder notes, phone calls, etc. (Campain et al, 2003). The obtained information was then put in an on-line data analysis tool and information on name, code and ingredients of the food was assessed. The information on demographics was obtained from parents and from the Australian Bureau of Statistics. The two-year surface level caries increment measured by the WHO criteria was used as the main outcome variable and was modeled as: total DMFS increment, pit and fissure increment and smooth surface increment. The generalized linear approach was used to examine the associations between caries increments (dichotomous variable) and the intake of various foods containing sugar and starch. The baseline caries level was divided into three DMFS categories of 0, 1-3 and 4+ (Campain et al, 2003).

The authors reported that mean DMFS was 1.43 and 59% of the subjects were caries free, while when negative increments (reversals) were included, the number of caries-free subjects included rose to 62% (Campain et al, 2003). Out of the 190 subjects with any caries increment, 63 (33%) subjects had caries incidence on both smooth and pit and fissure surfaces and the mean DMFS increment was 0.71, but the standard deviation values were not reported. Seventy percent of the disease increment was observed in pit and fissures and 80% of the pit and fissure caries was observed on occlusal surfaces. In the adjusted model, dietary intake of medium sugar -low starch foods and low sugar-high starch foods were significantly positively associated with pit and fissure caries (RR=1.17, (1.05-1.31); [RR=1.19 (1.08-1.30)]. The low sugar high starch foods and low sugar-medium starch foods was positively and significantly associated with all-surface caries risk [RR=1.20, (1.05-1.38)] and [RR=1.06, (1.03-1.09)], respectively. In the multivariate model, low sugar-high starch food was the only significant predictor of all-surface caries risk [RR=1.23, (1.06-1.43)] and pit-and fissure surface caries risk [RR=1.27, (1.09-1.47)]. It was observed that the risk of caries on both all surfaces and on pit and fissure surfaces increased with increase in levels of starch, even when accompanied with low sugar intake (p=0.02 and p=0.01, respectively).

The study had a longitudinal design; hence, it was possible to determine causal associations between caries increments and sugar and starch intakes (Campain et al, 2003). It is essential to understand that the baseline disease levels were used as a surrogate composite measure to account for the effects of age, gender, ethnicity, and socio-economic status, history of exposure to fluoridated water, oral hygiene practices, and microorganisms. Thus, instead of broadly comparing the associations between the different independent variables in the model and sugar-starch intake, the authors' use of this composite measure may not be appropriate. It was noteworthy that the authors compared the initial and the final sample of the study to determine the differences at baseline. The authors assessed only intake of sugar and starch, but did not examine the association of the frequency of intake per day or the amount of intake per serving or the time of consumption of the cluster specific items. In addition, as with other studies, the authors did not assess cumulative fluoride exposures separately. They did not determine the effect of different proportions of sugar and starch, adjusting for the effects of fluoride.

In a study by Petridou et al (1996), the authors assessed the relationships between socioeconomic and dietary factors and caries prevalence among 380 Greek adolescents aged 12 to 17 years (Petridou et al, 1996). The sample was randomly selected from two urban and two rural schools in the Greater Athens area, with students from lower and higher socio-economic status. Out of 380 students, 140 were from the two rural schools while 156 and 84 were from low to middle class urban area and higher income urban schools, respectively.

The information on dietary variables was obtained by assessing the intake of nine items as recommended by Davidson and Passmore (Petridou et al, 1996). The data were reported by the adolescent themselves in a 50-item semi-quantitative food frequency questionnaire. The frequency of consumption of all food items were recorded and were expressed as number per week or per day, per month. When food items were less frequently consumed, then a weighted average for such food items (seasonally consumed items) was considered in the analyses. The other predictor variables included age, sex, tooth-brushing, school performance and residence. Residence was used to derive information about residence in rural and urban settings and socio economic status.

The relationship between dependent and independent variables was assessed by using linear regressions (Petridou et al, 1996). It was observed that gender, age, and residing in a rural area were significantly and positively associated with caries prevalence at age 12-17 years. On the other hand, residence in urban settings and higher SES schools, higher family income and better school performance were significantly and negatively associated with caries in adolescents. Milk and dairy products had a significant protective effect against caries as measured by DMFS and DMFT (p=0.04 and p=0.006, respectively).

In the given analyses, the authors did not report inter-examiner reliability of the examiners, and whether the examiners were blinded with regards to the independent variables (Petridou et al, 1996). Although the analyses included intake of sugar and starchy foods along with all other confounding variables, due to the cross-sectional design, causal association between the outcome and predictor variables could not be determined and is suggestive of a future research with longitudinal design.

In a study by Ayo-Yusuf et al (2007), the authors assessed the association between household smoking as a risk indicator for caries in adolescents aged 13 to 15 years (Ayo-Yusuf et al, 2007). The study was cross-sectional in nature of 1873 adolescents of South Africa. The information on demographics, household income and family was self-reported by the subjects. The authors posed a question asking about presence of a person in the household who smoked and those who responded affirmatively were classified as exposed. The information on oral health behaviors included past dental visits, frequency of tooth brushing (less than two times daily vs. two or more o times daily), and intake of sugary snacks (less than four times daily vs. four or more times daily). The participants were examined to determine dental caries experience by six calibrated dentists and hygienists who were trained to the WHO criteria. The associations between independent and the dependent variables were determined by using the chi-square test and multiple logistic regression analyses and significant results were reported at $p<0.05$. Sugar intake frequency, exposure to second hand smoke and female sex was positively and significantly associated with caries experience at ages 12-19 years. The study results suggest negative behaviors, such as high sugar intake, often occurs together with other negative behaviors, such as smoking in the home.

The study was cross-sectional and assessed the relationship between caries in adolescents and second hand smoking; therefore, the causal relationships between second-hand smoking and caries prevalence cannot be established in this study (Ayo-Yusuf et al, 2007). In addition, the authors did not investigate the frequency at which the children were exposed to second-hand smoke or the total smoke exposure throughout the day. Hence, a dose response relationship could not be assessed. It is not clear whether the examiners were blinded to the smoking status of the household members. It was possible that the responses by the subjects could have been biased by the presence of the examiners/dentists. Additional longitudinal studies are needed to clarify the strength of association between caries in adolescents and second hand smoke that also take into account the role of confounding variables. It is also important to understand the association of self-smoking behaviors with caries in adolescents. Lastly, the sampling method was not clear so that the generalizability of the results is unknown.

Rugg-Gunn et al (1984) conducted a study beginning in 1979 and continuing until 1981, to assess the relationships between dietary habits and caries increment observed at two-year follow-up exam in a sample of 405 school children in their final two years of middle school (Rugg-Gunn et al, 1984). The sample was from seven middle schools of Numberland (England) that constituted about 87.5% of middle schools in south Numberland. It was a voluntary sample and consent was obtained from parents of the participating children.

Dietary intake of subjects for three consecutive days was recorded in a dietary diary five times throughout the study period (Rugg-Gunn et al, 1984). Each subject recorded dietary intake twice every year, i.e., three days in the first and second year of the study period, respectively, such that both weekdays (all) and weekend days were included in the assessment. After the three-day dietary diaries were completed, the dietician interviewed participating subjects in person for more clarification. The dental examinations were conducted three times during the study period at baseline, 1 year follow-up and two year follow-up. Caries was recorded as pre-cavitation or cavitation by visual examinations and bitewing radiographs by one examiner; but were scored by different examiner after examining the radiographs in 1.5 times magnification. Instead of a whole mouth assessment, 71% of sites were assessed that comprised mainly of fissure sites, approximal sites and free smooth surfaces.

Fissure sites included were occlusal surfaces of first and second premolars, first and second molars; palatal surfaces of maxillary first and second molars and buccal surfaces of mandibular first and second molars (Rugg-Gunn et al, 1984). Approximal sites included for the assessments were mesial and distal surfaces of first and second incisors, second premolars and first molars, mesial surfaces of canines and second molars and distal surfaces of first premolars. Free smooth surfaces included buccal surfaces of first and second maxillary incisors, first and second mandibular premolars, buccal surfaces of canines and first and second molars, and palatal surfaces of first and second maxillary molars. Gingival inflammation was assessed using the Gingival Index of Sillness and Loe (1963) on six teeth at two sites (either buccal or lingual) and was also used to measure level of plaque in children. The independent dietary variables assessed for the study were the weight in gm and frequency of categories of foods consumed (confectionary, cake and biscuits); energy intake from food consumed, weight of macro- and micro-nutrients, t frequency of food consumption categorized according to their percentage of sugar content (<1.0%, 1.1-10.0%, 10.1- 60.0% sugars and >60% sugars) and interval between intake of food or dietary item (that had the McCance and Widdowson's Food Code, defined such that "a food" comprised of various category of food items eaten together, (Rugg-Gunn et al, 1984)) at bedtime. The non-normal data were then log transformed as required and parametric statistical correlational analyses were conducted following univariable and bivariate analyses.

It was found that the reliability of measurement of caries and dietary information was 0.85 and 0.78, respectively (Rugg-Gunn et al, 1984). The mean (SD) cavitated caries experience for the study sample at baseline was 3.3 (2.3) DMFT and 5.0 (3.9) DMFS, whereas mean cavitated caries (SD) increment at the two-year follow-up exams was 2.2 (2.1) DMFT and 3.6 (3.6) DMFS. Almost half of the caries was observed as pit and fissure surfaces and 33% was observed in the posterior approximal surfaces, while the remainder of caries occurred in the approximal and smooth surfaces of the anterior teeth. The weight of daily sugar intake was significantly and positively correlated with overall surface level cavitated caries increment and pit and fissure cavitated caries (surface) increment ($r=0.143$) ($p<0.01$), but the correlation was low in magnitude. Weight of sugar intake was strongly related to the frequency of intake, whereas concentration of sugars in foods, sugar content in snack were positively correlated with cavitated caries ($p<0.05$). Caries increments were compared between lowest and highest sugar eaters. It was found that children who had highest sugar consumption by weight had 3.2 more DMFS than children who had the lowest consumption of sugar in the two-year period.

The major strength of this study was its longitudinal design and detailed analysis of the relationships of multiple factors with caries (Rugg-Gunn et al, 1984). However, some aspects of the study design were not clear. As the socioeconomic status, mean age and, gender variables of the study population were not specified, the generalizability of the study cannot be determined. The authors used some specific sites for examination, perhaps for making it easier to examine a few surfaces over a whole mouth assessment. However, the rationale for selection and definition of “sites” was not stated. It is neither convincing nor clear how the site-specific assessment is a better measure in comparison to whole mouth assessment for the given study population. The authors assessed natural and added sugar intake as a composite variable and, hence, the individual significance of each of these as a risk factor for cavitated and pre-cavitated caries cannot be determined.

Pontigo-Loyola et al (2007) conducted a cross-sectional study to determine the caries experience, prevalence and severity of caries in a sample 1,538 adolescents living in Hidalgo communities of Mexico and determine their relationships with the different fluoride concentrations present in the communities (Pontigo-Loyola et al, 2007). The target population was 12- and 15-year-old school children from the six locales of the municipality in Mexico. Of the total, 86.9% met the inclusion criteria of having informed consent from parents, living in the six locales of the Tula de Allende area and agreeing to participate in the study. Initially a pilot study was conducted where the examination criteria for caries and fluorosis were determined and the questionnaire to assess SES, behavioral and other demographic information was completed by the subjects. The examiners were trained and standardized for oral examinations of caries based on WHO criteria, and fluorosis was measured using Dean's Fluorosis Index. The oral exams were conducted in daylight settings, using number five mirrors, after plaque was removed using a toothbrush. The questionnaire was developed and tested for assessing the information on socio-demographic and behavioral variables from mothers of children.

The person level prevalence of caries was reported as DMFT, while the severity was reported at two levels (DMFT $\geq$ 4, DMFT $\geq$ 7) (Pontigo-Loyola et al, 2007). The SiC index was used to calculate one third of the entire sample that had highest severity levels of caries. The main dependent variable was presence of caries in the permanent dentition. The relationships between independent variables such as sex, age, dental visits, SES, locale or residence, dental fluorosis (included as a marker of exposure to fluoride) and cavitated caries experience was assessed in this study. The sample was divided into four groups based on their residence in fluoridated communities. Residence in fluoridated communities was assessed by knowing the community where subjects lived since birth; subject resided until 6 years of age, and did not live more than 1 year outside the locality where they were born. The final categories were defined as Tula del Centro, El Elano, San Marcos, and other. The independent variable for SES was defined by the occupation of parents and schooling information of the child that was not more clearly described. All subjects were divided into quartiles such that the first quartile was comprised of poorest children, while the fourth quartile was comprised of the wealthiest. In the bivariate analyses, the distribution of caries across variable categories was reported using logistic regression. Caries prevalence by selected independent variables such as age, sex, dental visits, SES, community of residence, current locale of residence and fluorosis was reported.

Approximately 47% percent of children had cavitated caries and the mean (SD) for the sampled population was 1.15 (1.17) (Pontigo-Loyola et al, 2007). Almost 10% of children had severe caries, whereas 1.7% had extremely severe caries (DMFT ≥ 7). It was found that relatively higher caries experience was observed in children who had dental visits in the past year and were classified in the wealthiest quartile of SES categories. Additionally, for fluoride-related variables, higher caries experience was also found among residents of San Marcos (1.38 ppm), and Tula Centro (1.42 ppm) children who did not have any fluorosis and those who had moderate to severe fluorosis.

Almost a third of the population had moderate to severe fluorosis, and exposure to fluoride was assessed using this variable (Pontigo-Loyola et al, 2007). It was also found that higher experience and prevalence of dental caries was associated with moderate to severe fluorosis. Also, severity of caries defined as DMFT ≥4, was associated with very mild/mild and moderate to severe fluorosis, respectively. It was not reported how the fluoride levels in the communities of San Marcos (1.38 ppm), and Tula Centro (1.42 ppm) were measured and, hence, validity of these measures could be questionable. It should be emphasized that, for all these bivariate analyses, p-values were not reported and, hence, statistical significance of the results cannot be confirmed. In addition, as it was a cross-sectional study, so causality cannot be determined. Analysis of additional risk factors and confounding effects is critical in determining the most significant factors responsible for higher caries prevalence and severity in this study population.

With the aim to assess relationships between dental caries in 458 Brazilian adolescents, demographic and dietary risk factors, Auad et al (2009) conducted a cross-sectional study with a sample of 13 to 14 year old children from fourteen schools in the Tres Coracoes region of Brazil (Auad et al, 2009). Information on demographics and education of the subjects was obtained from the parents using a questionnaire, while information on dietary intake was obtained from questionnaires completed by the subjects. The socioeconomic status of the subjects was determined by assessing the purchasing power of household, and subjects were initially divided into 7 classes (from highest =A1 to the lowest=E). These categories were further collapsed into high, middle and low SES categories that included individual categories A1 to B2, C, D, and E, respectively. Information on dietary factors included frequency of intakes of foods, drinks and free sugars that are acidic in nature and were dichotomized as ‘daily consumption’ (≥ 1x/day) and less than daily or no consumption (never, ≤1x/week, 2-4x/week). The final sample consisted of 458 children who volunteered to participate in the study and whose parents signed the consent forms and completed the questionnaires.

Prevalence of dental caries was assessed using DMFS and DMFT in accordance with the WHO criteria, as the main dependent variable in the analyses (Auad et al, 2009). Examinations were conducted by a calibrated examiner and reliability assessments were made on 10% of the subjects. A forward stepwise regression model was used in the multiple logistic regression modeling after determining significance in the bivariate analyses at $p<0.25$. Monte Carlo p- values were used for very large data sets.

Seventy-eight percent of children had some dental caries experience (DMFT ≥ 1) and the mean (SD) DMFT/DMFS reported for all children was 3.95 (±3.81)/6.37(±6.38), respectively (Auad et al, 2009). The filled component contributed most to the overall DMFT score. Median values for caries prevalence were statistically significantly higher among girls than in boys. Subjects with high SES had significantly lower incidence of caries when compared with moderate SES and low SES categories, respectively. Cavitated caries prevalence was higher in children who consumed more sugar-added carbonated drinks, fruit-flavored drinks, and had higher intake of sweets, however, when assessed relationships were not statistically significant in the multivariable model. Of the variables maternal education and economic class, level of maternal education was significantly and negatively associated with caries experience of subjects [OR=0.79, p=0.04] whereas economic status was not significant.

The authors did not assess factors such as oral hygiene, fluoride exposure from water, dentifrice, or topical fluoride application (Auad et al, 2009). The data cannot be generalized to the United States, as it was a study based in Brazil. Frequencies of dietary intake were combined into two categories, thus, individual effects of 1x/day, and greater than equal to two times per day of consumption were not determined separately. Also, the cross-sectional nature of the study was another drawback as causal associations cannot be determined.

Summary by Category of Risk Factors

This section presents summaries of findings for different categories of risk factors. The risk factor categories discussed in detail include demographics, diet, fluoride intake and/or exposure, oral hygiene, sealants, previous dental visits, insurance and previous caries experience etc. The section uses the same studies described individually in earlier pages.

Demographics

This section provides a summary of findings on relationship of caries with demographic characteristics such as age, sex, race-ethnicity, parents' education, family income, socioeconomic status, and immigration status, across the U.S. and non-U.S. based studies.

Petridou et al (1996) and Ditmyer et al (2008, 2010) provided some evidence that residing in rural areas is associated with cavitated caries prevalence. Another common finding was a tendency for females to have more cavitated caries. Petridou et al (1996) observed 380 Greek adolescents, 12 to 17 years old at baseline, to examine the association between self-reported socio-demographic factors and cavitated caries experience as determined by WHO criteria in a prevalence study. Authors found that the cavitated caries prevalence among adolescents was higher in females and adolescents who resided in rural areas; and was also significantly associated with older age. Similar findings for females and adolescents residing in rural areas were also reported by Ditmyer et al (2008, 2010). Ditmyer et al (2008) observed 9,202 adolescents in Nevada, aged 13 to 18 years cross-sectionally to assess the relationship between cavitated caries prevalence and demographic variables including age, sex and race-ethnicity. The information on demographic variables was self-reported by subjects. When compared to Caucasians, the prevalence was significantly higher among Native Americans, followed by Asian/Pacific islanders and African-Americans. In addition, prevalence of cavitated caries was also higher among females, those with residence in rural areas and older children. In another study, Ditmyer et al (2010) observed over 4,000 adolescents of Nevada, aged 12-19 years and examined the associations between cavitated caries prevalence demographic variables. The cavitated caries prevalence and experience/extent was recorded using the WHO criteria, whereas the demographic information was recorded using face-to-face interviews. The prevalence and extent of caries was significantly and positively associated with age. The authors found that for the relatively diverse sample in this study, females and Hispanic subjects were more likely to have higher caries scores than males and Non-Hispanic White and African-American subjects, respectively. In addition, 16 to 19 year old subjects were significantly more likely to have cavitated caries than 12 to 15 year-olds, indicating that older age was a risk indicator in this study.

In a few of the European studies, some evidence was supportive of associations of immigration status and parental education with cavitated caries. Haugejorden and Birkeland (2006) examined caries experience among 12-year old Norwegian adolescents born from 1985 to 2004. The authors also used data for age 12 to 18 caries incidence as the outcome variable among adolescents born from 1973 to 1986 and assessed their relationship with demographic variables such as education, income, income support, mobility and immigrants. Education was defined as the “percent of the population 16 years of age and older who had completed a university or college degree” income was defined in unit of Norwegian Kroner. Additional assessments were made to observe subjects with income support, net mobility of people per year by county at county level, and whether the subjects were first or second generation immigrants. After controlling for baseline caries, authors found that greater mobility in a county, income of the parent, receiving social assistance were significantly and negatively associated with the age 12 to age 18 year increments in all cohorts observed from 1973 to 1986 (Haugejorden and Birkeland, 2006).

Kallestal and Fjelddahl (2007) observed a cohort of 12-year old Swedish adolescents to examine the associations between the four-year cavitated and non-cavitated caries increments and demographic factors such as sex, ethnicity, and socioeconomic status levels (Kallestal and Fjelddahl, 2007). The information on demographic variables was self-reported in a questionnaire while the caries increments were scored by using C.K. assessment criteria that scored caries from 0 to 4, separately for each proximal, occlusal and smooth surface (Kallestal and Fjelddahl, 2007). They found that children whose parents were workers (occupation other than civil servants or those having own-business), or belonged to ethnicities other than Swedish and Western European, were significantly more likely to have cavitated caries increments when compared with children whose parents were civil servants, had self-run business or those who belonged to Swedish and Western European ethnicities, respectively. Alm et al (2012) observed 671 adolescents to examine the associations between the cavitated caries experience among 15-year old adolescents and demographic and early childhood behaviors (Alm et al, 2012). Demographic variables considered in the analyses included sex, parents' counties of birth, which was categorized into four categories, including both parents born in Sweden, mother born in Sweden, father abroad, father born in Sweden and mother abroad, and both parents born abroad. The information on these parent related variables was self-reported by parents in a structured questionnaire. Among the demographic variables, females were more likely to have cavitated caries experience at age 15 and children with both parents born outside of Sweden were significantly more likely to have caries prevalence at 15 years, followed by children with mother or father born outside of Sweden, respectively, when compared to children with both parents born as Swedish citizens.

Findings by Auad et al (2009) and Chankanka et al (2011) provided some evidence of the association between socioeconomic status and cavitated caries among adolescents. Auad et al (2009) observed 359 Brazilian school children 11 to 14 years old, to assess relationships between cavitated caries prevalence and demographics, including variables such as economic class, mothers' years of school education, father's years of school education and sex (Auad et al, 2009). The information on parents' education was self-reported and the families' economic profiles were categorized according to the Brazilian Economic Classification Criteria while the prevalence of cavitated caries was assessed using WHO criteria. It was found that cavitated caries (DMFT) experience was more common among girls than boys; however, the difference was statistically significant only when median DMFT/DMFS values were considered. More years of schooling for both mothers and fathers were associated with caries-free children, and this trend was stronger and more significant in case of maternal education. Moreover, subjects belonging to “low” and “middle” socioeconomic classes were significantly more likely to have caries when compared with subjects of “high” socio-economic class. This was a result of the level of dental care and oral health education provided to subjects of both low and middle economic classes. In a U.S.-based longitudinal study, Chankanka et al (2011), used data for 160 children of a birth cohort recruited in 1992-1995 as part of the Iowa Fluoride Study. These children were prospectively observed from age 5 to age 13 to examine the associations between different risk factors for cavitated and non-cavitated caries. The demographic variables assessed in this study included age, sex and socioeconomic status. Socioeconomic status categories were defined as low, middle and high, based on the family income and maternal education collected at the time of recruitment from the recruitment questionnaire. When compared with children from low and middle socioeconomic status categories. The children from high socioeconomic status were significantly less likely to have non-cavitated caries, but not cavitated caries. Sex was not a significant variable, and other demographic variables such as race-ethnicity were not studied in the analyses, as the cohort was comprised mostly of Non-Hispanic Whites.

In another non-U.S. based study, Campain et al (2003) observed two-year cavitated caries increment among 504 Australian adolescents, with average age of 12.5 years. The authors sought to assess the associations between caries increments on pit and fissure and smooth surfaces and self-reported demographic variables that included data on household income, education level, occupation and ethnicity (Campain et al, 2003). The data were collected and coded according to the Australian Bureau of Statistics 1991 Census categories and, therefore, could not be generalized to U.S.-based populations.

Moreover, as these variables were used as fixed covariates in the analyses, no results for the demographic variables were reported. Pontigo-Loyola et al (2007) examined 12 and 15 year old Mexican adolescents cross-sectionally to assess the association between prevalence and severity of cavitated caries and demographics and other factors (Pontigo-Loyola et al, 2007). The cavitated caries prevalence was scored according to the WHO criteria and the socioeconomic data were self-reported by subjects. Females and adolescents with low socioeconomic status had higher cavitated caries DMFT scores. Adolescents aged 15 years had higher caries prevalence when compared to adolescents aged 12 years, indicating greater age was positively associated with cavitated caries prevalence. However, the results were reported only for bivariate analyses with no reported p-values; multivariable modeling was not conducted, nor was there any adjustment for confounding variables. Ayo-Yusuf et al (2007) examined 1,873 South African adolescents and assessed the relationship between cavitated caries prevalence and demographic variables, including sex, age, income of breadwinner, family structure, and race-ethnicity (Ayo-Yusuf et al, 2007). The information on all these demographic variables was self-reported and caries prevalence was scored using the WHO criteria. They found that females were significantly more likely to have caries experience than males, while variables such as income of the breadwinner, family structure, race-ethnicity and age of the adolescent were not statistically significantly associated with cavitated caries prevalence.

The demographic findings from these studies show some evidence supporting the association between cavitated caries measures in adolescents with greater age (Pontigo-Loyola et al, 2007; Petridou et al, 1996; and Ditmyer et al 2008 and 2010). Some evidence on positive association between cavitated caries outcomes and being female has also been documented (Pontigo-Loyola et al, 2007; Petridou et al, 1996; and Ditmyer et al 2008, 2010; Ayo-Yusuf et al, 2007; Auad et al, 2009; Alm et al 2012). Being from a minority race-ethnicity group was also a predictor of greater caries in adolescents (Kallestal and Fjelddahl, 2007; Ditmyer et al, 2008). Among the studies based on European subjects, immigrant status was a significant variable. Results from these studies assessing the association between cavitated caries outcomes and SES or other measures of social background (family income and parent's/mother's education) were mixed. While negative association between the caries outcomes in adolescents and SES were seen in some studies (Auad et al, 2009; Haugejorden and Birkeland, 2006), others suggested a positive (Pontigo-Loyola et al, 2007) or no association (Ditmyer et al, 2008; Ayo-Yusuf et al, 2007). However, most of these studies were cross-sectional in nature, so causal relationships could not be drawn. Additionally, the generalizability of these studies is limited due to the differences in the target populations. Moreover, long-term influences of demographic characteristics on cavitated caries increments and incidence can be studied only by using a prospective cohort design which is suggested for future research.

Dietary Behaviors

This section provides a summary of findings on relationship of caries and dietary behaviors discussed across the U.S. and non-U.S. based studies.

The majority of the studies conducted to date have looked at the relationship between dietary factors and dental decay. One hypothesis has been that caries is more common in teenagers who consume sugary snacks. However, researchers have not found much support for this claim. Burt et al (1988) studied 499 Michigan children, aged 11-15 years, to investigate the associations between three-year approximal caries and pit and fissure cavitated caries increments and dietary habits, such as intake and frequency of intake of sugary foods. The information on dietary intake was recorded using a 24-hour recall interview used in the NHANES-II study and by a food frequency questionnaire used four times during the study period. The information was then used to derive quantitative estimates of nutrient intakes and sugar intakes. Burt et al (1988) reported that the average number of daily eating occasions and the average number of sugary snacks consumed between meals were not related to the total caries increments. Children with higher caries increments generally were found to have higher intakes of sugar between meals, but the association was significant for proximal caries only. The frequency of eating sugary foods between meals was not significantly associated with pit and fissure caries. Similar results for dietary variables were reported by Kallestal and Fjelddahl (2007), where the authors assessed relationships between four-year caries increments among 12-year old Swedish adolescents and enrollment in preventive programs, along with other factors such as frequency of consumption of candy and soft drinks. However, none of the variables were significantly associated with cavitated caries increments. Rugg and Gunn et al (1984) assessed the relationships between two-year cavitated caries increment and diet among 405 English adolescents, aged 11.5 years at baseline. The highest correlation was seen between the weight of daily sugar intake and caries increment. Positive association between intake of milk and dairy products was also seen with cavitated caries; however, it was not statistically significant and only suggestive in nature.

Other researchers have looked more specifically at different kinds of foods. Clancy et al (1977) assessed the relationships between cavitated caries increments and the frequency of eating 18 categories of snack foods (milk, presweetened beverages, milk drinks, soda, fruit drinks, fruit juice, cakes, cookies, salty snacks, oranges, apples, dried fruit, chocolate candy, caramels, hard candy, sugarless gum, regular gum, and ice-cream). Baseline caries scores and caries increment were significantly and positively associated with frequency of chocolate candy intake, and were significantly and negatively associated with intake of apples, fruit juice, and sugarless gum. However, a higher incremental caries score was associated with greater frequency of intake of fruit drinks, cookies, and apples when taken in between meals or at bedtime. In a similar study by Petridou et al (1996), the authors examined cross-sectional associations between cavitated caries and socio-demographic and dietary factors among 12-17 year old Greek adolescents. Nine food groups were included in the analyses. For each food item in each group, the frequency of intake per week and frequency of eating occasions per day were measured. Of the nine food groups (cereals, starchy roots, sugars, legumes and nuts, vegetables, fruits, meat, fish and egg; milk and dairy products, and oils and fats), increased frequency of consumption of vegetables and milk and dairy food products were significantly and negatively associated with cavitated caries prevalence, and the relationship for milk and dairy foods was stronger. It was also reported that intakes of sugars, oils and fats and starchy roots were not significantly associated with cavitated caries prevalence. In a two-year prospective study by Campain et al (2003), the authors assessed the relationships between two-year cavitated caries incidence among Australian adolescents aged 12-13 years at baseline and different food groups defined on the basis of percentage of sugar and the percentage of starch. They found that the mean daily intake of low sugar and high starch group (breads, muffins, crumpets, crackers, some cereals, pastries, potato chips, corn chips) was most significantly and positively associated with cavitated caries incidence across two years. The authors also found intake of low sugar-medium starch foods (i.e., rice, pasta, spaghetti, noodles, pizza, burgers, sausage rolls, pastries, spring rolls and sweet corn) to be less significantly and positively associated with cavitated caries incidence. In study of 405 English adolescents, 12 years old at baseline, Beighton et al (1996) investigated the associations between dietary intake and cavitated caries prevalence. The dietary variables studied included number of eating events per day, number of eating events for foods containing sugar, confectionary, and starch, respectively. Significant positive associations were found between cavitated caries incidence and number of eating events of sugar and confectionary foods, respectively, however, no significant association were reported for foods containing starch and cavitated caries increments. Bruno-Ambrosius et al (2005) investigated the relationships between eating behaviors and found that irregular main meals and skipping breakfast were significantly and positively associated with surface level cavitated caries increments. These findings were observed among 162 Swedish girls, 12 years old at baseline and followed for three years. However, consuming snacks frequently on a daily basis, and intake of sweets or sugar containing beverages were not statistically significantly associated with increments over the three year period.

In a study by Chankanka et al (2011), subjects were recruited from birth and followed through adolescence. They examined 9 to 13 cavitated caries increment count as one of the outcomes. Only the beverage variables were included in the analyses and greater frequency of exposure to 100% juice was associated positively and significantly with cavitated caries surfaces in the bivariate model but was not significant in the multivariate model. Other variables such as frequency of intake of regular soda pop, frequency of intake of juice drinks, frequency of intake of milk and frequency of intake of water were not significantly related to cavitated caries increment count in children from age 9 to 13 years. Ayo-Yusuf et al (2007) estimated daily frequency of consumption of sugary snacks/sugary drinks as a single independent variable and examined its relationship to cavitated caries prevalence among South African children with an average age of 14.6 years. Higher cavitated caries prevalence was reported among subjects who consumed sugary snacks/sugary drinks four or more times per day. Similarly, in Alaskan children, Klejka et al (2011) found significant positive associations between frequency of soda pop consumption and cavitated caries prevalence. The strength and significance of the association increased as frequency of soda pop intake increased (once per day vs. twice per day vs. thrice per day or greater). Thus, the most significant positive association was found between children who consumed soda pop three times per day or greater. The studies by Ayo-Yusuf et al (2007) and Klejka et al (2011) are suggestive of the strong relationships between soda pop consumption and cavitated caries among adolescents; however, due to the cross-sectional nature of the data such relationships may not be causal and an appropriate dose-response relationship could not be determined. Auad et al (2009) assessed the relationship between cavitated caries prevalence and diet, dental erosion and socio-demographic variables among 13-14 year old Brazilian school children. They found a tendency towards cavitated caries in children with a higher daily consumption of sugared carbonated beverages, fruit flavored drinks and sweets but none of the associations were significant.

Mixed evidence on the effect of soft-drink consumption on cavitated caries outcomes in adolescents has been reported. While some studies did not show any significant association between soft drinks and cavitated caries outcomes in adolescents (Kallestal and Fjelddahl, 2007; Auad et al, 2009; Bruno-Ambrosius et al, 2005 and Chankanka et al, 2011), a few others found significant positive associations (Ayo-Yusuf et al, 2007; Klejka et al, 2011). Significant negative associations between 100% juice and net cavitated caries increments have been reported in two incidence studies (Chankanka et al; 2011 and Clancy et al, 1977), however, the length of follow-up in the two studies was different. Rugg and Gunn et al (1984) found a positive association between amounts of sugar consumed daily, calculated by weight, and two-year caries incidence in English adolescents; this was also confirmed by findings of Burt et al (1988) in a three-year incidence study. Burt et al (1988) found no significant relationships between sugar consumption and pit and fissure caries specifically, but found a significant association between caries incidence and sugar consumption between meals. Campain et al (2003) studied the effects of sugar in presence of starch on 2-year cavitated caries incidence among adolescents and found that the low sugar and high starch group comprising both beverages and solid foods was positively associated with the caries outcome. In assessing the relationship between the carbohydrate content of food and dental caries at a broader level, Campain et al (2003) defined the food groups in a more logical way based on their sugar and starch percentage. Classification of groups was derived by using algorithms rather than "cut-off" values, as done earlier by Burt et al (1988). However, in considering sugar-starch content, foods with greater content of sugar were not assessed. In addition, other kinds of foods richer in starch-protein were not assessed.

A major problem was that the food groups were defined differently in each of these studies. In some cases both solids and liquid dietary variables were grouped in a single category (Clancy et al, 1977; Campain et al, 2003), whereas, in other studies, food categories included solid foods, but the list did not include beverages (Petridou et al, 1996). Clancy et al (1977) grouped apples and oranges in different categories, while Petridou et al (1996) had a single category for fruits. As the effects of beverages and solid-foods on caries in adolescents were not assessed separately, future research based on analyses of separately-defined beverage and solid food categories on cavitated caries in adolescents is recommended.

Oral hygiene and toothbrushing behaviors

This section provides a summary of findings on toothbrushing behaviors and their association with caries in adolescents from the U.S. and non-U.S. based studies.

Many of the studies conducted on risk factors associated with dental caries have considered toothbrushing behaviors. It is hypothesized that the frequency of brushing per day among adolescents is negatively associated with cavitated caries. The findings from Kallestal and Fjelddahl (2007), Petridou et al (1996), Chankanka et al (2011), and Ayo-Yusuf et al (2007) do not provide sufficient definitive evidence in support of this hypothesis. Kallestal and Fjelddahl (2007) observed 12-year-old Swedish children and examined the associations between cavitated and non-cavitated caries as outcome variables and utilization of preventive programs, one of which was toothbrushing. The authors used variable toothbrushing frequencies that were self-reported at the time of first, second and third examination. The analyses were considered for subjects in high risk groups and total study groups for both cavitated (DMFS) and non-cavitated caries (DeFS). For the total study group comprising subjects with both cavitated and non-cavitated caries, they found that subjects who reportedly brushed their teeth more than twice per day atone examination were more likely to have cavitated and non-cavitated caries increments, respectively, when compared with those who reported brushing more than twice per day at both first and second examinations. Similar findings were reported for subjects in the high-risk group for both cavitated and non-cavitated caries incidence outcomes. In addition, it was also found that children from both high risk and total study groups who reported more than twice daily brushing for all three examinations were least likely to have cavitated and non-cavitated caries increments, respectively, when compared to those who reported more than twice daily brushing for one or two examinations.

Petridou et al (1996) observed 380 Greek adolescents, 12 to 17 year old and assessed the association between risk indicators including frequency of toothbrushing and cavitated caries prevalence as outcome. They found that adolescents who brushed their teeth more than once per day were less likely to have cavitated caries prevalence. Regular toothbrushing was defined as a dichotomous variable (i.e., none or occasional vs. brushing once per day or more. Brushing once per day or more was associated with lower prevalence of DMFT by 1.1 teeth ($p=0.07$) and DMFS by 1.9 surfaces when compared to the subjects who had none or occasional brushing. These results were not statistically significant but were suggestive at $p=0.07$.

Ayo-Yusuf et al (2007) observed 1,873 South-African adolescents with a mean age of 14.6 years to examine the association between cavitated caries prevalence and risk indicators including frequency of toothbrushing (dichotomized as less than twice per day and twice per day or more). Results were not statistically significant at the bivariate levels and were, therefore, not included in the multivariable regression analyses. Chankanka et al (2011) observed 156 children from 1.5 months to 13 years old to examine the associations of cavitated and non-cavitated increments from 0 to 5 years, 5 to 9 years and 9 to 13 years, respectively, with risk factors including daily toothbrushing frequency. Toothbrushing data were collected using one set of questionnaires that parents completed from age 6 weeks to 8.5 years, with slightly different questionnaires used from 9 years. All toothbrushing frequencies reported for the periods of 3 to 5 years, 6 to 8 years and 11 to 13 years were averaged using AUC separately for each child as number of times teeth were brushed per day. Daily frequency of toothbrushing was negatively associated with both cavitated and non-cavitated caries increments, however, the results were only statistically significant for non-cavitated caries increments.

Some other studies like Klejka et al (2011) and Bruno-Ambrosius et al (2005) have observed an association between toothbrushing behaviors at daily vs. non-daily levels and cavitated caries prevalence, the results, however; were not significant. Klejka et al (2011) observed Alaskan adolescents aged 12-15 years cross-sectionally to examine the associations between risk indicators, including frequency of toothbrushing defined in days/week and cavitated caries prevalence. Brushing one day per week was more strongly and positively associated with cavitated caries prevalence, followed by brushing two, three, four, five, and six days per week, respectively, when compared with seven days/week. These result were not statistically significant but were suggestive at the level of p=0.06 level. Bruno-Ambrosius et al (2005) observed 162 Swedish adolescent females aged 12 years at baseline and followed them prospectively for three years to examine the association between cavitated caries increment on all surfaces and proximal surfaces, respectively, with risk factors including toothbrushing frequency. Toothbrushing frequency was based on whether the subjects omitted brushing either during morning or evening. This was because 95% subjects reported brushing daily throughout the study period. Omitting toothbrushing at morning or evening times was not significantly associated with caries increments observed at the three-year follow-up period when compared to those who did not omit toothbrushing.

Fontana et al (2011) studied associations between risk factors associated with caries progression among 5 to 12-year-old Puerto Rican children. The authors developed caries risk assessment models for identifying individuals with lesions progressing from the baseline to 12-month follow-up and 12-month to 24-month follow-up periods. Frequency of brushing was defined as “child brushes teeth twice daily” or “more” or “not”. This variable was not significant in bivariate analyses and was not included in the multivariable analyses.

The variable frequency of brushing in studies by the Haugejorden and Birkeland (2006), Kallestal and Fjelddahl (2007), Chankanka et al (2011), and Petridou et al (1996) was defined in different ways and focused on different population groups. In addition, analyses of non-daily vs daily brushing behaviors did not demonstrate substantial definitive effects on cavitated caries due in part to the cross-sectional nature of the studies. Although the protective effect of greater toothbrushing frequency on cavitated caries in adolescents was reported, it was suggestive and not statistically significant in most studies (Petridou et al, 1996; Ayo-Yusuf et al, 2007; Chankanka et al, 2011; Bruno-Ambrosius et al, 2005; Klejka et al, 2011). In general, the protective effect of greater toothbrushing frequency has been attributed largely to the use of fluoridated toothpaste. However, rarely have studies investigated the effects of daily toothbrushing, along with other explanatory variables such as fluoride intake and dietary behaviors, demographic information, use of preventive agents, and frequency of dental visits. The evidence on association of frequency of toothbrushing with cavitated caries in adolescents is therefore, incomplete, and future research using a longitudinal cohort design is recommended.

Fluoride exposures

This section provides a summary of findings about the association of fluoride variables with cavitated caries, as seen in the U.S. and non-U.S. based studies.

The effects of fluoride exposures and fluoride intake have been investigated as risk factors for caries. It has been hypothesized that fluoride is protective against cavitated caries in adolescents; however, studies have yielded inconclusive results.

Several cross-sectional studies have demonstrated a correlation between fluoridation of water and lower prevalence of cavitated caries. Pontigo-Loyola et al (2007) observed 1,538 Mexican adolescents cross-sectionally to assess the relationship between cavitated caries prevalence and risk indicators, including residence in areas with various fluoride concentrations (Pontigo-Loyola et al, 2007). Fluoride concentrations in the four observed communities were 1.42 ppm F, 3.07 ppm F, 1.38 ppm F and not available. It was found that higher caries prevalence and severity were associated with being a girl, dental visit in the past year, adolescents belonging to the wealthiest SES group, and residents of San Marcos (1.38 ppm F) and Tula Centro (1.42 ppm F). A contradictory finding was that higher prevalence and severity of caries was observed in children who did not have fluorosis and in those who had moderate to severe fluorosis. Then again, children having mild or moderate to severe fluorosis were observed to have more severe carious lesions when compared to those who were fluorosis-free. However, the results were based on bivariate analyses and significant p-values were not reported, hence the validity of these results could not be truly determined.

More recently, Ditmyer et al (2010) observed over 4,000 Nevada adolescents aged 12 to 19 years to assess the relationships between risk indicators including fluoridation status (residence in area with water fluoridation) and cavitated caries increments (Ditmyer et al, 2010). Adolescents living in areas without water fluoridation were significantly more likely to have high caries prevalence (defined as top 30% of DMFT scores). In another study by Ditmyer et al (2008), the authors observed over 9,200 Nevada adolescents aged 13 to 18 years to cross-sectionally assess the relationships between risk indicators, including living in fluoridated area (Clark County) vs. in non-fluoridated area (outside Clark County). Residence in area with fluoridated water was negatively and significantly associated with moderate (DMFT=2.7-4.4) and high (DMFT > 4.4) cavitated caries prevalence. Similarly, Klejka et al (2011) observed 98 Alaskan children aged 12- to 15 years cross-sectionally to assess the relationship between cavitated caries prevalence and risk indicators, including residence of adolescents in fluoridated vs. non-fluoridated villages. Adolescents in non-fluoridated area were significantly more likely to have severe dental caries when compared with adolescents in fluoridated areas. Although results by Ditmyer et al (2008 and 2010) and Klejka et al (2011), show that residence in fluoridated areas is a protective factor, no causal associations can be determined due to the cross-sectional nature of the data.

A few studies have attempted to address the factor of temporality using longitudinal data. Haugejorden and Birkeland (2006) observed a cohort of Norwegian adolescents aged 12 years from 1985 to 2004. The authors also recorded age 12 to 18 caries incidence in birth cohorts from 1973 to 1986, to assess the relationship between cavitated caries incidence defined as D3MFT increments and risk factors, including intake of fluoride tablets. Intake of fluoride tablets was measured using the surrogate variables “Fluorexp” and “$\text{Fluorexp}_{1\text{-}10}$” defined as sale of fluoride tablets in defined daily dose (DDD) per person under 12 years of age per year and average sale of fluoride tablets during the first 9 years of each cohort’s life, respectively. Significant negative bivariate associations were reported between cavitated caries prevalence at age 12 and sales of fluoride tablets but it was not clear as to which of the two variables were significant. However, none of the two variables associated with sales of fluoride tablets were significantly associated with cavitated caries increments from age 12 to age 18 years at bivariate levels and, hence, were not included in the multivariable models.

Kallestal and Fjelddahl (2007) observed 3,373 Swedish adolescents 12-year-old at baseline and followed them for four years to examine the associations between cavitated and non-cavitated caries increments and different oral prevention programs including toothbrushing with fluoridated toothpaste, a fluoride lozenge program, and a fluoride varnish program (Kallestal and Fjelddahl, 2007). Other fluoride variables included use of fluoridated drinking water and self-administered fluoride. The fluoride lozenge program provided subjects with information about and prescription of fluoride lozenges (0.25 mg x 3 times per day to 6 years and thereafter 0.25 mg x 4-6 times daily) and the subjects were then followed-up on regular use, once per year. Fluoride varnish was provided to high-risk children in two different programs. In one program, children were provided oral prophylaxes followed by fluoride varnish application three times in a week, which was then repeated every 6 months. The other program involved checking oral hygiene and providing dietary and oral hygiene counselling, followed by oral prophylaxis, and fluoride varnish application every 3 months. Nurses determined the fluoride levels of drinking water at each clinic based on community water resources and information based on private wells. The fluoride concentration was categorized into < 1.0 ppm and ≥ 1.0 ppm. Self-administered fluoride was defined as any fluoride intake other than that given by means of prevention programs. The subjects were asked if they used extra fluorides, fluoride mouthrinse for more than one month or had 1-3 pieces of fluoride chewing gum/day at least 4 days per week or whether they used 1-3 fluoride lozenges a day for 4 days a week. The variable was dichotomized into “none” or “other self-administered program” and was recorded at all three time points during the study period. Adolescents were also asked if they participated in any fluoride preventive programs prior to enrollment.

It was reported that most adolescents lived in areas with low fluoride levels throughout the study period (Kallestal and Fjelddahl, 2007). Concentration of fluoride in drinking water was negatively associated with both non-cavitated caries and cavitated caries increments; however, the results were not statistically significant for non-cavitated caries increments. Adolescents who participated in none of the fluoride preventive programs were significantly more likely to have cavitated caries increments in the four-year period, especially in the high-risk group (high risk group was defined as adolescents having more than one decayed proximal surface, including enamel and/or dentine caries, a filled surface or a missing tooth because of caries). Additionally, adolescents who did not have any fluoride preventive programs prior to 12 years of age were significantly more likely to have cavitated caries increments in the four-year period. Participation in a fluoride varnish program was significantly and negatively associated with non-cavitated caries increments, however, the results were not statistically significant for cavitated caries increments. Moreover, a detailed analysis of longitudinal exposures of fluoride from combined sources was lacking in studies by both Haujorden and Birkeland (2006) and Kallestal and Fjelddahl (2007).

Most recently, Chankanka et al (2011) conducted secondary analyses of data on 156 Iowan children from 6 weeks to 13 years to assess the longitudinal associations between cavitated and non-cavitated dental caries increments and risk factors including composite water fluoride level. The cavitated and non-cavitated increments were defined for ages 0-5, 5 to 9, and 9 to 13. The composite water fluoride level was defined at all-time points as weighted average of the main sources of water (i.e., home/school, bottled/filtered/tap water), with results aggregated separately for each child using from 3-5, 6-8 and 11-13 years. For children who used separate water with filtration, water samples were collected and fluoride levels were determined by individual fluoride assay with a fluoride–ion specific electrode. For public water without filtration, water fluoride information was obtained from the Iowa State Health Department. Composite water fluoride level (ppm) was negatively associated with cavitated and non-cavitated caries increments, but results were not statistically significant.

The studies mentioned above provide some evidence on the negative association between cavitated caries incidence and residence in a fluoridated area (Ditmyer et al, 2008; 2010; Klejka et al, 2011. Negative relationships between fluoride levels in water and cavitated caries outcomes in adolescents were reported in some studies (Pontigo-Loyola et al, 2007; Chankanka et al, 2011 and Kallestal and Fjelddahl, 2007). Overall, few studies considered cumulative fluoride exposures from multiple sources, which may have led to underestimation of the strength of association between fluoride exposures and cavitated caries outcomes in adolescents. Even though Chankanka et al (2011) investigated fluoride exposures in detail from birth to 13 years, additional study is needed to more carefully look at the influence of fluoride in adolescent beyond 13 years of age.

Sealants

This section provides a summary of findings on the association between sealant variables and cavitated caries, as discussed in the U.S. and non-U.S. based studies.

A few cross-sectional studies have investigated the associations between sealants and cavitated caries prevalence and found sealants to be a protective factor. Ditmyer et al (2010), observed 12- to 19-year-old Nevada adolescents cross-sectionally to examine the association between cavitated caries prevalence and presence of sealants based on NHANES criteria. Sealants were negatively and significantly associated with cavitated caries. Ditmyer et al (2008) also observed 13 to 18-year-old Nevada adolescents cross-sectionally to examine the association between cavitated caries prevalence and presence of sealants determined by using NHANES criteria. Adolescents without sealants were least likely to be caries-free. Absence of sealants was positively and significantly associated with severity of cavitated caries surfaces. In both Ditmyer et al (2008, 2010) studies, sealants were found to be protective against cavitated caries prevalence; however, due to the cross-sectional nature of the data, causal associations could not be determined.

In order to quantify and assess the temporal association between sealants and cavitated caries increments, Kallestal and Fjelddahl (2007) conducted a prospective cohort study. They observed 12-year-old Swedish adolescents longitudinally to examine the association between 4-year cavitated and non-cavitated caries increments and a four-year prevention program. Adolescents were considered present if any one of the surfaces of teeth were sealed. For both, cavitated and non-cavitated caries, absence of sealants was positively and significantly associated with greater four-year increments.

The two studies by Ditmyer et al (2008, 2010) were consistent in documenting the negative relationship of sealants with cavitated caries prevalence. However, causality could not be determined. Kallestal and Fjelddahl (2007) found results similar to the Ditmyer et al (2010) studies, but were based on different target populations, making generalizability to the U.S. population, difficult. Moreover, the criteria for documenting presence of sealant were different in the Ditmyer et al (2008, 2010) studies and Kallestal and Fjelddahl (2007) study. Overall, besides sealant clinical trials, studies investigating the effects of sealants on prevention of cavitated caries in adolescents are few, suggesting the need for longitudinal study in this area.

Previous caries experience

This section provides a summary of findings on the association of previous caries experience with cavitated caries in adolescents as described in U.S. and non-U.S. based studies.

Few longitudinal studies of adolescents have investigated the association of cavitated caries with previous caries experience. It is hypothesized that previous caries experience is associated with greater cavitated caries in adolescents. The results from a few longitudinal studies support this claim; however, none explores the association in a U.S. adolescent population.

Campain et al (2003) examined the associations between two-year cavitated caries increments among 12 to 13-year-old Australian adolescents, at baseline. The variable considered as the measure of previous caries was baseline cavitated caries experience recorded as DMFS. Children who had a caries score of 4 DMFS or greater at baseline were at higher risk of having cavitated caries increment than those who had 1-3 DMFS at baseline. Similarly, children who had caries scores of 1-3 were more likely to have cavitated caries increment than those who had baseline DMFS score of 0. All these results were statistically significant, indicating that severity of baseline caries had significant and positive associations with cavitated caries increment.

Alm et al (2012) assessed the association between approximal caries lesions and fillings at age 15 years and previous caries experience at 3 and 6 years among 15-year-old Swedish adolescents. The caries experience at age 15 was defined as a DFa score- a combined measure of both cavitated and non-cavitated caries lesions and fillings. The previous caries experience were considered for caries experience at age 3 years and at age 6 years recorded as defs (initial/enamel caries) and DFa (manifest/dentinal caries) scores, which were the mean totals number of non-cavitated (initial) and proximal cavitated (manifest) caries, respectively. The caries at age 15, i.e., DFa scores were positively and significantly associated with both cavitated and non-cavitated caries prevalence at age 6 years in the final model. Children with 4 or more non-cavitated caries defs scores at 6 years were more likely to have DFa score of 4 or more approximal lesions, while children with cavitated caries at age 6 years were more likely to have greater number of approximal caries lesions and fillings at age 15 years (DFa ≥8). The results were statistically significant for both findings.

Haugejorden and Birkeland (2006) assessed the association between cavitated caries (D3MFT) at age 18 and previous cavitated caries at age 12 among Norwegian birth cohorts of adolescents observed from 1985 to 2004. Similarly, the authors also assessed the relationship between caries prevalence at age 5 years and caries prevalence at age 12 years for birth cohorts observed from 1985 to 2004. For the six-year increment from age 12 to age 18 years, baseline D3MFT score at age 12 years was positively and significantly associated with the six-year caries increment at age 18 years for all birth cohorts observed. It was also the most significant risk factor in the multivariable regression models. Previous caries experience at age 5 (d3 threshold) was also significantly and positively associated with caries experience at age 12 years for the birth cohorts over the entire observation period from 1985 to 2004.

There is evidence that baseline caries and/or previous caries experience are significantly and positively associated with caries in adolescents. However, the age considered for previous caries experience in all studies was different and the studies were inconsistent on including or excluding non-cavitated caries measures and scoring criteria. Although the evidence obtained is based on longitudinal studies capable of establishing temporal relationships, the results of the non-U.S. based studies could not be generalized to the U.S.-based adolescent population.

Also, for all of the variables assessing previous caries, prevalence measures were used. This approach could be refined by using caries incidence measures, which may be better reflection of caries activity during the observation period and would also serve as a surrogate measure for the effect of early childhood or pre-adolescent behaviors on cavitated caries.

Previous Dental Visit

This section provides a summary of findings for the association between previous dental visits of adolescents and dental caries experience in the U.S. and non -U.S.-based studies.

The cross-sectional studies and longitudinal studies found in the literature do not provide definitive evidence for the association between dental caries in adolescents and previous dental visit behaviors. While Pontigo-Loyola et al (2007) found insignificant associations; Alm et al (2012) failed to look at effects of dental visits that resulted more proximal to the occurrence of caries. Fontana et al (2011) discussed the effect of previous dental visits on caries progression but did not assess the effects on either prevalence or incidence of cavitated caries. Overall, the evidence for association between cavitated caries in adolescents and their dental visit behaviors is scarce.

In a cross-sectional study, Pontigo-Loyola et al (2007) examined 12- and 15-year-old Mexican adolescents (N=1,538) to study the associations between prevalence and severity of cavitated caries measured using WHO criteria and independent variables including dental visit history. The status on dental visits was self-reported by subjects and was defined as a dichotomous variable for having had a dental visit in the previous year (yes/no). Those who reported having a previous dental visit had higher DMFT scores than those who did not. However, the results were based merely on bivariate analyses with no reported p-values or multivariable analyses. This limited the validity of study findings.

Ayo-Yusuf et al (2007) examined adolescents with mean age of 14.6 years to study a similar association between cavitated caries prevalence and time since last dental visit among other independent variables. Cavitated caries prevalence was scored according to the WHO criteria, while the information on past dental visits was self-reported by the subjects. Time since last dental visit was categorized as “never visited before”, “visit>12 months ago” “visit 6-12 months ago” and “visit <6 months ago.” However, the variable was not included as part of the final multivariable analyses because it was not significant at the bivariate level ($p<0.01$).

Alm et al (2012), observed children from age 1 to 15 years to examine the association between cavitated caries prevalence at age 15 and early childhood behaviors including dental avoidance behavior at age 1, i.e., the dental visit behavior at age 1. Dental avoidance behavior at age 1 was defined as dichotomous variable where subjects either had only age 15 dental exam and did not have a dental examination at the age 1 and who had dental examination at both age 1 and 15, as determined from parents using a structured questionnaire. Although there was a significant negative bivariate association between cavitated caries experience at age 15 and dental visit at age 1, the results were not significant in the multivariable model.

Fontana et al (2011) recorded caries progression and number of lesions progressing in children aged 5 to 13 years at baseline to assess 12-month follow-up and baseline to 24-month follow-up. The independent variables included time elapsed since last dental visit. The information on dental visit was obtained using questionnaires, where subjects' parents reported whether they had had a dental visit in the previous 3 months or previous 3-6 months or > 6 months. The questionnaires were completed by the subjects at both 12- and 24- month follow-up exams. The authors developed multivariable risk assessment models to identify at risk individuals for progression of caries at the 12- and 24- month time periods. Time elapsed since previous dental visit was significant, and positively associated with progression of caries to ICDAS score ≥3 from baseline to 12 months and baseline to 24 months. They derived results for dental and non-dental settings models where the predictors such as previous caries experience and non-dental variables, respectively, were first introduced into the models. In all four models, they found that time elapsed since previous dental visit of <3 months was positively associated with progression outcomes at both 12- and 24- month follow-ups, when compared to subjects who last visited a dentist ≥ 6 months ago.

In all of these studies the dental visit behavior was self-reported from parents. It is possible that the parents probably reported positive status on dental visits to give a positive impression to the examiners, which may have led to bias. Studies by Pontigo-Loyola et al (2007) and Ayo-Yusuf et al (2007) could not be used to assess true associations due to their cross-sectional design. The longitudinal studies by Fontana et al (2011) and Alm et al (2012) were significantly different and were based on a wide age range. The differences in findings and population groups show that there is a need for longitudinal research, to study the effects of dental visits on cavitated caries among U.S. adolescents.

Insurance

This section provides a summary of findings on the association between dental insurance and cavitated caries prevalence from studies of U.S. adolescents. It was found generally that Nevada adolescents were less likely to have caries prevalence if they had dental insurance.

Ditmyer et al (2008) cross-sectionally observed Nevada adolescents aged 13 to 18 years of age, respectively, and assessed the association between cavitated caries prevalence and independent variables including self-reported dental insurance status from an interview dichotomized as yes/no. The authors found that subjects without dental insurance were significantly more likely to have moderate (DMFT 2.7-4.4) and high (DMFT>4.4) scores, however, the number of people in the two groups was not reported.

Ditmyer et al (2010) examined over 4,000 adolescents aged 12 and 19 year olds to assess the association between cavitated caries prevalence and self-reported dental insurance by interview, with insurance status as dichotomous outcome (yes/no). Insurance status was one of the significant predictors of cavitated caries prevalence, the uninsured were 1.25 times as likely to be among those 30% of the subjects who had the highest caries.

In both these studies, the subjects self-reported status, possibly resulting in reporting bias. Although both studies were conducted on U.S. adolescents, the Ditmyer et al (2008, 2010) studies are cross-sectional in nature and causal interferences should not be drawn, furthermore, longitudinal associations should be studied between the two variables.

Smoking-related behaviors

This section provides a summary of findings that assess the association between caries and tobacco-related behaviors such as the subjects-smoking behaviors and exposure to second-hand smoke. Generally, the studies report a positive association between exposure to second-hand smoke and cavitated caries prevalence.

Some of the cross-sectional studies in the literature (Ditmyer et al, 2008 and 2010; Ayo-Yusuf et al, 2007) have investigated the effects of tobacco, smoking status and exposure to second-hand smoke on cavitated caries in adolescents and found that deleterious behaviors related to tobacco and smoking are likely associated with cavitated caries in adolescents. Due to the cross-sectional nature of the studies, however, a temporal relationship to this finding could not be determined. Ditmyer et al (2008, 2010) examined Nevada adolescents in 2008-09 and 2010-2011 to assess the relationship between cavitated caries prevalence and independent variables, including tobacco use (Ditmyer et al, 2008) and status of smoking and second-hand smoke (Ditmyer et al, 2010). They observed over 9,000 (Ditmyer et al, 2008) and over 4,000 Nevada adolescents (Ditmyer et al, 2010) in a statewide Oral Health Screening Survey. The survey was done to collect data to assess associations of cavitated caries prevalence with tobacco use (Ditmyer et al, 2008) and status of smoking and second-hand smoke

(Ditmyer et al, 2010), respectively. The information on these explanatory variables was obtained by face-to-face interviews. Cavitated caries prevalence was assessed using WHO criteria. Cavitated caries prevalence was positively and significantly associated with tobacco use (Ditmyer et al, 2008). Positive smoking status and exposure to second-hand smoke were positively associated with cavitated caries prevalence, but the exposure to second-hand smoke was a stronger significant predictor than smoking status (Ditmyer et al, 2010). Ayo-Yusuf et al (2007), in a cross-sectional study examined 1,873 South-African adolescents to assess the relationship between cavitated caries prevalence and independent variables, including second-hand smoke exposure. The variable exposure to second-hand smoke was dichotomized as “no exposure at home” vs. “exposure at home”. Subjects who had family members who were smokers were almost twice as likely to have cavitated caries prevalence compared to those who did not have a smoker at home, with the results statistically significant.

Similarly, Bruno-Ambrosius et al (2005) examined 162 12-year old Swedish girls to assess the relationship between smoking behavior and two-year cavitated caries increments. The cavitated caries was scored using the WHO criteria, while smoking status was assessed by questionnaire. Smoking was dichotomized into cigarette smoking as two days a week vs. no smoking at all. Smokers in eighth grade had a significantly higher three year mean caries increment than non-smokers in the same grade.

The studies discussed here found that smoking behaviors were positively associated with cavitated caries prevalence and incidence measures. However, causal relationships between smoking behaviors and cavitated caries could not be established as the majority of the studies were cross-sectional. In addition, the variables were defined in different ways in all of these studies. Only a single study had a longitudinal component, but it studied Swedish female eighth graders and the generalizability of such findings is limited.

Overall Summary of Gaps and Limitations

The findings from Beighton et al (1996), Petridou et al (1996), Haugejorden and Birkeland (2006), Pontigo-Loyola et al (2007) Ayo-Yusuf et al (2007), Klejka et al (2011) and Ditmyer et al (2008,2010) are based on cross-sectional studies. The studies focus on different populations and emphasize research on various risk factors. Due to the cross-sectional nature of the studies, causality and temporality among different risk factors and cavitated caries outcomes could not be determined. Overall, due to this cross-sectional nature, the studies help in hypothesis generation but do not test the hypothesis for associations between risk factors and cavitated caries in adolescents.

While there are a few studies focusing on longitudinal associations of risk factors and caries in adolescents, there are still some major differences in each of these studies. To begin with, the follow-up period among the studies ranges from 1 year (Clancy et al, 1977) to almost six years (Haugejorden and Birkeland, 2006). Additionally, the results of these studies may not be interpretable in today’s times due to the nature of the data and cohorts used in these studies. Most of the studies have emphasized dietary associations with cavitated caries increments, however, clear relationship between the intake and frequency of consumption of different dietary components and cavitated caries increments have not been documented. The results on dietary behaviors may not be comparable across most studies due to the different criteria defining the food groups (e.g., the categorization of foods based on sugar content is different in studies by Rugg-Gunn et al, 1984; Burt et al, 1988; and Campain et al, 2003) and beverages that have been studied. Studies on risk factors such as oral hygiene behaviors, use of topical fluorides and sealants, and previous dental visits do not provide clear evidence. It is not known p whether tooth-brushing frequency among adolescents could have a cut off that could be favorable as opposed to having no effect. While previous caries experience was a significant variable in most studies, it is critical to note that the caries scoring criteria varied in some of these studies, i.e., with tooth vs. surface level focus. In studies using the WHO criteria of DMFT scores, the authors did not discuss the flaws of the criteria themselves. In the study by Kallestal and Fjelddahl (2007), it is not known if the sample after loss to follow-up was representative of the sample that was recruited. In Alm et al (2012) and Fontana et al (2011) studies, the age groups of the study population were very different. While Alm et al (2012) focused on childhood behaviors and their effects on cavitated caries prevalence at age 15; they failed to account for the effects of behaviors that were manifested close to the time of the caries examination/adolescent period which could be one of the major confounding variables. Fontana et al (2011) developed caries risk assessment models for children aged 5 to 12 years. However, they failed to address the differences in the nature of risk factors for cavitated caries associated with different age groups and dentition period. While Chankanka et al (2011) had a well-designed study, the sample size was modest and the study did not address the entire adolescent period. In addition, both the cross-sectional and longitudinal studies had data that were self-reported which could have led to reporting bias. In cases where interviews were used to derive information from the subjects, it is unknown if the interviewers or examiners were blinded from the purpose of the study and had any role in the kind of responses given by subjects. Such biases, when present, could have led to challenges of internal validity among these studies. Furthermore, differences in study designs and study populations make the generalizability of results to American population extremely limited.

Need for the Study

Overall, the review results suggest a need for longitudinal research focused on assessing the main etiologic, preventive and demographic risk factors for caries in adolescents with an aim to investigate a comprehensive set of risk factors and their associations with cavitated caries in the U.S. adolescents. Such a study will have an advantage in assessing complex causal relationships between cavitated caries in adolescents and risk factors. Results from such a study will help policymakers, dentists and dental public health professionals develop and program better preventive oral health strategies. The evidence will also be useful for educating teachers, parents, school staff and adolescents in adopting or helping to adopt protective behaviors and discourage behaviors that increase the risk of cavitated caries in adolescents.

CHAPTER 3

MATERIALS AND METHODS

Introduction

Dental caries is a serious problem among adolescents in the United States. One of the Healthy People 2020 objectives is to reduce the proportion of adolescents aged 13 to 15 years with dental decay from the current levels of 53.7% to 48.3% (Healthy People, 2020). According to the American Academy of Pediatric Dentistry (2010), adolescence is characterized by substantial changes in dietary and beverage behaviors and an inclination toward poor oral hygiene. These changes can lead to an increased risk of caries activity resulting in a higher incidence of caries in this age group. It is, therefore, important to analyze the associations of caries with various risk and protective factors, and to quantify the effects that these variables have on caries incidence in this age group.

The literature on risk factors for caries in adolescents has relatively few studies based on individual level data. In addition, the pool of studies assessing risk factors for caries in adolescents is based mostly on cross-sectional designs, which are incapable of identifying a causal association. Thus, additional comprehensive longitudinal studies are needed for this age group. The purpose of the present study is to determine the risk factors for cavitated caries incidence in adolescent subjects of the Iowa Fluoride Study (IFS) examined at the age 13 and 17 dental examinations.

Iowa Fluoride Study General Methods

Recruitment and IRB Approval

The Iowa Fluoride Study is a longitudinal study that recruited mothers and their newborns from eight hospitals post-partum wards. These hospitals were major sites for the majority of births in the area. These eight Iowa hospitals had about 8,000 births per year, which was approximately 20 percent of all births in Iowa. The recruitment phase lasted for three years, with subjects recruited from March 1992 to February 1995.

It was a convenience sample and participation was voluntary. Approval for the study was obtained from the University of Iowa Human Subjects Review Committee initially in 1991 and renewed every year (Chankanka et al, 2011). Initial written informed consent was obtained from the mothers at the time of recruitment. Separate assent was given by the subjects.

Data Collection

Demographic Information and Variables

Age of the child was defined as age at the previous dental exam. Age increments were defined as the number of years between exams. The information about family income and parents’ education levels was collected via questionnaires at three different time points. First, the information on sex of the child, maternal education (Q.29), and family income (Q.36), race and ethnicity, and number of children in the family were collected at the time of recruitment (1992-1995), using the recruitment questionnaire (Appendix D). Second, the information on family income and parents’ education was collected in 2000-04 and in 2007 (from separate mailings) using Iowa Fluoride Study

Demographic Questionnaire (Appendix B). From 2003-2011, once subjects were age 11 or older, information about the race and ethnicity of the subjects and their parents and both paternal and maternal grandparents was collected using the Family Background Assessment Questionnaire (Appendix A).

Sex was defined as male or female. Subjects were divided into six categories depending on the annual family income, i.e., less than $20,000, $20,000-$39,999, $40,000-$59,999, $60,000-$79,999, $80,000 or more (Q. 5, Appendix B). Subjects were also divided into six categories depending on the status of maternal education- self-reported by mothers. Subjects were categorized based on maternal education as some high school, high school diploma or GED, some college, two year college degree or technical/beauty school education, four year college degree, post graduate or professional degree (Question 1, Appendix B)..

Iowa Fluoride Study Questionnaires

The Iowa Fluoride Study collected data using the Iowa Fluoride Study Questionnaire, which was sent to the recruited mothers initially when subjects were 1.5 months old. Additional, similar questionnaires were sent when subjects were 3, 6, 9 and 12, months old and then 2-3 times yearly after that. Thus, the questionnaires were sent when subjects were 16, 20, 24, 28, 32, 36, 40, 44, 48, 54, 60, 66, 72, 84, 96 and 102 months old. Then, a modified questionnaire (Appendix C) was used beginning at age 9 years (108 months) and has been continued to be sent every six months.

The IFS questionnaires collected data on physical factors such as weight and height. Importantly, information obtained using the questionnaires included daily tooth brushing frequency, fluoride toothpaste use, water sources, food and beverage intakes at home and childcare, use of dietary fluoride supplements, antibiotic use, illnesses and other medication use up to age 5 years. The questionnaires were modified for different age groups and included variables relevant for the respective age of the child. The main purpose of the Iowa Fluoride Study was to assess the association between childhood fluoride intake and dental fluorosis. Hence, all questionnaires assessed the intake of fluoride through different dietary and non-dietary sources. The dietary sources included drinking water, other beverages and selected foods with substantial amounts of added water, and dietary fluoride supplements, while the non-dietary fluoride agents were fluoride toothpaste, fluoride mouthrinse, and topical fluoride agents. Throughout the study, information on water fluoride levels was obtained from state lab results or by testing it annually. Secondarily, the IFS data were also used to assess relationships with caries at different ages of the cohort.

Mothers were also sent three-day food and beverage diaries at the same time as the main IFS questionnaires until the subjects were 8.5 years old. At 9 years of age, the dietary diaries were discontinued due to decreased subject response, and the IFS developed a new questionnaire with more detailed questions on dietary intake information (Appendix C). This detailed questionnaire on dietary variables became a part of the main Iowa Fluoride Study questionnaire from age 9 onwards, at 6-month intervals until the present time (to age 21+ years). Detailed information about the collection of dietary variables has been published previously for very young subjects below 5 years enrolled in IFS study (Marshall et al, 2005). Information on beverage and food exposures was determined from 3-day diaries for 1, 2, 3, 4 and 5 years. An eating event was defined as 30-minute intervals. All eating events were classified as meals or snacks based on the nature of the food items and time of consumption. In addition, beverage and food exposures were classified by carbohydrate content (Marshall et al, 2005). Other information from the questionnaires concerned oral hygiene and dental visit behaviors. The details of information collected at different ages prior to age 13 years, are described thoroughly by Chankanka et al (2010).

The Iowa Fluoride Study questionnaires were sent to subjects semi-annually from age 9 onward. However, in some cases, it was not convenient for the subjects to respond to the questionnaire on a semi-annual basis. Hence, to avoid attrition of study subjects, the IFS questionnaires were sent to some subjects on an annual basis, i.e., at ages 13, 14, 15, 16 and 17 years. However, 6- monthly questionnaires were sent to the majority of study subjects, with greater than 70% response overall. The questionnaires that were sent every six months assessed information on independent variables for the prior six months each. However, the questionnaires assessed information on dietary variables for the prior week.

Information collected from Iowa Fluoride Study Questionnaire (Appendix E and Appendix F) is described in detail below.

A. Oral hygiene and related behaviors

The IFS questionnaire (Q. 11, Appendix E) assessed the type of toothbrush, specifically whether the child used adult size, child size or never brushed in the previous six months. The questionnaire assessed the frequency of brushing for the previous six months, where the mother was asked to report if the brushing was more than three times per day, three times per day, twice per day, once per day or less than once per day (Q. 12,

Appendix E). The questionnaire also assessed the length of time teeth were brushed, i.e., 15 seconds, 30 seconds, 45 seconds, or 1 minute (Q. 14, Appendix E). The data for frequency of tooth brushing were averaged over the four and one half year response period using AUC estimates for each individual subject and were considered as an independent variable.

B. Fluoride

1. Exposure to fluoride from drinking water

Subjects were also asked to select the main source of home drinking water from three options in the questionnaire which were well, Rural Water Association (RWA) or city/ public drinking water. Information for the consumed water was recorded by asking the primary source location, i.e., state and city area, which served as the main source of drinking water (Q. 4, Appendix E). The purpose of this assessment was to record the different sources of water consumed during the previous six months. Four sources of water were defined– home, school, bottled and other. Home water included water sources where subjects lived on a regular basis. School water was recorded as the intake of water at school or during school activities. Bottled water included only commercially bottled water. The sources of “other” water included sources away from school and home where the subject spent at least two full weeks or more on a regular basis. However, “other” water sources did not include of places where the subject spent less than a week continuously or a total of two full weeks.

Several aspects of the different sources of water intakes were recorded, including: intake of water (average number of ounces of water consumed), number of weeks the water was consumed (26 weeks was considered maximum time), days/week, source type (public, RWA or well), and whether a water filter was used. The subjects were given a calendar to count back six months from the date they were completing the questionnaire to help calculate the number of weeks at home, school, etc. In addition, separate information on the state and city where the child's home was located was reported by the mother. Similarly, the names of the subjects' schools were also recorded. Use of bottled water was recorded for the variables of total bottled water per day (oz./day), total weeks consumed, number of days consumed per week, and bottled water consumed in one week (oz./week). For home, school and "other" sources, water fluoride levels for public water systems were obtained on an ongoing basis from the Iowa Department of Public Health. For non-public water systems, private wells or filtered water, and bottled water, the fluoride level in drinking water was determined by individual fluoride assays. This was conducted by using a fluoride-ion specific electrode (Levy et al, 2001).

2. Fluoride exposure and intake from toothpaste

The questionnaire assessed information on whether toothpaste was used during the previous six months while toothbrushing and recorded the brands that were used during the previous six months (Q. 15, Appendix E). Respondents were also asked to choose the best picture, matching the amount of toothpaste they used, from seven different options that had different quantities of toothpaste associated with each (Q. 16, Appendix E). The approximate amounts of toothpaste represented 1.0 mg, 0.875 mg, 0.75 mg, 0.5 mg, 0.25 mg, 0.125 mg, and 0.0625 mg. The questionnaire also assessed the estimated amount of toothpaste swallowed per brushing during the previous six months (Q 17, Appendix E). Seven options were provided representing the intake as all, almost all, three quarters, one half, one quarter, very small amount, none at all or don't know. The amount of toothpaste in each picture was determined from responses and averaged for the time period considered in the analyses, using area under the curve estimates. In the above analyses, the approximate fluoride quantity was determined in milligrams.

3. Fluoride exposure from mouthrinse

The questionnaire assessed if mouthrinse or gel was used by the child and which of the two topical fluoride modes was used (Q 18, Appendix E and F). The amount of fluoride mouthrinse or gel swallowed was estimated as almost all, one-half, very small amount, none at all, or don't know. The questionnaire also assessed if the child participated in a fluoride mouthrinse program at school or at home during the previous six months (Q 18, Appendix E and F). In these analyses, fluoride mouthrinse use was categorized as yes/no and was defined as any use of fluoride mouthrinse in the four and one half year interval, at home or at school.

C. Beverage exposure variables

The IFS questionnaire beverage exposure data were recorded and brand names were collected for each type of beverage (Q 5, Appendix E). The exposures were recorded for water by itself, reconstituted sugared beverages from powder, beverages re-constituted from frozen or liquid concentrate, brewed or powdered coffees and tea, milk intake, and ready-to-drink beverages (e.g., tea, coffee, juice and juice drinks, sports drinks, soda pop, fitness waters, and energy drinks). Intake of wine, beer and mixed drinks were also recorded. For each of the beverages, a dichotomous response method in the IFS questionnaire was used to record whether a given beverage was consumed by the child. The next part of the questionnaire assessed the number of servings per week of each of the given beverages. The amount per serving in ounces was also recorded for the beverages consumed, in order to quantify the intake levels of the beverages during the previous week.

Sample Sizes

A total of 1,882 mothers of newborns were recruited, of which only 1,382 responded to the first questionnaires within the first three months of birth. At age 5 dental examination, the sample consisted of 698 subjects which declined to 629 at age 9 dental examination. A total of 550 subjects were examined at the age 13 year dental exams, whereas 444 subjects were examined at the age 17 dental examination.

Dental Examinations

Dental examinations were conducted when the subjects were approximately 5, 9, 13 and 17 years old. Examinations were performed primarily by visualization without using radiographs, with confirmation on the status of frank lesions via use of an explorer, if needed. A portable chair and halogen head light were used by trained and calibrated dentists and the teeth were dried during the examination with compressed air. Additional lighting and trans-illumination was obtained using the DenLite® mirror system (Welsh-Allyn Medical Products, Inc., Skaneatele Falls, NY) for all examinations. Reliability between the examiners was assessed by conducting repeated measurement on a subset of subjects and results were determined by using Kappa coefficients and percent agreement. Five different examiners conducted the dental examinations from age 5 to age 17 years. Yearly calibration exercises were conducted.

Diagnostic Criteria

The diagnostic criteria used for categorizing carious lesions were those defined by Warren et al (2002), based on criteria modified from Pitts and others (Pitts and Fyffe, 1988, Pitts 1997). In the IFS study, the examiners recorded non-cavitated enamel and dentin lesions, d_1 and D_1 for the primary and permanent dentition, respectively. Cavitated enamel and dentin lesions were scored as d_{2+} /D_{2+} in the primary and permanent dentition, respectively. Fillings were also noted and sealants were reported to be either partially retained or fully retained.

Caries Outcomes

Caries outcomes have been assessed and reported earlier for age 5, 9, 13 and 17. Incidence of cavitated and non-cavitated caries from age 5 to age 13 has been described earlier by Chankanka et al (2011) and for age 9 to 13 years has been described separately by Broffitt et al (2013).

Data Entry and Management

Dental exam recording forms for age 13 and 17 years were scanned and processed using Verity® TeleForm® (Sunnyvale, Calif. - 2005-05-03 - Verity Inc.). All data were independently reviewed by the statistical team. The information from the questionnaires was recorded using Microsoft Access. A double-entry method was used for this purpose to prevent and check any errors in data entry. The data were stored in the College of Dentistry and College of Public Health servers that were maintained by the informatics staff at the University Of Iowa College of Dentistry and the College of Public Health, respectively.

Iowa Bone Development Study

The Iowa Bone Development Study is an ancillary study that began parallel to the Iowa Fluoride Study in 1998. The Iowa Bone Development study involved parents and children who had been recruited in the Iowa Fluoride Study from 1992-1995. The study aimed at observing bone development over time beginning from early childhood to adulthood. The bone development has been studied using densitometry procedures characterized by low radiation. Genetic, dietary, anthropometric, demographic and parental factors have been included in the analyses. Diet was assessed for the enrolled subjects using the Block Kids Food Frequency Questionnaires (Appendix H).

At age 5, 471 of the enrolled subjects had their first bone densitometry study exam. This was followed by examination of 539 subjects at age 9, 483 at age 11, 489 subjects at age 13, 415 subjects at age 15 and 380 at age 17. Additional examinations are underway for age 19.

The study used Block Kids Food Questionnaire to assess the macronutrient quantity and quality of intake from subjects enrolled in the Iowa Bone Development Study. Dietary intake of calcium (mg) and vitamin D (I.U.) along with other mineral, vitamin and macronutrient intake was calculated for previous week from the participant's responses to the seventy-five item Block Kids Food Questionnaires. These responses were obtained at the time of clinical examination which has been described earlier. The Block Kids Food questionnaire assessed both solid and beverage intake of the subjects. Supplemental calcium and vitamin D intake was also assessed to determine the total dietary calcium and vitamin D intake. The details of variables used from the Block Kids

Food Frequency Questionnaire for the present study has been described in detail in a different section. The terms “Block Kids Food Questionnaire”, “Block questionnaire”, “Block Kids Food Frequency Questionnaire” and “BFFQ” are used synonymously with Block Kids Food Frequency Questionnaire.

Thesis-Specific Methods

Caries Examinations

Caries outcomes were determined based on the age 13 (wave 4) and age 17 (wave 6) dental examinations. Age 13 is the baseline age for these analyses, while age 17 is the final age. However, some of the subjects enrolled in the study did not attend all exams at precisely age 13 and age 17, due to issues related to time, convenience, logistics etc. To prevent confusion, subjects in this study are stated to have dental examinations at age 13 and 17. However, in the analyses and definitions, the exact chronological ages of the subjects have been considered. Additionally, the interval between final and baseline exams has also been considered with exact chronological ages.

Study Subjects

The subjects included in the analyses were enrolled in both the Iowa Fluoride Study and the Iowa Bone Development Study. Secondary analyses of data collected with the Iowa Fluoride Study Questionnaires included analyses of the data on demographics, dietary (beverages only), and fluoride from different dietary and non-dietary sources along with dental visit, topical fluoride application and oral hygiene variables. Dental examination data were used for information on sealants and previous caries incidence.

The secondary analyses of the data from Block Food Kids Questionnaire related to analyses of patterns of solid and beverage intake.

Use of IFS and Block Questionnaire

The secondary analyses of the Iowa Fluoride Study (IFS) questionnaires and Block Kids Food Questionnaires (Block) data were done in order to determine the longitudinal effect of risk and protective factors on cavitated caries incidence in adolescents. The responses from Iowa Fluoride Study Questionnaires and the Block Kids Food Questionnaires from age 13 to 17.5 years and 13.0 and 17.0 years, respectively, were used in the present analyses.

Response Period for Data Included in the Present Analyses

A. <u>Response period for Iowa Fluoride Study questionnaires</u>

The Iowa Fluoride Study data that were used for the current analyses included questionnaires from ages 13.0 to 17.5 years. In order to ensure that the responses reflected the full time period and possible changes over time observed from 13 to 17.5 years IFS questionnaires, the response period was divided into three sub-periods – early, middle and late, respectively. The early and late sub-periods each included three potential questionnaires, while the middle period included four potential questionnaires. The early period included questionnaires at ages 13.0, 13.5 and 14.0 years. The middle period included questionnaires at ages 14.5, 15.0, 15.5 and 16.0 years, while the late period included questionnaires at 16.5, 17.0 and 17.5 years. The subjects were included in analyses if the criteria for inclusion were satisfied. These criteria are described in a later section.

B. Response period for the Block Kids Food Questionnaire

Responses from the Block questionnaire that were used in the current analyses were those obtained from questionnaires administered at the age 13, 15 and 17 bone density examinations. If needed due to missing responses at age 13, responses from age 11 were used to interpolate responses for questionnaires administered at age 13. There was no dental exam at age 15.

Inclusion Criteria

The inclusion criteria for subjects were based on having proper interval between exams, and required set of responses from the IFS and Block questionnaires, respectively. These criteria were described using three rules, as follows

Rule-I based on dental examinations

The subjects who were present at both baseline (age 13) and final (age 17) dental examinations were included in the present analyses.

Rule-II based on IFS questionnaire responses

Questionnaires were sent to parents of all subjects at half-year intervals, from age 13.0 to 17.5 years. Subjects were able to be included in the analyses only if they met two sets of requirements related to questionnaire responses. First, subjects needed to have responses for the age 13.0 (or 12.5/12) and 17.5 (or 18.0/18.5) year IFS questionnaires and second the subjects were required to have at least one response from the middle sub-period. All the available responses from each of the three sub-periods--early, middle and late (described in the previous section) were used in these analyses.

Rule-III based on Block questionnaire responses

The responses to Block questionnaire were considered only for those subjects who satisfied inclusion criteria for the dental examinations and for having the required set of responses to the traditional IFS questionnaires. The subjects were then included if their responses to Block Kids Food Questionnaire were available for questionnaires completed at both the age 13 and age 17 dental examinations. In order to obtain better estimates, when available, responses from questionnaires administered at age 15 were also considered in the analyses.

Rule-IV based on interval between the exams

Subjects were excluded from the analyses if the interval between age 13 and age 17 dental exams was less than 3.0 and greater than equal to 5.0 years.

Sample size

The present analyses included the cohort of subjects who were present at both age 13 and age 17 dental examinations and who met the inclusion and exclusion criteria for responses as described above, i.e., 303 subjects .The responses for all variables were available for 288 subjects. The variables that met the inclusion criteria for multivariable analyses had fewer subjects with missing responses and the total sample size for the final multivariable models for both logistic and negative binomial regression was 297.

Independent variables

This section describes the information collected on the selected independent variables. The independent variables included demographic variables, non-dietary variables (oral hygiene, fluoride and dental visit variables) and dietary variables (beverage exposure variables) as obtained from IFS questionnaire. The section also describes the information collected on selected independent variables such as sealant variables (presence of sealants, number of zones with sealants) and previous caries incidence variables (9 to 13 net cavitated caries incidence {Y/N} and 9 to 13 net cavitated caries increment count {discrete count}) obtained at the time of baseline (age 13) dental exams.

A. *Iowa Fluoride Study Questionnaires Variables*

The details of the specific variables used from the IFS questionnaires and baseline and previous dental exams are described as follows

1. Oral Hygiene Variables

The current analyses aimed to study the effects of tooth brushing frequency and duration of brushing on net cavitated caries incidence from age 13 to age 17, among IFS adolescents. The period considered for inclusion of responses was from 13.0 to 17.5 years. The operational definitions for the variables are described in detail in a later section.

2. Fluoride Intake and Dental Visit Variables

The current analyses used data to assess the fluoride exposures and intake through different sources. These data were used to define variables as composite water fluoride level, daily fluoride intake from water, daily fluoride intake from combined sources, use of fluoride mouthrinse and any topical fluoride applications and their effects on age 13 to 17 net cavitated caries incidence among IFS adolescents. The exposure to and intake of fluoride from water and other sources, along with the use of fluoride mouthrinse, topical fluoride applications, and dental visits were considered from age 13.0 to age 17.5 years IFS questionnaires, as described earlier. The operational definition of each of these independent variables is described in detail in a later section.

3. Dietary Intake from IFS: Beverages

In order to study the effects of beverage intake on caries, secondary analyses of the data on beverage variables and its relation to net cavitated caries incidence was studied. For the present analyses, all beverages consumed by subjects were categorized as sugared beverages, 100% juice, milk or sugar-free beverages (i.e., beverages without added sugar including 100% juice but no water by itself). The beverages included in each of these categories are described below:

- Sugared Beverages (i.e., sugared juice drinks, sugared sports drinks, sugared energy drinks, soda pop with sugar, sugared powdered beverages, sugared fitness waters, sugared protein drinks, sugared tea and coffee and sugared alcohol)
- 100% juice (all 100% juice products containing only natural sugar)
- Milk (all milk including chocolate and soy milk)
- Sugar-free Beverages (i.e., 100% juice without added sugars, juice drinks without added or natural sugars, sports drinks without added or natural sugars, energy drinks without added or natural sugars, soda without added or natural sugars, powdered beverages without added or natural sugars, fitness waters without added or natural sugars, protein drinks without added or natural sugars, and tea and coffee without added or natural sugars, respectively, but no water by itself).

4. Use of Sealants

The current analyses also aimed to assess the effect of sealants on net cavitated caries incidence among IFS adolescents as observed between age 13 to age 17 dental examinations. The variables considered for sealants were the baseline presence of sealants, i.e., presence of sealants on surface zones of teeth at age 13 dental exam, among IFS adolescents. The other variable considered in the analyses was the “number of surface zones with sealants”. The operational definition for each of these variables is described in detail in a later section.

5. Previous Caries Incidence

The current analyses also aimed to assess the effect of age 9 to 13 net cavitated caries incidence and net cavitated caries increment count, respectively, on net cavitated caries incidence from age 13 to 17 among IFS adolescents, respectively. The data used for these analyses were obtained using caries measures at age 9 and age 13 dental exams and were described as number of $D_{2\text{-}3}$FS increment count from 9 to 13 and net cavitated caries incidence from age 9 to 13, respectively. The operational definition for each of these variables is described in detail in a later section.

Block Kids Food Frequency Questionnaire Variables

The Block Kids Food Questionnaire, which is originally a seventy five-item questionnaire, was divided into two parts. This was done with the aim of differentiating between the solid and beverage categories of food items (Appendix G). The sixty-five solid items were then sub-divided into seven different categories as described in Table 3-1. The present analyses used information collected for dietary variables and excluded information on page one and ‘Additional Questions’ on page eight, of the Block Kids Food Questionnaire. The information on page one, included age, sex, height, weight and nature of diet subjects had in the previous week. Additional information, such as participation in the school lunch program, race-ethnicity, languages spoken at home and highest grade of the household adult, was not used.

A. Solid food variables

The sixty-five solid food items in Block Kids Food Questionnaire were further divided into the following seven categories (Table 3-1):

1. Low Presumed Cariogenicity Based on Protein and Fat Content,
2. Low Presumed Cariogenicity Based on Fiber and Low Natural Sugar Content,
3. Moderate Presumed Cariogenicity Based on Natural Sugar Content,
4. Moderate Presumed Cariogenicity Based on Starch and Protein Content,
5. Moderate Presumed Cariogenicity Based on Starch Content,
6. High Presumed Cariogenicity Based on both Sugar and Starch Content, and
7. High Presumed Cariogenicity Based on Added Sugar Content

B. Liquid food variables

The liquid variables that were used in these analyses were divided into three categories (Table 3-2):

1. High presumed cariogenicity: Sugared Beverages (Sugared soda pop, Kool-aide or Gatorade, Sunny Delight, Hi-C, Hawaiian Punch or Ocean Spray)
2. Moderate Presumed Cariogenicity: 100% juice, and
3. Low Presumed Cariogenicity: Milk

C. Frequency of beverages and solid food consumption

The frequency of both beverage and solid food intake were measured in number of days/ week. The number of days a given category of food was consumed was determined by summation of number of days/week all specific foods in that category were consumed. For instance, foods classified as high presumed cariogenicity based on added sugar content consisted mainly of chocolate candy, other candy, pudding, ketchup, salsa or barbeque sauce, raisins, fruit rolls or dried fruit (Table 3-1). Therefore, in this case for each food item, the range of maximum and minimum days was 0 and 7, respectively. Similarly, the total intake of foods categorized as high presumed category had a maximum range of forty two days (6 foods *7 days=42 food days). Likewise, when the two categories were collapsed to form one broader category of "high cariogenicity foods" comprising of 12 total items, the maximum frequency of consumption further increased to 84 days per week (12 times seven days). Thus, the frequency of consumption for a given food category could exceed seven days/week, as it was an aggregate of frequencies of specific food items for that category.

Table 3-1 Categorization of solid-food items in Block Kids Food Questionnaire based on presumed cariogenic potential and predominant content

Category description	1. Foods With Lower Presumed Cariogenicity Predominant in Protein And Fat Content	2. Foods With Low Presumed Cariogenicity Predominant in Fiber And Low Natural Sugar Content	3. Foods With Moderate Presumed Cariogenicity Predominant in Natural Sugars Content	4. Foods With Moderate Presumed Cariogenicity Predominant in Starch And Protein Content.	5. Foods With Moderate Presumed Cariogenicity Predominant in Starch Content	6. Foods With Moderate Presumed Cariogenicity Predominant in Both Sugar And Starch	7. Foods With High Presumed Cariogenicity Predominant in Sugar Content
Brief description	*Protein/Fat*	*Vegetables*	*Fruits*	*Starch/Protein*	*Primarily Starch*	*Processed Starch Or Sugar + Starch*	*Primarily Sugar*
Food items	Eggs Including Breakfast Sandwiches With Eggs	Green Salad	Bananas	Hamburgers, Cheeseburgers Or Meat Loaf	Hamburger Buns Or Hotdog Buns, Or Bagels Either Alone Or As A Sandwich	Cold Cereal, Like Corn Flakes, Frosted Flakes, Or Any Other Kind Of Flakes	Chocolate Candy, Like Candy Bars, Hugs, M&Ms
	Bacon And Sausage Including Breakfast Sandwiches With Bacon Or Sausage	Green Beans, String Beans	Apples Or Pears	Tacos Or Burritos With Meat Or Chicken	Bread Or Toast Including Sandwiches	Hot Cereal Like Oatmeal	Other Candy Like Gummy Bears, Starburst, Skittles
	Beef Steak Roast Beef Or Beef In Frozen Dinners	Baked Beans, Chili Beans, Or Any Kind Of Beans	Oranges Or Tangerines	Sandwiches With Beef, Like Hot Pockets, Or Meat Ball Subs	Tortillas	Granola Bars, Breakfast Bars, Oatmeal Raisin Bars, Or Pop Tarts	Pudding
	Pork Chops Or BBQ Ribs	Corn Or Corn On The Cob	Canned Fruit Like Applesauce, Fruit Cocktail	Beef And Noodles, Pot Pie, Hamburger Helper Stew	French Fries, Fried Potatoes Or Tater Tots	Cinnamon Buns Or Muffins	Ketchup, Salsa Or Barbeque Sauce
	Fried Chicken Or Chicken Nuggets	Broccoli	Other Fruit, Like Grapes, Fresh Peaches Or Melon	Pizza And Pizza Pockets	Rice	Crackers, Snack Crackers Like Goldfish	Raisins, Fruit Roll Ups Or Dried Fruit
	Salad Dressing On Salad	Coleslaw Or Cabbage		Hot Dogs Or Corn Dogs	Gravy On Mashed Potatoes Or On Rice	Sweet Potato/ Sweet Potato Pie	

Table 3-1 Categorization of solid-food items in Block Kids Food Questionnaire based on presumed cariogenic potential and predominant content (Cont’d)

Category Description	1. Foods With Lower Presumed Cariogenicity Predominant in Protein And Fat Content	2. Foods With Low Presumed Cariogenicity Predominant in Fiber And Low Natural Sugar Content	3. Foods With Moderate Presumed Cariogenicity Predominant In Natural Sugars Content	4. Foods With Moderate Presumed Cariogenicity Predominant in Starch And Protein Content.	5. Foods With Moderate Presumed Cariogenicity Predominant in Starch Content	6. Foods With Moderate Presumed Cariogenicity Predominant in Both Sugar And Starch	7. Foods With High Presumed Cariogenicity Predominant in Sugar Content
	Any Other Kind Of Chicken Like Chicken And Gravy, Chicken Salad, Or In Frozen Dinners	Tomatoes (Excluding Tomato Sauce)		Other Soup Like Chicken Noodles Soup Or A Cup A Soup Excluding Vegetable Soup, Vegetable Beef Soup Or Tomato Soup.	Any Other Kind Of Potatoes Like Baked , Boiled Or Mashed Potatoes	Cookies	
	Fish, Like Fish Sandwich, Fish Sticks Or Any Other Kind Of Fish	Greens Including Spinach, Mustard Greens Or Collards		Peanut Butter Sandwich	Spaghetti, Ravioli Or Lasagna With Tomato Sauce	Pancakes, Waffles Or French Toast (Including Sugar Syrup Or No Sugar Syrup)	
	Lunch Meat Like Bologna Or Sliced Ham, Either On Sandwich Or By Itself	Carrots Either Raw Or Cooked		Nachos With Cheese		Ice-Cream, Ice-Cream Bars, Or Frozen Yogurt	
	Margarine Or Butter Use On Pancakes And Waffles	Other Vegetables Like Peas, Squash Or Peppers		Sliced Cheese, Cheese Whiz Or Grilled Cheese Sandwiches		Doughnuts	
	Peanut Or Other Nuts Or Seeds			Macaroni And Cheese		Cake, Cupcakes, Tasty Cake, Ho-Ho’s, Twinkies, Etc.	
				Refried Beans Or Bean Burritos		Pie Or Turnovers	

Table 3-2 Categorization of beverage items in Block Kids Food Questionnaire based on presumed cariogenic potential of beverages

Category Description	Beverages with High Presumed Cariogenicity	Beverages with Moderate Cariogenicity	Beverages with Low Cariogenicity
Beverage Variables	Sugared soda pop, Kool-aide or Gatorade, Sunny Delight, Hi-C, Hawaiian Punch or Ocean Spray	100% Juice	Milk

Area-Under-the-Curve Estimates

The area-under-the-curve estimates were used in the present analyses. Area-under-the-curve (AUC) is a method for summarizing continuous variables longitudinally using multiple points at different times across an observation period. For variables like fluoride intake and beverage consumption, the trapezoidal rule for AUC uses period-specific intakes to determine a weighted average of intake over a larger observation period. Period-specific intakes of fluoride and beverages were used to determine a weighted average of intake over the entire period using the trapezoidal rule for AUC (Levy et al, 2009).

For variables such as topical fluoride application, dental visit and mouthrinse use the AUC values were recorded as the proportion of 6-month periods with positive responses and the values ranged between zero and one. For instance, if a given child had a value of 0.6 for the variable dental visit averaged using AUC, it meant that the child reported of having dental visit for 0.6 of all the reported 6-month periods with visits. Also, if the AUC mouthrinse use had a value of 0.3 for a child, it meant that the child responded to using mouthrinse positively for 30% of the reported 6-month periods.

Similarly, for a child with a value of 0.5 for topical fluoride application, it meant that the child had a positive response for having topical fluoride application for 50% of all the reported 6 month periods. The AUC estimates were calculated for those who met the inclusion criteria.

Offset Value of the Interval

The use of an offset-variable allows the observational units to differ across observations, for instance, when the dental examinations to assess caries increments were conducted across different time periods, the interval between exams had to be adjusted to a common denominator by using the offset variable. In the model, the offset variable appeared as a covariate with its parameter restricted to one. The offset variable can be used in SAS code by inserting the term offset in the input dataset and is labeled “offset”.

Research Questions

I. *Demographic variables*

1. What is the association between sex and net cavitated caries incidence and increments among IFS adolescents?
2. What is the association between baseline age and net cavitated caries incidence and increments among IFS adolescents?
3. What is the association between socioeconomic status and net cavitated caries incidence and increments among IFS adolescents?

II. *Oral Hygiene variables*

4. What is the effect of greater daily tooth brushing frequency on net cavitated caries incidence and increments among IFS adolescents?

5. What is the effect of greater tooth brushing duration on net cavitated caries incidence and increments among IFS adolescents?

III. Fluoride and Dental Visit variables

6. What is the effect of greater composite water fluoride level on net cavitated caries incidence and increments among IFS adolescents?
7. What is the effect of greater daily fluoride intake from water on net cavitated caries incidence and increments among IFS adolescents?
8. What is the effect of greater daily fluoride intake from combined sources (water, dentifrice, other beverages and selected foods) on net cavitated caries incidence and increments among IFS adolescents?
9. What is the effect of use of any fluoride mouthrinse on net cavitated caries incidence and increments among IFS adolescents?
10. What is the effect of greater proportion of periods with topical fluoride applications on net cavitated caries incidence and increments among IFS adolescents?
11. What is the effect of greater proportion of periods with dental visits on net cavitated caries incidence and increments among IFS adolescents?

IV. Beverage Variables (IFS and Block)

12. What are the effects of greater frequency of intake (servings/week) of different categories of beverages on net cavitated caries incidence and increments among IFS adolescents, as determined using IFS questionnaires?
    i. Sugared beverages (i.e., sugared juice drinks, sugared sports drinks, sugared energy drinks, soda pop with sugar, sugared powdered beverages, sugared

fitness waters, sugared protein drinks, sugared tea and coffee and sugared alcohol)

ii. 100% juice

iii. Milk

iv. Sugar-free beverages (i.e., 100% juice without added sugars, along with juice drinks without added or natural sugars, sports drinks without added or natural sugars, energy drinks without added or natural sugars, soda without added or natural sugars, powdered beverages without added or natural sugars, fitness waters without added or natural sugars, protein drinks without added or natural sugars, and tea and coffee without added or natural sugars, respectively, and excluding water by itself).

13. What are the effects of greater frequency (days/week) of intakes of different categories of beverages on net cavitated caries incidence and increments among IFS adolescents, as determined using Block Kids Food Questionnaire?

    i. Sugared beverages **(**Sugared Soda-pop, Kool-aid, Gatorade, Sunny Delight, Hi-C, Hawaiian Punch or Ocean Spray)

    ii. 100% Juice (real orange juice and other real fruit juices)

    iii. Milk

V. Sealants variables

14. What is the effect of baseline presence of sealants (partially or fully retained) on net cavitated caries incidence and increments among IFS adolescents?

15. What is the effect of baseline presence of greater number of sealants on net cavitated caries incidence and increments among IFS adolescents?

VI. *Previous Caries Incidence*

16. What is the effect of positive net cavitated caries incidence from 9 to 13 years on net cavitated caries incidence and increments among IFS adolescents?
17. What is the effect of greater positive net cavitated caries increment count from 9 to 13 years on net cavitated caries incidence and increments among IFS adolescents?

VII. *Block Kids Food Questionnaire data on dietary solids*

18. What are the effects of greater frequency of intakes (days /week) of different categories of solid foods on net cavitated caries incidence and increments among IFS adolescents?
    - i. Low Presumed Cariogenicity Predominant in Protein and Fat Content,
    - ii. Low Presumed Cariogenicity Predominant in Fiber and Low Natural Sugar Content,
    - iii. Moderate Presumed Cariogenicity Predominant in Natural Sugar Content,
    - iv. Moderate Presumed Cariogenicity Predominant in Starch and Protein Content,
    - v. Moderate Presumed Cariogenicity Predominant in Starch Content,
    - vi. High Presumed Cariogenicity Predominant in Both Sugar and Starch Content, and
    - vii. High Presumed Cariogenicity Predominant in Sugar Content,
19. What are the effects of greater frequency of consumption of combined category of solid foods as obtained from Block questionnaire, on net cavitated caries incidence and increments among IFS adolescents?
    - i. Low presumed cariogenicity categories combined (i & ii from 18)

ii. Moderate presumed cariogenicity categories combined (iii, iv, v from 18.)

iii. High presumed cariogenicity categories combined (vi & vii from 18).

Operational Definitions

A. Dependent variables

1. Net cavitated caries incidence: Net cavitated caries incidence was reported as a dichotomous variable (Yes/No) for having any person level positive net cavitated caries increment (1+) vs. not having any person level positive net cavitated caries increment (≤ 0).
2. Net cavitated caries increment count: Net cavitated caries increment count ($D_{2\text{-}3}FS$) were defined as the net number of tooth surfaces with net cavitated caries increment. This was defined as the positive increment (new $D_{2\text{-}3}FS$) minus negative increment (reversals).

B. Independent Variables

I. Demographic variables

1. Sex: was defined as male or female. (Category= Male/Female)
2. Baseline age: was defined as age in decimal years at the time of age 13 exam.
3. Follow-up age: was defined as age in decimal years at the time of age 17 exam.
4. Interval: was defined as the difference in decimal years between initial and follow-up dental exams. The range of the interval was limited to 3.0 to 5.0 years.
5. Family income: Subjects were classified by family income into following categories: 1) less than $20,000 2) $20,000-$39,999 3) $40,000-$59,999 4) $60,000-79,999 and 5) $80,000 or more, as reported by parents in the IFS demographic questionnaire 2007(Unit= Income Category).

6. Maternal education: Maternal education was reported by parents in the 2007 demographic questionnaire, and the sample was classified into six categories based on the level of maternal education as follows: 1) some high school 2) high school diploma or GED 3) some college 4) two year college degree, technical or degree from beauty school 5) four year college degree and 6) post-graduate or professional degree (Unit= Maternal Education Category).
7. Socioeconomic status (SES): It was defined using maternal education and family income and was divided into three categories of low, middle and high SES (Unit= Category of SES).
    - i. Low SES: Subjects were considered to have low socioeconomic status under two conditions: when their family income was less than $39,999 irrespective of their mother's education level and when the subject's family income was $40,000 to $59,999 and their mother had education level up to some college or less.
    - ii. Middle SES: Subjects were considered to have middle socioeconomic status under two conditions: when their family income was $40,000-$59,999 and their mother had a two-year college degree, technical beauty school or more, and when the family income was $60,000-$79,999 and maternal education was equivalent to some college or less.
    - iii. High SES: Subjects were considered to have high socioeconomic status under two conditions: when their family income was $60,000-$79,999 and mother's education was two-year college degree/technical beauty school or more and when family income was $80,000, irrespective of mother's education.

II. Oral Hygiene Variables

8. Daily brushing frequency: The responses obtained from age 13.0 to 17.5 year IFS questionnaires on daily toothbrushing frequency were averaged using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was number of brushing events/day (range= 0.50-3.2).

9. Duration of brushing: Duration of brushing was defined as the time in minutes subjects brushed their teeth each time they brushed. The responses from the semiannual 13.0 to 17.5 year IFS questionnaires were averaged using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was minutes/brushing (range= 0.32-7.22).

III. Fluoride and Dental Visit Variables

10. Composite Water Fluoride Level: Period-specific average fluoride levels of water sources were defined as the average derived from concentration of fluoride in each of the major water sources weighted by volume consumed from each source determined from documentation of fluoride levels in public water supplies and individual assays of filtered, bottled or well water. The responses from 13.0 to 17.5 year IFS questionnaires were averaged using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was ppm of fluoride (range= 0.11-2.15).

11. Daily fluoride intake from water: Fluoride intake from water was defined as the sum of the products of daily amounts of water intake (L/day) and average concentrations of fluoride in each of the major water sources (in ppm). The responses from 13.0 to 17.5 year IFS questionnaires were averaged using area-

under-the-curve (AUC) to get a continuous variable. The unit of measurement was milligrams of fluoride /day (range = 0.01-2.04).

12. Daily fluoride intake from combined sources: Daily fluoride intake from combined sources was defined as total daily intake of fluoride in milligrams from dentifrice, water by itself, other beverages and selected foods with substantial amounts of added water (e.g., soup, rice, ramen noodles, etc.) The responses from 13.0 to 17.5 year IFS questionnaires were averaged using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was milligrams of fluoride/day (range = 0.24-2.95).

13. Use of fluoride mouthrinse (Y/N): Use of fluoride mouthrinse (yes/no) for each response from age 13.0 to age 17.5 years (at home or at school) was determined from the semi-annual IFS questionnaires as the proportion of periods a child responded to having any fluoride mouthrinse use. The responses from the 13.0 to 17.5 year IFS questionnaires were averaged using area-under-the-curve (AUC) which was used to define an overall binary variable for any vs. no use throughout the observation period. (Category= Y/N)

14. Proportion of Periods with topical fluoride application: Receiving topical fluoride application was defined as the proportion of all reported 6-month periods a child responded positively to having topical fluoride treatment on the age 13.0 to age 17.5 year questionnaires. The responses from the age 13.0 to age 17.5 year questionnaires were averaged using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was proportion of 6-month periods (range= 0-1).

15. Proportion of Periods with Dental Visit: Receiving dental visit was defined as the proportion of all reported 6-month periods that the subject responded positively to having dental visits on the age 13.0 to age 17.5 year IFS questionnaires. The responses from the age 13.0 to age 17.5 year questionnaires were averaged using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was proportion of 6-month periods (range= 0-1).

IV. Beverage variables (IFS)

16. Frequency of sugared beverage consumption: Frequency of intake of added sugar beverages was defined as intake of beverage in servings per week of all beverages containing added sugars (i.e., sugared juice drinks, sugared sports drinks, sugared energy drinks, soda pop with sugar, sugared powdered beverages, sugared fitness waters, sugared protein drinks, sugared tea and coffee and sugared alcohol), as determined from responses to the age 13.0 to age 17.5 year semi-annual IFS questionnaires. The responses were averaged over the entire period using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0-28.05).

17. Frequency 100% juice consumption: Frequency of intake of 100% juice was defined as intake of 100% juice of all juices containing natural sugar and no added sugar in servings/week, as determined from responses to the age 13.0 to age 17.5 year semi-annual IFS questionnaires. The responses were averaged over the entire period using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was servings/week (range = 0-15.70).

18. Frequency of milk consumption: Frequency of intake of milk was defined as intake of all milk in servings per week, as determined from responses to the age 13.0 to age 17.5 year semi-annual IFS questionnaires. The responses were averaged over the entire period using area-under-the-curve to get a continuous variable (AUC). The unit of measurement was servings/week (range = 0-29.34).

19. Frequency of sugar-free beverage (i.e., beverages without added sugars, including 100% juice but no water by itself) consumption: It was defined as intake in servings per week of all beverages containing 100% juice, beverages without added or natural sugar (i.e., 100% juice without added sugars, along with juice drinks without added or natural sugars, sports drinks without added or natural sugars, energy drinks without added or natural sugar, soda without added or natural sugars, powdered beverages without added or natural sugars, fitness waters without added or natural sugars, protein drinks without added or natural sugars, tea and coffee without added or natural sugars , respectively) and excluding water by itself as determined from responses from the age 13.0 to age 17.5 year semi-annual IFS questionnaires. The responses were averaged over the entire period using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was servings/week (range = 0- 18.20).

V. Sealant variables

20. Presence of sealants: Subjects were reported to have positive sealant status if they were observed to have one or more partially or fully retained sealant on specific zones of the surface at the age 13 examination. The unit of measurement was Y/N (range = 0, 1).

21. Number of surface zones with sealants was defined as the number of surface zones with sealants as determined from the age 13 dental examination. The unit of measurement was discrete surfaces with sealants (range = 0, 18).

VI. Previous Caries Incidence variables

22. Cavitated caries incidence from the age 9 to 13: It was defined as presence of positive net cavitated caries ($D_{2\text{-}3}FS$) in permanent teeth as observed from age 9 to age 13 dental examination. The unit of measurement was Y/N for caries incidence. (range = 0, 1)

23. Cavitated caries increment from age 9 to age 13 years: It was defined as number of net cavitated caries ($D_{2\text{-}3}FS$) increment count in permanent teeth, as observed from age 9 to age 13 dental examination. The unit of measurement was discrete count. (range=0-13)

VII. Block Kids Food Questionnaire data on dietary solids

24. Frequency of consumption of low presumed cariogenicity foods predominant in protein and fat content: This variable was defined as intake of solid foods predominant in protein and fat in days/week as determined by the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17 year Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range= 2.45-24.42).

25. Frequency of consumption of low presumed cariogenicity foods predominant in fiber and natural sugar content: This variable was defined as intake of solid foods predominant in fiber along with low natural sugar in days/week as determined by

the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17 year Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0-22.13).

26. Frequency of consumption of moderate presumed cariogenicity foods predominant in natural sugar content: This variable was defined as intake of solid foods predominant in natural sugar in days/week as determined by the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17 year Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0-14.55).

27. Frequency of consumption of moderate presumed cariogenicity foods predominant in starch and protein content: This variable was defined as intake of solid foods predominant in starch and protein in days/week as determined by the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17 year Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 2.24-30.88).

28. Frequency of consumption of moderate presumed cariogenicity foods predominant in starch content: This variable was defined as intake of solid foods predominant in starch in days/week as determined by the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17.0 year Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 4.76-27.37).

29. Frequency of consumption of high presumed cariogenicity foods predominant in both sugar and starch content: This variable was defined as intake of solid foods predominant in starch and sugar in days/week as determined by the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17.0 year Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 2.76-38.37).

30. Frequency of consumption of high presumed cariogenicity foods predominant in added sugar content: This variable was defined as intake of solid foods predominant in added sugar in days/week as determined by the Block Kids Food Questionnaire. The responses were then averaged from age 13.0 to age 17.0 Block questionnaire using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0.50-15.16).

31. Frequency of consumption of foods predominant in low presumed cariogenicity combined: This variable was defined as the sum of number of days per week a child consumed food items that were in the combined category of low presumed cariogenicity derived by adding the numbers of days per week child consumed foods predominant in protein and fat and, low natural sugar and fiber, as determined from the Block Kids Food Questionnaire, to get a continuous variable. The unit of measurement was days/week (range = 4.12-34.88).

32. Frequency of consumption of foods predominant in moderate presumed cariogenicity combined: This variable was defined as the sum of number of days per week a child consumed food items that were in the combined category of moderate presumed

cariogenicity, derived by adding the numbers of days per week a child consumed foods predominant in natural sugars and foods predominant in starch and protein, and foods predominant in starch, as determined from the Block Kids Food Questionnaire, to get a continuous variable. The unit of measurement was days/week (range = 9.85-70.56).

33. Frequency of consumption of foods predominant in high presumed cariogenicity combined: This variable was defined as the sum of number of days per week a child consumed food items that were in the combined category of high presumed cariogenicity, derived by adding the numbers of days per week a child consumed foods predominant in starch and sugar; and foods predominant in added sugar as determined from the Block Kids Food Questionnaire, to get a continuous variable. The unit of measurement was days/week (range = 3.75-52.19).

VIII. Block Kids Food Questionnaire Data on Beverages

34. Frequency of consumption of sugared beverages: Frequency of intake was defined as intake of beverages containing added sugar (e.g., Sugared Soda pop, Kool-aid or Gatorade, Sunny Delight, Hi-C, Hawaiian Punch or Ocean Spray) in days per week, as determined by responses from Block Kids Food Questionnaires. The responses were averaged from 13.0, 15.0 and 17.0 year questionnaires using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0-14.48).
35. Frequency of consumption of 100% juice: Frequency of 100% juice intake was defined as intake of 100% juice in days/week, as determined by responses from

Block Kids Food Questionnaires. The responses were averaged from age 13.0, 15 and 17.0 year Block Kids Food Questionnaires using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0-9.49).

36. Frequency of consumption of milk: Frequency of milk intake was defined as intake of milk in number of days/week (including number for breakfast, lunch, and dinner) as determined by responses from Block Kids Food Questionnaires. The responses were averaged from age 13.0, 15 and 17.0 year Block Kids Food Questionnaires using area-under-the-curve (AUC) to get a continuous variable. The unit of measurement was days/week (range = 0-21).

Specific Hypotheses

The given section describes the hypotheses relating for different IFS and Block variables.

I. Demographic variables:

1. Net cavitated caries incidence and increment count, respectively, from the age 13 to 17 dental examinations will be higher in girls than in boys.
2. Adolescents who were of low socioeconomic status category will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 when compared to those with high socioeconomic status.
3. Adolescents who were of middle socioeconomic status category will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 when compared to those with high socioeconomic status.
4. Adolescents with higher baseline age will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with lower baseline age.

II. *Oral Hygiene Variables*

5. Adolescents who brushed their teeth more times per day from age 13.0 to 17.5 years will have lower net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents who brushed their teeth fewer times per day.
6. Adolescents who brushed their teeth for a longer time per brushing from age 13.0 to 17.5 years will have lower net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents who brushed their teeth for shorter periods of time per brushing.

III. *Fluoride and Dental Visit Variables*

7. Adolescents with higher composite water fluoride levels from all water sources from age 13.0 to 17.5 years will have lower net cavitated caries incidence and increment count, respectively, from the 13 to 17, than adolescents who have lower composite water fluoride levels.
8. Adolescents with higher daily fluoride intakes from all water sources from 13.0 to 17.5 years will have lower net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents who have lower daily fluoride intakes from all water sources.
9. Adolescents with higher daily intakes of fluoride from combined sources from 13.0 to 17.5 years will have lower net net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents who have lower daily intakes of fluoride from combined sources.
10. Adolescents who have any fluoride mouthrinse use (AUC) from age 13.0 to 17.5 years will have lower net cavitated caries incidence and increment count,

respectively, from age 13 to 17 than those who have no fluoride mouthrinse use (AUC).

11. Adolescents who had greater proportion of periods with in-office fluoride application (AUC) from age 13.0 to 17.5 will have lower net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents who had lower proportion of periods with in-office topical fluoride application (AUC).
12. Adolescents who had a greater proportion of periods with dental visits (AUC) from age 13.0 to 17.5 will have lower net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents who had a lower proportion of periods with dental visits (AUC).

IV. Beverage Variables (IFS)

13. Adolescents with more frequent consumption of sugared beverages from age 13 to 17.5 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents who have lower frequency of intakes of sugared beverages.
14. Adolescents with more frequent consumption of beverages classified as 100% juice from age 13 to 17.5 years, will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with less frequent consumption of 100% juice.
15. Adolescents with less frequent consumption of all milk from age 13 to 17.5 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with more frequent consumption of milk.

16. Adolescents with less frequent consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice but no water by itself) from age 13 to 17.5 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with more frequent consumption of sugar-free (i.e., beverages without added sugar, including 100% juice but not water by itself).

V. *Sealant Variables*

17. Adolescents without sealants at the time of baseline dental examination will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 , than adolescents with no sealants.

18. Adolescents with a lower number of sealants at the time of baseline dental exams will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 , than adolescents with a higher number of sealants.

VI. *Previous Caries Incidence Variables*

19. Adolescents with net cavitated caries incidence from age 9 to age 13 years in the permanent teeth will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents who have no net cavitated caries incidence from age 9 to 13 dental exams.

20. Adolescents with greater net cavitated caries increment count in the permanent teeth from age 9 to age 13 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents who have lower net cavitated caries increments from age 9 to 13 dental exams.

VII. Block Kids Food Questionnaire Data on Dietary Solids

21. Adolescents with lower frequency of consumption of foods predominant in protein and fat from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with higher frequency of such intakes.
22. Adolescents with lower frequency of consumption of foods predominant in fiber and low natural sugar from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with higher frequency of such intakes.
23. Adolescents with lower frequency of consumption of foods predominant in high natural sugars from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with higher frequency of such intakes.
24. Adolescents with higher frequency of consumption of foods predominant in starch and protein from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with lower frequency of such intakes.
25. Adolescents with higher frequency of consumption of foods predominant in starch from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with lower frequency of such intakes.
26. Adolescents with higher frequency of consumption of foods predominant in starch and sugar from ages 13.0 to 17.0 years will have higher net cavitated caries incidence

and increment count, respectively, from age 13 to 17, than adolescents with lower frequency of such intakes.

27. Adolescents with higher frequency of consumption of foods predominant in added sugar from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with lower frequency of such intakes.
28. Adolescents with lower frequency of consumption of foods categorized with low presumed cariogenicity from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with higher frequency of such intakes.
29. Adolescents with higher frequency of consumption of foods categorized with moderate presumed cariogenicity from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with lower frequency of such intakes.
30. Adolescents with higher frequency of consumption of foods categorized with high presumed cariogenicity from ages 13.0 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17, than adolescents with lower frequency of such intakes.

VIII. Block Kids Food Questionnaire Data on Beverages

31. Adolescents with higher frequency of intake of sugared beverages from age 13 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with lower frequency of such intakes.

32. Adolescents with higher frequency of intake of beverages classified as 100% juice from age 13 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with lower frequency of such intakes.
33. Adolescents with lower frequency of intake of all milk from age 13 to 17.0 years will have higher net cavitated caries incidence and increment count, respectively, from age 13 to 17 than adolescents with higher frequency of such intakes.

Statistical Analyses

Univariate Analyses

Univariate descriptive statistics measures were determined for the independent and dependent variables. Measures such as mean, median, range and percentile values were calculated for continuous variables. For the dichotomous variables, frequency and cumulative frequency measures were calculated. All the above calculations were done to summarize the distributions of the data.

For all the procedures, SAS (9.3) software was used with codes such as proc freq, proc means (for percentiles), respectively.

Bivariate Analyses

Pearson and Spearman correlations were assessed to test the linear and rank order relationships among pairs of independent variables, respectively. Statistically significant correlations were considered as those that had $p<0.05$. The correlation was considered strong, moderate and weak when the results were statistically significant and the magnitude of correlation ranged from 0.7 to 1, 0.5 to 0.69 and less than 0.5, respectively.

Since most of the independent variables were non normal in nature, the results from spearman analyses were considered for these analyses.

Modelling approaches

In order to maintain consistency across parts of the analyses, regression analyses were used for both bivariate and multivariable procedures. Upon primary evaluation analyses of the distributions, negative binomial models and generalized linear models for binary outcomes based on log and logit link functions, respectively, were considered most suitable for the analyses (the evaluations were done before conducting the bivariate analyses and hence were included here). The generalized linear models for binary outcomes approach were used when the response variable was dichotomous, whereas negative binomial analyses were used when the dependent variable was count data. Poisson regression was considered as a possible alternative, if needed, in addition to negative binomial.

The primary evaluations of the distribution of $D_{2\text{-}3}$FS increment were done by comparing negative binomial regression for count with or without zero inflation by using AIC values. On comparing the AIC values, the distribution with the lowest AIC was selected for conducting subsequent analyses. The model distribution with lowest AIC and log-likelihood values was used and differences in log-likelihood of the models were considered to determine the functional form that was most appropriate. A log likelihood difference of two or more was used to assess best fit of the model so that the model with the smaller likelihood ratio was considered to have better fit.

Bivariate analyses were done to assess relationships between net cavitated caries increment and each independent variable separately. The screening level criterion in each bivariate analyses for subsequent inclusion in the multivariable analyses was $p<0.15$.

Bivariate Analyses

For Binary Outcome: Logistic Regression

Since the Bernoulli or Binomial distribution was the underlying distribution for the binary outcome data, logistic regression bivariate analyses were conducted. The details of the algorithm can be found in Appendix K. The “PROC GENMOD” procedure was used for the logistic regression analyses. Other commands used were the DESCENDING and CLASS command. The DESCENDING modeled the probability of positive net cavitated caries incidence, i.e., when the value of caries incidence was ‘1’. The CLASS command was used for categorical and dichotomous variables. Details of these and other commands are in Appendix K. The odds ratio was used as a measure of association for these analyses and was obtained by exponentiating the values of the beta coefficients for the variables, as explained in Appendix K. The odds ratio defined the odds of net cavitated caries incidence among the exposed vs. the odds of net cavitated caries incidence among the non-exposed.

For Count Outcome: Negative Binomial Regression

Since the outcomes were “discrete counts” with greater variance, the negative binomial regression was used as an ideal approach to account for the over-dispersion. The details of the algorithm have been described in Appendix K. The SAS (9.3) procedure used in this case for negative binomial regression analyses of count outcomes was GENMOD. The log offset was used to account for differences in the interval between exams among the subjects. The incidence rate ratio (IRR) was the measure of association used for these analyses. Each IRR was obtained by exponentiating the beta coefficient for the selected variable. The IRR defined the surface level incidence rate of net cavitated caries increments among the subjects included in the present study.

Alternative Approaches

Other tests that could be used alternatively to assess the relationships between net cavitated caries incidence and independent variables are summarized below.

1. Dichotomous independent variable (sex, fluoride mouthrinse use, net cavitated caries incidence from 9 to 13 and presence of sealants) –could use the Fischer's exact test.
2. Categorical independent variables (socioeconomic status and sex and presence of sealants, net cavitated caries increment count from 9 to 13), net cavitated caries increment count from 9 to 13) –could use the Cochran Armitage Trend Test.
3. Continuous independent variable (oral hygiene and fluoride variables, beverage and solid food variables including beverages and solid food categories, and dental visit variables) –could use the Kolmogorov Smirnov Test.

Other tests that could be used alternatively to assess relationships between net cavitated caries increment count and independent variables are summarized next.

1. Dichotomous independent variables (sex, fluoride mouthrinse use, net cavitated caries incidence from 9 to 13 and presence of sealants) –could use the Wilcoxon Rank Sum Test.

2. Categorical independent variables (socioeconomic status and sex, presence of sealants) and continuous independent variables (oral hygiene and fluoride variables, beverage and solid food variables, including combined categories of solid foods, and dental visit variables) –could use the Spearman correlation.

Multivariable analyses

Two separate multivariable regression analyses were conducted in this study. Multivariable logistic regression analyses were conducted relating net cavitated caries incidence (yes/no) to independent variables, whereas multivariable negative binomial regression analyses were conducted relating net cavitated caries increment count to independent variables. The model reduction was done using a backward step-wise algorithm for both logistic and negative binomial regression analyses. In order to keep consistency of methodology between bivariate and multivariable analyses, the GENMOD procedure was used for both regression analyses. Because GENMOD cannot be used to generate an automated backward elimination procedure, the elimination was done manually. The variables included for multivariable logistic regression and multivariable negative binomial regression analyses were those that had $p < 0.15$ in the bivariate analyses. In cases when two or more variables met this inclusion criterion, collinearity and statistical significance of the variables was considered so that variables that had the strongest relationship, as determined by the smallest p-value, were chosen among strongly correlated variables to be considered in the trimmed model. The first step in the backward elimination was to include all the variables in the model that met the criteria for inclusion and collinearity and remove the variable that had the highest p-value. After removing the variable with highest p-value, the model was refit without the variable and the procedure was repeated. This procedure was repeated until all the variables in the regression model had a p-value less than or equal to the alpha stay value ($\alpha_{stay\ =\ 0.05}$).

Model Reduction and Model Fitting

Model reduction is sometimes needed for variables that are collinear and to assess over- fitting of the models. Two-way interactions can be considered after model reduction and gaining the best fit**.**

Interaction in Multivariable Modelling

The details of the interaction in multivariable modelling along with the equations for mean function of linear predictor for logistic and negative binomial model are presented in Appendix L. Two-way interaction effects were considered only for the variables significant in the main effects model. One at a time, possible two-way interaction effects were tested on top of the main effects model, for both logistic and negative binomial regression analyses. Interactions were considered significant if the associated p-value was less than 0.05. After this, three-way interactions were tested for significance at p<0.05, when necessary. In order to acquire final models for negative binomial regression and logistic regression analyses, the significant two-way and three-way interactions were tested simultaneously in a single model, using backward step-wise elimination. Any variables or interactions not significant at p<0.05 were sequentially eliminated following the backward elimination procedure explained earlier. The graph presenting the significant interaction in the final logistic regression model showed the probability of the net cavitated caries incidence from 13 to 17, whereas the graph presenting the significant interaction in the negative binomial regression model showed count estimates for net cavitated caries increment from 13 to 17 for the variables part of the significant interaction. The process of deriving probabilities and count estimates for significant two-way interaction effects observed in logistic regression and negative binomial regression modeling, respectively, are presented in Appendix L.

CHAPTER 4

RESULTS

Descriptive Statistics: Dependent Variables

Table 4-1 summarizes the frequency distribution of person-level cavitated caries experience at age 13 ($D_{2-3}FS$). Of the 303 subjects, 64.4% subjects were caries-free and 35.6% had some caries experience at age 13 dental examinations, including 29.4% with 1-5 affected surfaces and 6.3% with 6 or more affected surfaces.

Table 4-1 Frequency distribution of net cavitated caries experience at age 13 dental examination

$D_{2-3}FS$ Age 13 Caries	Frequency	Cumulative Frequency	Percent	Cumulative Percent
0	195	195	64.36	64.36
1-5	89	284	29.37	93.73
6-10	16	300	5.28	99.01
11-15	3	303	0.99	100.00

Table 4-2 summarizes the frequency distribution of person-level cavitated caries experience at age 17 ($D_{2-3}FS$). Of the 303 subjects, 37.6% of subjects were caries-free and 62.4% had some caries experience at age 17 dental examinations, including 39.3% with 1-5 affected surfaces and 23.1% with six or more affected surfaces.

Table 4-3 summarizes the frequency distribution of person-level net cavitated caries increment ($D_{2-3}FS$) between age 13 and 17 dental exams. Of the 303 subjects, 5.94% had negative net cavitated caries increments, 38.94% subjects had no net cavitated caries increment and 55.12% had a positive net cavitated caries increment from age 13 to age 17 dental exams.

Table 4-2 Frequency distribution of net cavitated caries experience at age 17

$D_{2-3}FS$ Age 17 Caries	Frequency	Cumulative frequency	Percent	Cumulative Percent
0	114	114	37.62	37.62
1-5	119	233	39.27	76.90
6-10	38	271	12.54	89.44
11-15	25	296	8.25	97.69
16-20	2	298	0.66	98.35
21-25	4	302	1.32	99.67
36-40	1	303	0.33	100.00

Table 4-4 collapses the results in Table 4-3 for net cavitated caries increments into three broad categories:, i.e., negative, none and positive person level net cavitated caries increment between age 13 and age 17 dental examination which are 5.94%, 38.94% and 55.12%, respectively.

Table 4-5 summarizes the frequency distributions of net cavitated caries experience at age 13 years, net cavitated caries experience at age 17 years and the net cavitated caries increment observed between age 13 and age 17 dental examinations. The mean caries prevalence ($D_{2-3}FS$) was 1.2 surfaces at age 13 and increased considerably to 3.5 surfaces at age 17. The mean net cavitated caries increment was 2.4.

Table 4-3 Frequency distribution of net cavitated caries increment observed between age 13 and age 17 dental examination

Net Cavitated Caries Increment	Frequency	Cumulative Frequency	Percent	Cumulative Percent
-1 to -3	18	18	5.94	5.94
0	118	136	38.94	44.88
1-5	118	254	38.94	83.82
6-10	37	291	12.21	96.04
11-15	8	299	2.64	98.68
16-20	2	301	0.66	99.34
21-25	1	302	0.33	99.67
26-30	1	303	0.33	100.00

Table 4-4 Frequency distribution of net cavitated caries increment observed between age 13 and age 17 dental examination with collapsed categories

Person Level Net Cavitated Caries Increment	Frequency	Cumulative Frequency	Percent	Cumulative percent
Negative	18	18	5.94	5.94
Zero	118	136	38.94	44.88
Positive	167	303	55.12	100

Table 4-5 Frequency distribution of caries experience at age 13 (wave 4), age 17 (wave 6) and net $D_{2-3}FS$ increment from age 13 to age 17

Caries $D_{2-3}FS$	Min	1	5	10	25	50	75	90	95	99	Max	Mean	SD
Age 13 Total	0	0	0	0	0	0	2	4	7	10	14	1.20	2.4
Age 17 Total	0	0	0	0	0	1	5	11	13	22	40	3.50	5.1
Net Increment	-3	-2	-1	0	0	1	4	7	9	16	29	2.31	3.8

Inter-Examiner Reliability

Inter-examiner reliability was assessed using person level agreement and simple kappa. The reliability between examiners for person level agreement scores on some vs. no cavitated caries experience for age 13 and age 17 were 86% and 78%, respectively. The reliability between examiners for simple kappa scores on some vs no cavitated caries experience for age 13 and age 17 were 0.59 and 0.58, respectively.

Descriptive Statistics: IFS Variables

Table 4-6 summarizes the frequency distribution of subjects based on sex. Approximately 47% of the subjects were males and 53% of subjects were female.

Table 4-6 Frequency distribution of subjects by sex

Gender	Frequency	Percentage
Male	142	46.86
Female	161	53.14

Table 4-7 summarizes the frequency distribution of subjects based on categories of family income. Subjects were divided into five categories of family incomes in 2007. Three percent were less than $20,000, 11% were $20,000-$39,000, 17% were $40,000-$59,999, 23% were $60,000-79,999 and 46% were $80,000 or more.

Table 4-7 Frequency distribution of subjects by category of family income

Family Income	Frequency	Percentage	Cumulative Percentage
Less than $20,000	8	2.75	2.75
$20,000-$39,999	33	11.34	14.09
$40,000-$59,999	50	17.18	31.27
$60,000-79,999	67	23.02	54.30
$80,000 or More	133	45.70	100.00

Table 4-8 summarizes the frequency distribution of subjects based on six maternal education categories. About 1% had some high school, 9% had a high school diploma or GED, 17% had some college, 25% had a two-year college degree or technical/beauty school education, 28% had four-year college degree and 21% had a post-graduate or professional degree. In addition, seven subjects reported no information on maternal education.

Table 4-9 summarizes the frequency distribution of subjects based on three socioeconomic status categories. About 21% of subjects were from low socioeconomic status. The largest number of subjects had high socioeconomic status (63%) and almost 16% of subjects were from middle socioeconomic status. In addition, thirteen subjects reported no information on socioeconomic status.

Table 4-10 summarizes the frequency distribution of subjects based on presence of sealants at the baseline dental examination. About 77% had one or more surface zones with sealants and 23% of subjects were without any sealants at baseline.

Table 4-11 summarizes the frequency distributions of number of surface zones with sealants. About 54% of the subjects had at least four or more surface zones with fully or partially retained sealants and 23% of the subjects had one, two or three surfaces zones with fully or partially retained sealants. The median (mean) number of surface zones with sealants was 4 (4.36) surfaces.

Table 4-8 Frequency distribution of subjects by maternal education categories

Maternal Education	Frequency	Percentage	Cumulative Percentage
Some High School	2	0.68	0.68
High School Diploma + GED	28	9.46	10.14
Some College	50	16.89	27.03
Two-Year College Degree, Technical/Beauty School	74	25.00	52.03
Four-Year College Degree	82	27.70	79.73
Post-Graduate or Professional Degree	60	20.27	100.00

Table 4-9 Frequency distribution of subjects by socioeconomic status category at baseline

Socioeconomic Status Category	Frequency	Percentage	Cumulative Percentage
Low	60	20.69	20.69
Middle	47	16.21	36.90
High	183	63.10	100.00

Table 4-10 Frequency distribution of subjects by presence of sealants

Presence of Sealants#	Frequency	Percent
Present	232	76.57
Absent	71	23.43

Presence of sealants was defined as some surface zones with sealants (Y) vs. no surface zones with sealants (N)

Table 4-12 summarizes the frequency distribution of ages at the time of the age 13 and 17 dental examinations and the interval between exams. For the age 13 exams, 50% were aged 13.2 (mean=13.3) years or more, while for age 17 exams 50% were aged 17.5 years or more (mean=17.5). The median time interval between the age 13 and age 17 exams was 4.20 (mean=4.18) years, while the range of interval was 3-5 years.

Table 4-13 summarizes the frequency distribution of net cavitated caries increments observed from age 9 to age 13 dental examinations. About 70% of the subjects had no net cavitated caries increments. Among the 30% of subjects with positive increment, the average net cavitated caries increment from age 9 to 13 was 2 surfaces.

Table 4-14 summarizes the frequency distribution for daily brushing frequency (AUC) and duration of brushing (AUC). Fifty percent of the subjects brushed 1.79 times or more per day (mean = 1.64), while fifty percent repeatedly spent at least 1.06 minutes or more brushing (mean = 1.25).

Table 4-15 summarizes the frequency distribution of average composite water fluoride levels (AUC), daily fluoride intake from water (AUC), and daily fluoride intake from combined sources (AUC). The median composite water fluoride level (AUC) was 0.75 ppm (mean = 0.71). The median daily intake of fluoride from water (AUC) was 0.29 mg/day (mean = 0.39) and the median intake of fluoride from combined sources (AUC) was 0.79 mg/day (mean = 0.87).

Table 4-16 summarizes the frequency distribution of selected IFS questionnaire beverage variables for frequency of consumption. Median (mean) frequencies of consumption were 5.68 (6.97) for sugared beverage consumption (AUC) 1.18 (1.94) for

100% juice consumption (AUC), 8.64 (9.68) for milk consumption (AUC), and 2.62(3.37) for sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC).

Table 4-11 Frequency distribution of number of surface zones with sealants at age 13 dental examination

Variable	Min	1	5	10	25	50	75	90	95	99	Max	Mean	SD
Number of Surface Zones with Sealants	0.00	0.00	0.00	0.00	1.00	4.00	7.00	10.00	12.00	16.00	18.00	4.36	4.03

Table 4-12 Frequency distributions of ages at the time of the age 13 and 17 dental examinations, and interval between the dental examinations.

Age	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Age 13	12.4	12.7	12.8	12.9	13.0	13.2	13.6	14.0	14.2	14.4	14.9	13.3	0.4
Age 17	16.8	16.9	16.9	17.0	17.2	17.5	17.8	8.0	18.2	18.3	18.5	17.5	0.4
Interval	3.01	3.11	3.41	3.59	3.88	4.20	4.50	4.76	4.88	4.97	5.00	4.20	0.4

Table 4-13 Frequency distribution of net cavitated caries increment count from age 9 to 13

Parameter	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Age 9 to 13 Increment	-6	-2	-1	0	0	0	1	3	5	10	13	0.70	2.00

Table 4-14 Frequency distributions of daily brushing frequency (AUC) and duration of brushing (AUC)

Variables	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Daily Brushing Frequency (AUC)	0.50	0.55	0.88	0.98	1.22	1.79	2.00	2.10	2.23	2.69	3.20	1.64	0.50
Duration of Each Brushing (AUC)	0.32	0.41	0.53	0.59	0.80	1.06	1.58	2.06	2.40	3.10	7.22	1.25	0.73

Table 4-15 Frequency distributions of composite water fluoride level from all water sources, daily fluoride intake from water, and daily fluoride intake from combined sources (AUC)

Fluoride Variables	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Composite Water Fluoride Level (AUC)	0.11	0.13	0.24	0.30	0.46	0.75	0.92	1.05	1.11	1.39	2.15	0.71	0.29
Daily Fluoride Intake from Water (AUC)	0.01	0.03	0.07	0.09	0.15	0.29	0.50	0.86	1.00	1.83	2.04	0.39	0.35
Daily Fluoride Intake from Combined Sources (AUC)	0.24	0.25	0.32	0.39	0.53	0.79	1.10	1.46	1.76	2.33	2.95	0.87	0.46

Table 4-16 Frequency distributions of the frequencies of categories of beverage consumption as obtained from IFS questionnaire beverage variables (AUC)

Dietary Variables (IFS) (Servings/Week)	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Frequency of Sugared Beverage Consumption (AUC)	0.00	0.73	1.94	2.53	3.82	5.68	9.02	13.56	15.41	21.80	28.05	6.97	4.46
Frequency of 100% Juice Consumption (AUC)	0.00	0.00	0.00	0.00	0.28	1.18	2.91	4.94	6.59	8.47	15.70	1.94	2.20
Frequency of Milk Consumption (AUC)	0.00	0.00	1.58	2.88	5.38	8.64	13.03	17.92	21.29	25.76	29.34	9.68	5.96
Frequency of Sugar-Free Beverage Consumption (AUC)#	0.00	0.00	0.00	0.24	1.22	2.62	4.84	7.21	8.87	14.30	18.20	3.37	3.03

Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself

Table 4-17 summarizes the frequency distribution of proportion of periods with fluoride mouthrinse use (AUC). Sixty-one percent (61.39%) of the subjects did not use fluoride mouthrinse (AUC) during any of the reported 6-month periods. The mean proportion of 6-month periods (mean AUC) subjects reported using fluoride mouthrinse (AUC) was 0.12. Only one individual (0.33%) used fluoride mouthrinse during all reported 6-month periods.

Table 4-18 summarizes the frequency distribution of proportion of periods with topical fluoride application (AUC). Ninety-three percent (93.36%) of subjects reported having topical fluoride application during at least one 6-month period, and the mean proportion of periods (mean AUC) the subjects reported having a topical fluoride application (AUC) was 0.60. Approximately fifty-one percent (50.83%) of subjects reported having topical fluoride applications (AUC) for 63% or more of all the reported 6-month periods. Twenty-one percent (20.60%) reported having topical fluoride applications during all reported periods.

Table 4-19 summarizes the frequency distribution of proportion of periods with dental visits (AUC). Ninety-nine percent (98.68%) of subjects reported having a dental visit (AUC) during at least one 6-month period, and the mean proportion of 6-month periods (mean AUC) the subjects reported having a dental visit (AUC) was 0.80. Fifty percent of subjects reported having dental visits (AUC) at least 94% of the time, and 46% (46.20%) reported a visit to the dentist for all reporting periods.

Table 4-17 Frequency distribution of proportion of periods with fluoride mouthrinse use (AUC) (Y/N) as obtained from the IFS questionnaires

Variable (AUC)	Min	1	5	10	25	50	75	90	95	99	Max	Mean	SD
Proportion of Periods with fluoride Mouthrinse Use (AUC) (Y/N)	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.42	0.55	0.84	1.00	0.12	0.20

Table 4-18 Frequency distribution of proportion of periods with topical fluoride application (AUC) as obtained from the IFS questionnaires

Variable (AUC)	Min	1	5	10	25	50	75	90	95	99	Max	Mean	SD
Proportion of Periods with Topical Fluoride Application (AUC)	0.00	0.00	0.00	0.12	0.33	0.63	0.90	1.00	1.00	1.00	1.00	0.60	0.33

Table 4-19 Frequency distribution of proportion of periods with dental visits (AUC) as obtained from IFS questionnaires

Variable (AUC)	Min	1	5	10	25	50	75	90	95	99	Max	Mean	SD
Proportion of Periods with Dental Visits (AUC)	0.00	0.00	0.28	0.43	0.67	0.94	1.00	1.00	1.00	1.00	1.00	0.80	0.25

Descriptive Statistics: Block Variables

Table 4-20 summarizes the frequency distribution of subjects based on Block Kids Food Frequency questionnaire solid food variable categories. The unit for frequency of consumption for a given category of solid foods was days/week, for which the number of days could exceed seven days/week. In a given category with multiple solid food items, each specific food could be consumed to a maximum of 7 days in a week. Therefore, when the consumption of each of these food items was considered in number of days, a combined estimate of frequency of consumption could be greater than seven days per week for the entire category. This has been explained in detail in Chapter 3.

The median (mean) values for frequency of consumption (days/week) of foods predominant in fat and protein (AUC) were 9.06 (9.45), foods predominant in fiber and natural sugar (AUC) were 5.03 (5.55), foods predominant in high natural sugar (AUC) were 4.30 (4.85), foods predominant in starch and protein (AUC) were 8.66 (8.94), foods predominant in starch (AUC) were 10.97 (11.24), foods predominant in sugar and starch (AUC) were 10.64 (11.03), and foods predominant in added sugar (AUC) were 4.96 (5.31), respectively. Subjects most frequently consumed foods predominant in starch and starch and sugar, while they least frequently consumed foods predominant in high natural sugar. As explained earlier in Chapter 3, the unit for these combined categories of solid food variables was days/week and the frequency of each category could exceed 7 days/week. The frequency of intake of each combined category of solid foods was an aggregate measure of individual frequencies of solid food items in that category, so the combined frequency of the entire category of solid food items could exceed 7 days/week.

Table 4-20 Frequency distributions of frequency of intake of solid food categories (AUC) (days/week) as obtained from Block Kids Food Frequency questionnaire

Frequency of Consumption of Dietary Variables Solids	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Foods Predominant in Fat and Protein (AUC)*	2.45	3.40	4.32	5.28	6.90	9.06	11.43	14.25	15.80	19.75	24.42	9.45	3.61
Foods Predominant in Low Natural Sugar (AUC)*	0.00	0.50	1.02	1.66	3.00	5.03	7.63	9.89	12.07	17.74	22.13	5.55	3.60
Foods Predominant in High Natural Sugar (AUC)*	0.00	0.00	0.80	1.49	2.67	4.30	6.58	8.75	10.38	13.35	14.55	4.85	2.95
Foods Predominant in Starch and Protein (AUC)*	2.24	3.95	4.5	5.32	6.62	8.66	10.5	12.75	14.7	17.50	30.88	8.94	3.27
Foods Predominant in Starch (AUC)*	4.76	5.16	6.25	7.27	8.81	10.97	13.07	15.51	17.41	19.08	27.37	11.24	3.31
Foods Predominant in Sugar and Starch (AUC)*	2.76	3.25	4.86	6.25	8.25	10.64	13.77	16.63	17.89	20.16	38.375	11.03	4.17
Foods Predominant in Added Sugar (AUC)*	0.50	1.15	2.00	2.50	3.56	4.96	6.73	8.45	9.86	11.71	15.16	5.31	2.38

*Several distinct categories of food items are aggregated; the number of days is not limited to 0-7.

Table 4-21 summarizes frequency distribution of combined categories of solid foods with Block Kids Food Frequency questionnaire solid food variables by frequency of intake of the low presumed cariogenicity (AUC), the moderate presumed cariogenicity (AUC), and the high-presumed cariogenicity. The median (mean) values for the frequency of intake of low presumed cariogenicity category solid foods (AUC) were 14.22 (15.00), moderate presumed cariogenicity category solid foods (AUC) foods were 24.34 (25.00), and high presumed cariogenicity category solid foods (AUC) were 15.54 (16.35) days/week, respectively. The frequency of consumption of the solid food items in the moderate cariogenicity category was highest when compared with the frequency of consumption of food items in the low and high cariogenicity categories.

Table 4-22 summarizes frequency distribution of selected Block Kids Food Frequency Questionnaire beverage variables of frequency of sugared beverage consumption (AUC), 100% juice consumption (AUC), and milk consumption (AUC). The median (mean) values for the frequency of sugared beverage consumption (AUC) were 4.32 (4.68), the frequency of 100% juice consumption (AUC) were 1.88 (2.36), and the frequency of milk consumption (AUC) were 9.50 (9.46), days/week respectively. The frequency of consumption of all beverage categories could exceed seven days/week. This was because, just as with solid foods, the frequency of each beverage category was assessed by aggregating the frequencies of each beverage item in the category. In addition, the frequency of consumption of milk exceeded seven days/week. This was because overall frequency of milk consumption was assessed from Block Kids Food Frequency questionnaire as an aggregate of frequencies of milk consumption for breakfast, lunch and dinner.

Table 4-21 Frequency distributions of frequency of intake of combined categories of solid foods (days /week) (AUC) from Block Kids Food Frequency questionnaire

Frequency of Consumption of Combined Categories of Solid Foods (Days/Week)	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Low Presumed Cariogenicity (AUC)*	4.12	5.19	6.64	7.53	10.51	14.22	18.54	23.28	25.87	31.51	34.88	15.00	6.03
Moderate Presumed Cariogenicity (AUC)*	9.85	12.27	14.79	16.56	20.14	24.34	29.1	33.5	37.41	43.33	70.56	25.00	7.23
High Presumed Cariogenicity (AUC)*	3.75	5.85	8.60	10.06	12.42	15.54	19.98	23.71	25.39	29.76	52.19	16.35	5.62

* Several distinct categories of food items are aggregated, so the number of days is not limited to 0-7.

Table 4-22 Frequency distributions of frequency of intake of beverage (days/week) categories of Block Kids Food Frequency questionnaire variables (AUC)

Dietary variables	Min	1	5	10	25	50	75	90	95	99	Max	Mean	S.D.
Frequency of Sugared Beverage Consumption (AUC)	0.00	0.00	1.03	1.40	2.54	4.32	6.50	8.00	9.60	11.32	14.48	4.68	2.68
Frequency of 100% Juice Consumption (AUC)	0.00	0.00	0.00	0.16	0.66	1.88	3.50	5.42	6.56	7.98	9.49	2.36	2.08
Frequency of Milk Consumption (AUC)	0.00	0.00	1.22	2.46	5.52	9.50	13.01	16.72	18.44	20.15	21.00	9.46	5.05

*Frequency of consumption of milk exceeded 7 days/week, as it is an aggregate of frequencies for breakfast, lunch and dinner.

Bivariate Analyses: Correlations

Table 4-23 describes the spearman rank order correlation results between pairs of independent variables. All pairs of Spearman and Pearson correlation results between a given pair of variables were very similar. Due to the mostly non-parametric nature of the data, only the results for Spearman correlations are shown. Even though the large majority of correlation results were statistically significant ($p<0.05$), the magnitudes of correlation were mostly weak (less than 0.49) or moderate (0.50 to 0.69), with few strong (0.70 to 1). The few strong correlations found were between frequency of consumption of 100% juice (AUC) (IFS) and sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC) (IFS), frequency of sugared beverage consumption (AUC) (Block) (days/week) and frequency of sugared beverage consumption (AUC) (IFS) (servings/week) and fluoride intake from water (AUC) and composite water fluoride level (AUC).

Among the IFS questionnaire variables, a strong (0.7 to 1) correlation was found between frequency of 100% juice consumption (AUC) and frequency of consumption of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC). The pairwise correlations between frequency of sugared beverage consumption (AUC) and frequency of 100% juice consumption (AUC) and those between milk consumption (AUC) and sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC) were not statistically significant ($p>0.05$). Additionally, there were weak (0 to 0.49) correlations between frequency of milk consumption (AUC) and 100% juice consumption (AUC). For other IFS variables, strong (0.7 to 1) correlations were found between fluoride intake from water (AUC) and composite water fluoride level (AUC), while correlations for all the other pairwise comparisons between composite water fluoride levels (AUC), daily fluoride intake from combined sources (AUC) and fluoride intake from water (AUC) were weak to moderate in magnitude. For the remaining correlations among IFS variables, moderately correlated variables included topical fluoride application (AUC) and dental visit (AUC). The oral hygiene variables of daily brushing frequency (AUC) and brushing minutes (AUC) were not significantly correlated (p>0.05).

Among the Block Kids Food Frequency questionnaire (Block's questionnaire) variables, the pairwise comparisons between frequency of consumption of the seven solid food categories from the Block's questionnaire had weak strength of correlation, except for the moderate (0.5 to 0.69) correlations between frequency of consumption of foods predominant in fat and protein (AUC) and those predominant in starch (AUC), and the correlations between frequency of consumption of foods predominant in starch and protein (AUC) and those predominant in starch (AUC). For the solid foods combined category variables from the Block questionnaire, frequency of consumption of foods with moderate presumed cariogenicity (AUC) was moderately (0.5 to 0.69) correlated with frequency of consumption of foods with low presumed cariogenicity and high presumed cariogenicity (AUC), respectively. The magnitudes of remaining correlations between frequency of intake of solid foods with low and high presumed cariogenicity were weak (0 to 0.49). In addition, for the Block's questionnaire beverage variables, weak pairwise correlations were found for frequency of consumption of 100% juice (AUC), milk (AUC), and sugared beverages (AUC).

The correlations among the Block’s questionnaire and the IFS questionnaire beverage variables ranged from strong to moderate. Strong (0.70 to 1.00) correlations were found between frequency of sugared beverage consumption (AUC) from (IFS) (servings/week) and frequency of sugared beverage consumption (AUC) (Block) (days/week).

Moderate (0.5 to 0.69) correlations for IFS and Block’s questionnaire variables were identified between frequency of milk consumption (AUC) (IFS) (servings/week) and frequency of milk consumption (AUC) (Block) (days/week) (0.68) and frequency of 100% juice consumption (AUC) (Block) (days/week) and frequency of 100% juice consumption (AUC) (IFS) (servings/week) (0.61), respectively.

After consideration of the strength of correlation between these variables and with an objective to avoid collinearity issues in multivariable analyses, the frequency of intake of beverages assessed by Block Kids Food Frequency Questionnaire and frequency of intake of beverages with 100% juice (IFS questionnaire) were excluded from backward regression model development.

Table 4-23 Correlation results between pairs of independent variables

Variable-1	Variable-2	Sample Size	Spearman Correlation Coefficient	P-Value
Composite Water Fluoride Level (AUC) (ppm F)	Daily Fluoride Intake from Combined Sources (AUC)(mg F/Day)	288	0.50	<0.0001
Fluoride Intake from Water (AUC) (mg F/Day)	Daily Fluoride Intake from Combined Sources (AUC) (mg F/Day)	296	0.75	<0.0001
Fluoride Intake from Water (AUC) (mg F/ Day)	Composite Water Fluoride Level (AUC) (ppm F)	296	0.59	<0.0001
Daily Brushing Frequency (AUC)	Duration of Brushing (AUC) (minutes)	302	0.07	0.29
Frequency of 100% Juice Consumption(IFS) (Servings/Week)	Frequency of Sugared Beverage Consumption (AUC) (Servings/Week)	303	-0.04	0.49
Frequency of 100% Juice Consumption (AUC) (Servings/Week)	Frequency of Sugar-Free Beverage Consumption (AUC)# (Servings/Week)	303	0.73	<0.0001
Frequency of 100% Juice Consumption (AUC) (Servings/Week)	Frequency of Milk Consumption (AUC) (Servings/Week)	303	0.17	0.0036
Frequency of Sugared Beverage Consumption (AUC) (Servings/Week)	Frequency of Milk Consumption (AUC) (Servings/Week)	303	-0.12	0.05
Frequency of Sugar-Free Beverage Consumption (AUC) (Servings/Week)	Frequency of Milk Consumption (AUC) (Servings/Week)	303	0.04	0.52

Variable-1	Variable-2	Sample Size	Spearman Correlation Coefficient	P-Value
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Starch and Sugar (AUC) (Days/Week)	303	0.30	<0.0001
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Days/Week)	303	0.10	0.09
Frequency of Consumption of Foods Predominant in High Natural Sugar (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Starch and Protein (AUC) (Days/Week)	303	0.14	0.02
Frequency of Consumption of Foods Predominant in High Natural Sugar (AUC)(Days/Week)	Frequency of Consumption of Foods Predominant in Starch (AUC)(Days/Week))	303	0.23	<0.0001
Frequency of Consumption of Foods Predominant in High Natural Sugar (AUC)(Days/Week)	Frequency of Consumption of Foods Predominant in Starch And Sugar (AUC)(Days/Week)	303	0.39	<0.0001
Frequency of Consumption of Foods Predominant in High Natural Sugar (AUC)(Days/Week)	Frequency of Consumption of Foods Predominant in Added Sugar (AUC)(Days/Week)	303	0.12	0.06

Variable-1	Variable-2	Sample Size	Spearman Correlation Coefficient	P-Value
Frequency of Consumption of Foods Predominant in Starch And Protein (AUC)(Days/Week)	Frequency of Consumption of Foods Predominant in Starch (AUC)(Days/Week)	303	0.53	<0.0001
Frequency of Consumption of Foods Predominant in Fat and Protein (AUC)	Frequency of Consumption of Foods Predominant in High Natural Sugar (AUC)	303	0.24	<0.0001
Frequency of Consumption of Foods Predominant In Fat and Protein (AUC)	Frequency of Consumption of Foods Predominant in Starch and Protein (AUC)	303	0.39	<0.0001
Frequency of Consumption of Foods Predominant in Fat and Protein (AUC)	Frequency of Consumption of Foods Predominant in Starch (AUC)	303	0.55	<0.0001
Frequency of Consumption of Foods Predominant in Fat and Protein (AUC)	Frequency of Consumption of Foods Predominant in Starch and Sugar (AUC)	303	0.23	<0.0001
Frequency of Consumption of Foods Predominant in Fat and Protein (AUC)	Frequency of Consumption of Foods Predominant in Added Sugar	303	0.29	<0.0001
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC)	Frequency of Consumption of Foods Predominant in High Natural Sugar (AUC)	303	0.55	<0.0001
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC)	Frequency of Consumption of Foods Predominant in Starch and Protein (AUC)	303	0.13	0.04

Variable-1	Variable-2	Sample Size	Spearman Correlation Coefficient	P-Value
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC)	Frequency of Consumption of Foods Predominant in Starch (AUC)	303	0.34	<0.0001
Frequency of Consumption of Low Presumed Cariogenicity (AUC) (Days/Week)	Frequency of Consumption of Moderate Presumed Cariogenicity (AUC) (Days/Week)	303	0.59	<0.0001
Frequency of Consumption of Low Presumed Cariogenicity (AUC) (Days/Week)	Frequency of Consumption of High Presumed Cariogenicity (AUC) (Days/Week)	303	0.34	<0.0001
Frequency of Consumption of Moderate Presumed Cariogenicity (AUC) (Days/Week)	Frequency of Consumption of High Presumed Cariogenicity (AUC) (Days/Week)	303	0.53	<0.0001
Frequency of Consumption of Foods Predominant in Starch and Protein (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Starch and Sugar (AUC) (Days/Week)	303	0.31	<0.0001
Frequency of Consumption of Foods Predominant in Starch and Protein (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Days/Week)	303	0.39	<0.0001
Frequency of Consumption of Foods Predominant in Starch (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Starch and Sugar (AUC) (Days/Week)	303	0.35	<0.0001
Frequency of Consumption of Foods Predominant in Starch (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Days/Week)	303	0.38	<0.0001

Variable-1	Variable-2	Sample Size	Spearman Correlation Coefficient	P-Value
Frequency of Consumption of Foods Predominant in Fat and Protein (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Days/Week)	303	0.45	<0.0001
Frequency of Consumption of Foods Predominant in Starch and Sugar (AUC) (Days/Week)	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Days/Week)	303	0.39	<0.0001
Frequency of Consumption of Frequency of 100% Juice Consumption (AUC) (Block) (Days/Week)	Frequency of Consumption of Frequency of 100% Juice Consumption (AUC) (Servings/Week)	303	0.61	<0.0001
Frequency of Sugared Beverage Consumption (AUC) (Block) (Days/Week)	Frequency of Sugared Beverage Consumption (AUC) (Servings/Week)	303	0.72	<0.0001
Frequency of Milk Consumption (AUC) (Servings/Week)	Frequency of Milk Consumption (AUC) (Block) (Days/Week)	303	0.68	<0.0001
Frequency of 100% Juice Consumption (AUC) (Block) (Days/Week)	Frequency of 100% Juice Consumption (AUC) (Servings/Week)	303	0.61	<0.0001
Topical Fluoride Application (AUC)	Dental Visit (AUC)	301	0.59	<0.0001
Frequency of Sugared Beverage Consumption (AUC) (Servings/Week)	Frequency of Milk Consumption (AUC) (Servings/Week)	303	-0.12	0.05
Frequency of Sugar-Free Beverage Consumption (AUC)#	Frequency of Milk Consumption (AUC) (Servings/Week)	303	0.04	0.52

Variable-1	Variable-2	Sample Size	Spearman Correlation Coefficient	P-Value
Frequency of 100% Juice Consumption (AUC) (Block) (Days/Week)	Frequency of Milk Consumption (AUC) (Block) (Days/Week)	303	0.16	0.0074
Frequency of 100% Juice Consumption (AUC) (Block) (Days/Week)	Frequency of Sugared Beverage Consumption (AUC) (Block) (Days/Week)	303	-0.13	0.0334
Frequency of Milk Consumption (AUC) (Block) (Days/Week)	Frequency of Sugared Beverage Consumption (AUC) (Block) (Days/Week)	303	-0.18	0.0022
Frequency of 100% Juice Consumption (AUC) (Block) (Days/Week)	Frequency of Milk Consumption (AUC) (Block) (Days/Week)	303	0.16	0.0074

Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself

Bivariate Regression Analyses: Binary

Table 4-24 summarizes the bivariate logistic regression results relating the demographic variables of sex and socioeconomic status (low, middle and high) to net cavitated caries incidence as dependent variable. The relationship between net cavitated caries incidence and sex was not significant at the 0.05 level, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling, with females having more caries incidence. For females, the odds of having a positive net cavitated caries incidence from age 13 to 17 were 1.47 times as high as that for males. For subjects who were in the middle socioeconomic category, the odds of having a positive net cavitated caries incidence from age 13 to age 17 were 1.60 times as high as for those in the low socioeconomic status category. For subjects in the high socioeconomic status category, the odds of having a positive net cavitated caries incidence from age 13 to 17 were 0.47 times as high as for subjects with low socioeconomic status. This association was significant at $p<0.05$ level and overall subjects with low socioeconomic status were more likely to have caries incidence. The relationship between net cavitated caries incidence and baseline age (age 13) was not significant at $p<0.05$, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For subjects who were one year older at the baseline exam, the odds of having net cavitated caries incidence from age 13 to 17 were 1.57 times as high as for those with younger age at baseline exam.

Table 4-25 summarizes the bivariate logistic regression results relating IFS questionnaire oral hygiene variables of frequency of daily brushing (AUC) and duration of brushing (AUC) to caries incidence as a dependent variable. A significant negative relationship was found between net cavitated caries incidence and daily brushing frequency (AUC) (p=0.01), which met the screening criterion of p<0.15 for inclusion in multivariable modeling. A weak non-significant positive relationship was found between net cavitated caries incidence and duration of brushing (AUC). For subjects who brushed one additional time per day, the odds of having net cavitated caries incidence from age 13 to age 17 were 0.57 times as high as for those with lower daily brushing frequency.

Table 4-26 summarizes bivariate logistic regression results relating IFS questionnaire fluoride variables of composite water fluoride levels (AUC), daily fluoride intake from water (AUC), daily fluoride intake from combined sources (AUC), fluoride mouthrinse use dichotomized as (Y/N), and proportion of periods with topical fluoride application (AUC) to net cavitated caries incidence as the dependent variable. Weak non-significant relationships were found between net cavitated caries incidence and composite water fluoride levels (AUC), daily fluoride intake from water (AUC), daily fluoride intake from combined sources (AUC), and proportion of periods with topical fluoride treatment (AUC). The relationship with fluoride mouthrinse use was not significant at p<0.05, but met the screening criterion of p<0.15 for inclusion in multivariable modeling. For children who reported any use of fluoride mouthrinse, the odds of having positive net cavitated caries incidence from age 13 to 17 were 0.70 times as high as for those without any use of fluoride mouthrinse.

Table 4-24 Bivariate logistic regression analyses relating net cavitated caries incidence to selected IFS questionnaire demographic variables

Parameter	Category	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Sex	1=Female 0=Male	303	0.3900	0.233	-0.066, 0.846	2.82	0.10*	1.47
Socioeconomic Status (Ref = Low)	Middle	291	0.4690	0.405	-1.263, 0.325	1.34	0.25	1.60
	High		-0.7582	0.315	-1.375, -0.142	5.81	0.02*	0.47
Baseline Age	Decimal Years	303	0.4494	0.268	-0.076, 0.975	2.81	0.10*	1.57

*Relationship met screening criterion of p<0.15.

Table 4-25 Bivariate logistic regression analyses relating net cavitated caries incidence to selected IFS questionnaire oral hygiene variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Daily Brushing Frequency (AUC)	(Brushings/Day)	302	-0.5704	0.237	-1.034, -0.1074	5.83	0.02*	0.57
Duration of Brushing (AUC)	(Minutes/Brushing)	303	0.0123	0.164	-0.196, 0.444	0.58	0.45	1.02

*Relationship met screening criterion of p<0.15.

Table 4-26 Bivariate logistic regression analyses relating net cavitated caries incidence to IFS questionnaire fluoride variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Average Composite Water F Level (AUC)	ppm F	299	0.1166	0.399	-0.665, 0.898	0.09	0.77	1.13
Fluoride Intake From Water (AUC)	mg F/day	296	-0.3325	0.337	-0.992, 0.3269	0.98	0.33	0.72
Daily Fluoride Intake From Combined Sources (AUC)	mg F	288	-0.2043	0.257	-0.780, 0.300	0.63	0.44	0.82
Fluoride Mouthrinse Use	Any vs. No Periods With Mouthrinse Use	303	-0.3695	0.240	-0.839, -0.100,	2.38	0.13*	0.70
Proportion of Periods with Topical Fluoride Application (AUC)	Proportion of Periods	303	0.0878	0.354	-0.605, 0.780	0.06	0.81	1.09

*Relationship met screening criterion of p<0.15.

Table 4-27 summarizes bivariate logistic regression results relating selected IFS questionnaire beverage variables of frequency of consumption of sugared beverages (AUC), frequency of 100% juice consumption (AUC), frequency of milk consumption (AUC) and frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC), respectively, to net cavitated caries incidence as dependent variable. Significant negative relationships were found between net cavitated caries incidence and frequency of 100% juice consumption (AUC) ($p<0.02$) and frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC) ($p<0.005$), both of which met the screening criterion of $p<0.15$ for the inclusion in multivariable modeling. For subjects who had one extra serving/week of 100% juice, the odds of having net cavitated caries incidence from ages 13 to 17 were 0.88 times as high as for those with lower frequency of consumption. For subjects who had one extra serving/week of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself), the odds of having net cavitated caries incidence from age 13 to 17 were 0.90 times as high as for those with lower frequency of consumption.

A weak non-significant negative relationship was found between net cavitated caries incidence and frequency of milk consumption, whereas a non-significant positive relationship was found between net cavitated caries incidence and frequency of sugared beverage consumption (AUC) ($p>0.15$).

Table 4-28 summarizes bivariate logistic regression results relating presence of sealants and number of surface zones with sealants at baseline age to net cavitated caries incidence as a dependent variable. The positive relationship between net cavitated caries incidence and presence of sealants was significant and met the screening criterion of p< 0.15 for inclusion in multivariable modeling. For subjects with presence of sealants, the odds of having net cavitated caries incidence were 1.60 times as high as for those with without sealants. For subjects with one additional surface zone with sealant, the odds of having net cavitated caries incidence from age 13 to 17 were 1.05 times as high as for those with the lower number of surface zones with sealants.

Table 4-29 summarizes bivariate logistic regression results relating previous caries incidence variables of person level and surface level age 9 to 13 net cavitated caries incidence, respectively, to net cavitated caries incidence from age 13 to 17 years as a dependent variable. The positive relationships between age 13 to age 17 caries incidence and person level and surface level net cavitated caries incidence from age 9 to 13 were significant at $p<0.05$. For subjects who had positive net cavitated caries incidence from 9 to 13, the odds of having net cavitated caries incidence from age 13 to age 17 were 2.60 times as high as for those without any positive 9 to 13 net cavitated caries incidence. For subjects who had one additional surface of positive net cavitated caries increment from 9 to 13 years, the odds of net cavitated caries incidence from the age 13 to the age 17 were 1.24 times as high as for those with lower net cavitated caries increment from 9 to 13 years.

Table 4-30 summarizes bivariate logistic regression results relating IFS questionnaire previous dental visit variables to net cavitated caries incidence as a dependent variable. A weak non-significant relationship was found between net cavitated caries incidence and proportion of periods with dental visits (AUC).

Table 4-27 Bivariate logistic regression analyses relating net cavitated caries incidence to selected IFS questionnaire beverage variables.

Parameter (Servings/week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Frequency of Sugared Beverage Consumption (AUC)	303	0.0265	0.027	-0.026, 0.017	1.01	0.32	1.02
Frequency of 100% Juice Consumption (AUC)	303	-0.1322	0.056	-0.241, -0.024	5.71	0.02*	0.88
Frequency of Milk Consumption (AUC)	303	-0.0207	0.0195	-0.059, 0.0175	1.13	0.29	0.98
Frequency of Sugar-Free Beverage Consumption (AUC)#	303	-0.1113	0.041	-0.191, -0.033	7.57	0.006*	0.90

*Relationship met screening criterion of p<0.15.
#Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself.

Table 4-28 Bivariate logistic regression analyses relating net cavitated caries incidence to sealant variable

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Presence of Sealants*#	Yes/No	303	0.7543	0.276	1.296, 0.214	7.47	0.007*	1.60
Number of Surface Zones with Sealants	Count	303	0.0444	0.030	-0.013, 0.102	2.29	0.14*	1.05

*Relationship met screening criterion of p<0.15.

Presence of sealants was defined as any tooth surface zones with sealants (Y) vs. all zones without sealants (N).

Table 4-29 Bivariate logistic regression analyses relating net cavitated caries incidence to previous caries incidence variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
9 to 13 Net Cavitated Caries Incidence in Permanent Teeth	Yes/No	297	0.9552	0.272	0.423, 1.488	12.37	0.0004*	2.60
9 to 13 Net Cavitated Caries Increment Count in Permanent Teeth	Discrete Count Surfaces	297	0.2162	0.077	0.066, 0.367	7.91	0.005*	1.24

*Relationship met screening criterion of p<0.15.

Table 4-30 Bivariate logistic regression analyses relating net cavitated caries incidence to IFS questionnaire dental visit variable (AUC)

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-value	OR
Proportion of Periods with Dental Visits (AUC)	Proportion of Periods	303	0.3261	0.463	-0.582, 1.234	0.50	0.49	1.39

Table 4-31 summarizes bivariate logistic regression analyses relating the selected Block Kids Food Frequency questionnaire solid food variables of foods predominant in fat and protein (AUC), foods predominant in fiber and natural sugar (AUC), foods predominant in high natural sugar (AUC), foods predominant in starch and protein (AUC), foods predominant in starch (AUC), foods predominant in sugar and starch (AUC), and foods predominant in added sugar (AUC) to net cavitated caries incidence as a dependent variable. The negative relationship between net cavitated caries incidence and frequency of consumption of foods predominant in fiber and low natural sugar (AUC) and foods predominant in starch and sugar (AUC) was not significant at $p<0.05$, but met the screening criterion of $p<0.15$ for the inclusion in multivariable modeling. For subjects who consumed foods predominant in fiber and low natural sugar, for one additional day/week, the odds of net cavitated caries incidence from age 13 to 17 were 0.95 times as high as for those with lower frequency of consumption.

The relationship between net cavitated caries incidence and frequency of consumption of foods predominant in starch and protein was not significant at $p<0.05$, but met the screening criterion of $p<0.15$ for the inclusion in multivariable modeling. For subjects who had foods predominant in starch and protein for one additional day/week, the odds of net cavitated caries incidence from age 13 to age 17 were 1.07 times as high as for those with lower frequency of consumption. There was a significant and positive relationship between frequency of consumption of foods predominant in added sugar (AUC) and caries incidence ($p<0.05$). For subjects who had foods predominant in added sugars for one additional day/week, the odds of net cavitated caries incidence from age 13 to age 17 were 1.14 times as high as the odds for those with lower frequency of consumption. Non-significant relationships were found between net cavitated caries incidence and frequency of consumption of foods predominant in fat and protein (AUC), foods predominant in high natural sugar (AUC), foods predominant in starch, and foods predominant in sugar and starch (AUC).

Table 4-32 summarizes bivariate logistic regression analyses relating selected Block Kids Food Frequency questionnaire (AUC) solid food variables categorized by presumed cariogenicity: frequency of intake of solid foods with low presumed cariogenicity (AUC), moderate presumed cariogenicity (AUC), and high presumed cariogenicity, respectively, to net cavitated caries incidence. The positive relationship between caries incidence and frequency of intake of moderate presumed cariogenicity category solid foods was not significant at $p<0.05$, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. A weak negative non-significant relationship was found between net cavitated caries incidence and frequency of intake of low presumed cariogenicity solid foods (AUC), whereas a weak positive non-significant relationship was found between caries incidence and frequency of intake of solid foods with high presumed cariogenicity (AUC), respectively. For subjects who consumed foods in the moderate presumed cariogenicity category for one additional day/week, the odds of caries incidence from age 13 to age 17 were 1.03 times as high as for those with lower frequency of consumption.

Table 4-33 summarizes bivariate logistic regression analyses relating selected Block Kids Food Frequency questionnaire beverage variables of frequency of sugared beverage consumption (AUC), frequency of 100% juice consumption (AUC), and frequency of milk consumption (AUC) to net cavitated caries incidence as a dependent variable. The positive relationship between net cavitated caries incidence and frequency of sugared beverage consumption (AUC) was not significant at $p<0.05$, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For subjects who consumed sugared beverages for one additional day/week, the odds of caries incidence from age 13 to age 17 were 1.05 times as high as for those with lower frequency of consumption. Weak non-significant and negative relationships were found between caries incidence and frequency of intake of 100% juice (AUC) and frequency of milk consumption (AUC), respectively.

Table 4-31 Bivariate logistic regression analyses relating net cavitated caries incidence to selected Block Kids Food Frequency questionnaire solid food variables

Frequency of Consumption of Solid Foods (Days/Week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Foods Predominant in Fat and Protein (AUC)	303	0.0309	0.033	-0.033, 0.095	0.91	0.35	1.03
Foods Predominant in Fiber and Natural Sugar (AUC)	303	-0.0484	0.033	-0.112, 0.016	2.23	0.14*	0.95
Foods Predominant in High Natural Sugar (AUC)	303	0.0247	0.040	-0.053, 0.102	0.39	0.54	1.02
Foods Predominant in Starch and Protein (AUC)	303	0.0664	0.038	-0.007, 0.140	3.15	0.08*	1.07
Foods Predominant in Starch (AUC)	303	0.0389	0.036	-0.040, 0.110	1.22	0.28	1.04
Foods Predominant in Sugar and Starch (AUC)	303	-0.0087	0.028	-0.064, 0.046	0.10	0.76	0.99
Foods Predominant in Added Sugar (AUC)	303	0.1262	0.051	0.027, 0.227	6.14	0.02*	1.14

*Relationship met screening criterion of p<0.15.

Table 4-32 Bivariate logistic regression analyses relating net cavitated caries incidence to selected Block Kids Food questionnaire combined categories of solid foods

Frequency of Consumption of Combined Categories of Solid Foods Based on Cariogenicity (Days/Week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	OR
Frequency of Low Presumed Cariogenicity Solid Food Consumption (AUC)	303	-0.0063	0.020	-0.044, 0.032	0.11	0.75	0.99
Frequency of Moderate Presumed Cariogenicity Solid Food Consumption (AUC)	303	0.0261	0.017	-0.007, 0.059	2.45	0.12*	1.03
Frequency of High Presumed Cariogenicity Solid Food Consumption (AUC)	303	0.0174	0.0210	-0.024, 0.059	0.69	0.41	1.02

*Relationship met screening criterion of p< 0.15.

Table 4-33 Bivariate logistic regression analyses relating net cavitated caries incidence to selected Block Kids Food questionnaire beverage variables

Parameter (Days/Week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-value	OR
Frequency of Sugared Beverage Consumption (AUC)	303	0.0743	0.045	-0.020, 0.161	2.85	0.10*	1.08
Frequency of 100% Juice Consumption (AUC)	303	-0.0773	0.056	-0.187, 0.033	1.91	0.17	0.93
Frequency of Milk Consumption (AUC)	303	-0.0041	0.023	-0.050, 0.041	0.03	0.86	1.00

*Relationship met screening criterion of $p<0.15$.

Bivariate Analyses: Count Variables

Table 4-34 summarizes bivariate negative binomial regression results relating the demographic variables of sex and socioeconomic status (low, middle and high) to net cavitated caries increment count as a dependent variable. Both socioeconomic status and baseline age (age 13) were significantly associated with net cavitated caries increment. Socioeconomic status was negatively associated with net cavitated caries increment, while baseline age (age 13) was positively associated. For subjects who were in the middle socioeconomic status category, the surface level cavitated caries incidence rate from age 13 to age 17 was 0.61 times as high as for those who were in the low socioeconomic status. For subjects, who were in high socioeconomic status category, the surface level cavitated caries incidence rate from age 13 to age 17 was 0.59 times as high as for those who had low socioeconomic status. This association was significant at $p<0.05$ level. Overall, subjects with low socioeconomic status were more likely to have higher surface level caries incidence The relationship between baseline age (age 13) and net cavitated caries increment was significant at $p<0.05$. For subjects who were one year older at the baseline exam, the surface level net cavitated caries incidence rate was 1.68 times as high as for those with lower baseline age. A weak non-significant relationship was found between sex and net cavitated caries incidence.

Table 4-35 summarizes bivariate negative binomial regression results relating oral hygiene variables of frequency of daily brushing (AUC) and duration of brushing (AUC) to net cavitated caries increment count as a dependent variable. A significant relationship was found between net cavitated caries increment count and daily brushing frequency (times/day) ($p<0.05$). For every additional time of daily brushing, the surface level cavitated caries incidence rate was 0.56 times as high for those with lower daily brushing frequency. A weak non-significant, negative relationship was found between net cavitated caries increment count and duration of brushing (AUC).

Table 4-36 summarizes bivariate negative binomial regression results relating the fluoride variables of composite water fluoride levels (AUC), daily fluoride intake from water (AUC), daily fluoride intake from combined sources (AUC), fluoride mouthrinse use dichotomized as (Y/N), and proportion of periods with topical fluoride application (AUC) to net cavitated caries increment count as the dependent variable. Weak non-significant relationships were found between net cavitated caries increment count and composite water fluoride levels (AUC), daily fluoride intake from combined sources (AUC), fluoride mouthrinse use (Y/N), and proportion of periods with topical fluoride application (AUC), respectively. The relationship between net cavitated caries increment count and fluoride intake from water (AUC) was not significant at $p<0.05$ level, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For every additional mg of daily fluoride intake from water, the surface level net cavitated caries incidence rate was 0.66 times as high as for those with lower daily fluoride intake from water.

Table 4-34 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to demographic variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Sex	1=Female 0=Male	303	0.2745	0.200	-0.010, 0.690	2.07	0.16	1.33
Socioeconomic Status (Ref=Low)	Middle	291	-0.4930	0.312	-1.104, 0.118	2.51	0.12*	0.61
	High		-0.5236	0.236	-0.985, -0.070	4.96	0.03*	0.59
Baseline Age	Decimal Years	303	0.5183	0.203	0.123, 0.915	8.58	0.02*	1.68

*Relationship met screening criterion of p<0.15.

Table 4-35 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to IFS questionnaire oral hygiene variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Daily Brushing Frequency (AUC)	Brushings/Day	302	-0.5877	0.193	-0.966, 0.210	9.27	0.003*	0.56
Duration of Brushing (AUC)	Minutes/Brushing	303	0.0239	0.134	-0.238, 0.286	0.03	0.86	0.86

*Relationship met screening criterion of p<0.15.

Table 4-36 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to IFS questionnaire fluoride variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Composite Water Fluoride Level (AUC)	ppm F	299	0.0286	0.352	-0.660, 0.717	0.01	0.94	1.02
Daily Fluoride Intake from Water (AUC)	mg F/day	296	-0.4177	0.278	-0.962, 0.127	2.27	0.14*	0.66
Daily Fluoride Intake from Combined Sources (AUC)	mg F/day	288	-0.0579	0.231	-0.511, 0.395	0.06	0.81	0.95
Fluoride Mouthrinse Use	Any vs. No Periods With Mouthrinse Use	303	0.2150	0.195	-0.167, 0.587	1.22	0.68	0.28
Proportion of Periods with Topical Fluoride Application (AUC)	Proportion of Periods	301	-0.2434	0.298	-0.527	0.23	0.63	0.43

*Relationship met screening criterion of p<0.15.

Table 4-37 summarizes bivariate negative binomial regression results relating the selected Iowa Fluoride Study questionnaire beverage variables of frequency of sugared beverage consumption (AUC), 100% juice consumption (AUC), milk consumption (AUC), and sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC) to net cavitated caries increment count as the dependent variable. The positive relationship between net cavitated caries increment count and frequency of sugared beverage consumption (AUC) was significant at $p<0.05$. For subjects who consumed one additional serving per week of sugared beverages, the surface level net cavitated caries incidence rate was 1.05 times as high as for those with lower frequency of consumption. The negative relationship between frequency of milk consumption (AUC) and net cavitated caries increment count was not significant at the 0.05 level, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For subjects who had one additional serving of milk per week, the surface level net cavitated caries incidence rate was 0.98 times as high as for those with the lower number of servings per week. Weak non-significant negative relationships were found between net cavitated caries increment count and frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC) and 100% juice consumption (AUC), respectively.

Table 4-37 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to IFS questionnaire beverage variables

Parameter (Servings/Week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Frequency of Sugared Beverage Consumption (AUC)	303	0.0426	0.021	0.002, 0.090	4.11	0.05*	1.05
Frequency of 100% Juice Consumption (AUC)	303	-0.0601	0.046	-0.151, 0.031	1.70	0.20	0.94
Frequency of Milk Consumption (AUC)	303	-0.0260	0.015	-0.056, 0.004	3.01	0.09*	0.98
Frequency of Sugar-Free Beverage Consumption (AUC)#	303	-0.0254	0.032	-0.090, 0.038	0.64	0.43	0.97

*Relationship met screening criterion of p<0.15.

#Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself)

Table 4-38 summarizes bivariate negative binomial regression results relating the variables presence of sealants, number of surface zones with sealants at baseline exam and baseline age (age 13) to net cavitated caries increment count as the dependent variable. A significant relationship was found between net cavitated caries increment count and presence of sealants at $p<0.005$ and met the inclusion criterion for $p<0.15$ for multivariable modeling. For subjects who had sealants, the surface level net cavitated caries incidence rate was 1.9 times as high as for those without any sealants. A weak positive non-significant relationship was reported between number of surface zones with sealants at baseline and net cavitated caries increment count.

Table 4-38 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to sealant variables obtained from dental exams

Parameter	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Presence of Sealants	303	0.6321	0.230	0.183, 1.090	7.59	0.006*	1.89
Number of Surface Zones With Sealants	303	0.0343	0.025	-0.014, 0.083	1.97	0.16	1.04

*Relationship met screening criterion of p<0.15.

[#] Presence of sealants was defined as having tooth surface zones with sealants (Y) and having no tooth surface zones with sealants (N).

Table 4-39 summarizes bivariate negative binomial regression results relating previous caries experience variables to net cavitated caries increment count as the dependent variable. Significant positive relationships were found between net cavitated caries increment count and person level and surface level net cavitated caries incidence from age 9 to 13, respectively, ($p<0.05$ level). For subjects with net cavitated caries incidence from 9 to 13, the surface level net cavitated caries incidence rate was 3.04 times as high as for those without cavitated caries from 9 to 13. For subjects with an additional surface of net cavitated caries increment from 9 to 13, the surface level net cavitated caries incidence rate was 1.25 times as high as for those with lower net cavitated caries increment from 9 to 13.

Table 4-40 summarizes bivariate negative binomial regression results relating selected IFS questionnaire dental visit variables to net cavitated caries increment count as the dependent variable. The relationship between proportion of periods with dental visit (AUC) and net cavitated caries increment was not significant at $p<0.05$, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For subjects with dental visits during all reporting periods, the surface level net cavitated caries incidence rate was 1.83 times as high as for those who reported no periods with dental visits.

Table 4-39 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to previous caries incidence variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Age 9-13 Incidence in Permanent Teeth	Yes/No	297	1.1113	0.193	0.734, 1.490	33.17	0.0001*	3.04
Age 9-13 Incidence in Permanent Teeth	Discrete Count	297	0.2162	0.077	0.066, 0.367	7.91	0.005*	1.25

*Relationship met screening criterion of p<0.15.

Table 4-40 Bivariate negative binomial regression results relating cavitated caries increment count as a dependent variable to IFS questionnaire dental visit variables

Parameter	Unit	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Proportion of Periods with Dental Visit (AUC)	Proportion of Periods	303	0.6051	0.403	0.184, 1.400	2.26	0.14*	1.83

*Relationship met screening criterion of p<0.15.

Table 4-41 summarizes bivariate negative binomial regression results relating selected Block Kids Food Frequency questionnaire solid food variables of foods predominant in fat and protein (AUC), foods predominant in natural sugar and fiber (AUC), foods predominant in high natural sugar (AUC), foods predominant in starch and protein (AUC), foods predominant in starch (AUC), foods predominant in sugar and starch (AUC), and foods predominant in added sugar (AUC) to net cavitated caries increment count as the dependent variable. A significant negative relationship was found between net cavitated caries increment count and frequency of consumption of foods predominant in natural sugar and fiber (AUC) at p<0.05, which met the screening criterion of p<0.15 for inclusion in multivariable modeling. For subjects who had solid foods predominant in natural sugar and fiber for one additional day/week (AUC), the surface level net cavitated caries incidence rate was 0.97 times as high as for those with lower frequency of consumption. A significant positive relationship was found between net cavitated caries increment count and frequency of consumption of foods predominant in added sugar (AUC) at p<0.02. For subjects who had solid foods predominant in added sugar for one additional day/week (AUC), the surface level net cavitated caries incidence rate was 1.09 times as high as for those with lower frequency of consumption. Both the relationships were significant and met the screening criterion of p<0.15 for multivariable modeling. Non-significant negative relationships were found between net cavitated caries increment count and frequency of intake of foods predominant in fat and protein (AUC), and ,high natural sugar (AUC), respectively, while positive relationships were found between net cavitated caries increment count and foods predominant in starch and protein (AUC), starch and, sugar and starch (AUC), respectively.

Table 4-41 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to solid food variables

Frequency of Consumption of Solid Foods (Days/week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Foods Predominant in Fat and Protein (AUC)	303	0.0145	0.028	-0.041, 0.070	0.27	0.61	1.02
Foods Predominant in Fiber and Natural Sugar (AUC)	303	-0.0726	0.031	-0.133, -0.015	6.06	0.03*	0.93
Foods Predominant in High Natural Sugar (AUC)	303	-0.0380	0.030	-0.105, 0.029	1.26	0.27	0.97
Foods Predominant in Starch and Protein (AUC)	303	0.0193	0.029	-0.038, 0.077	0.44	0.51	1.02
Foods Predominant in Starch (AUC)	303	0.0203	0.030	-0.037, 0.078	0.48	0.49	1.02
Foods Predominant in Sugar and Starch (AUC)	303	0.0168	0.023	-0.028, 0.062	0.55	0.46	1.02
Foods Predominant in Added Sugar (AUC)	303	0.0858	0.036	0.020, 0.157	5.70	0.02*	1.09

*Relationship met screening criterion of p<0.15.

Table 4-42 describes bivariate negative binomial regression results relating selected Block Kids Food Frequency questionnaire solid food variables categorized by presumed cariogenicity: frequency of intake of solid foods with presumed low cariogenicity (AUC),presumed moderate cariogenicity (AUC) and presumed high cariogenicity (AUC), respectively to net cavitated caries increment count as the dependent variable. Weak and non-significant relationships were found between cavitated caries increment count and frequency of low presumed cariogenicity solid food consumption (AUC) and frequency of moderate presumed cariogenicity solid food consumption (AUC), respectively. The relationship between net cavitated caries increment count and frequency of high presumed cariogenicity solid food consumption (AUC), was not significant at $p<0.05$ level, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For subjects who consumed one additional day/week of high presumed cariogenicity solid food, the surface level net cavitated caries incidence rate was 1.03 times as high as for those with lower frequency of consumption.

Table 4-43 bivariate negative binomial regression results relating selected Block Kids Food Frequency questionnaire beverage variables of frequency of sugared beverage consumption (AUC), frequency of 100% juice consumption (AUC), and frequency of milk consumption (AUC), respectively, to net cavitated caries increment count as the dependent variable. The positive relationship between net cavitated caries increment count and frequency of sugared beverage consumption (AUC) was significant ($p=0.03$) and met the screening criterion for $p<0.15$ for inclusion in multivariable modeling. For subjects who consumed sugared beverage, for one additional day/week, the surface level net cavitated caries incidence rate was 1.08 times as high as for those with lower frequency of consumption. The negative relationship between net cavitated caries increment count and frequency of milk consumption (AUC) was not significant at the 0.05 level, but met the screening criterion of $p<0.15$ for inclusion in multivariable modeling. For subjects who consumed milk for one additional day/week, the surface level net cavitated caries incidence rate was 0.97 times as high as for those with lower frequency of consumption. A weak non-significant relationship was found between net cavitated caries increment count and frequency of intake of 100% juice (AUC).

Table 4-42 Bivariate negative binomial regression results relating net cavitated caries increment count as a dependent variable to Block Kids Food questionnaire combined category variables

Frequency of Combined Categories of Solid Foods Based on Cariogenicity (Days/Week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Frequency of Low Presumed Cariogenicity Consumption(AUC)	303	-0.0176	0.0180	-0.052, 0.017	1.04	0.30	0.99
Frequency of Moderate Presumed Cariogenicity Consumption (AUC)	303	0.0028	0.140	-0.024, 0.030	0.04	0.84	1.00
Frequency of High Presumed Cariogenicity Consumption((AUC)	303	0.0255	0.017	-0.007, 0.060	2.51	0.12*	1.03

*Relationship met screening criterion of p<0.15.

Table 4-43 Bivariate negative binomial regression results relating cavitated caries increment count as a dependent variable to Block Kids Food Frequency questionnaire beverage variables

Parameter (Days/Week)	Sample Size	Unstandardized Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Frequency of Sugared Beverage Consumption (AUC)	303	0.0831	0.036	-0.013, 0.154	5.38	0.03*	1.09
Frequency of 100% Juice Consumption (AUC)	303	-0.0317	0.046	-0.122, 0.065	0.48	0.50	0.97
Frequency of Milk Consumption (AUC)	303	-0.0313	0.019	-0.069, 0.006	2.72	0.10*	0.97

*Relationship met screening criterion of $p<0.15$.

Multivariable Logistic Regression Main Effects Results

Table 4-44 summarizes the results of multivariable logistic regression analyses relating seven independent variables to cavitated caries incidence. The model began with twelve variables, as they met the inclusion criterion for multivariable analyses, i.e., all the included variables had p<0.15 in the bivariate analyses. The variables included were frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), frequency of consumption of foods predominant in starch and protein (AUC) (days/week) , frequency of consumption of foods predominant in added sugars (AUC) (days/week), frequency of consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC), sex, presence of surface zones with sealants, fluoride mouthrinse use (AUC), baseline age(age 13), daily brushing frequency (AUC), frequency of consumption of foods in the moderate presumed cariogenicity category (AUC) (days/week) , socioeconomic status category and cavitated caries increment count from 9 to 13.

The backward elimination technique was used to remove the least significant variables. Variables eliminated sequentially from each step of the model were frequency of consumption of foods predominant in starch and protein (AUC) (p=0.83), fluoride mouthrinse use (AUC) (p=0.41), frequency of consumption of foods predominant in added sugars (AUC) (p=0.18), socioeconomic status category (low, middle, high) (p=0.15) and baseline age (age 13) (p=0.09). In all, five variables were removed and the main effects model consisted of seven variables.

The main effects regression model found cavitated caries incidence from 13 to 17 was related to presence of surface zones with sealants, net cavitated caries incidence from

9 to 13, frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), frequency of consumption of foods predominant in added sugar (AUC) (days/week), frequency of consumption of foods with moderate presumed cariogenicity (AUC) (days/week), frequency of consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC) and daily tooth brushing frequency (AUC), respectively. For subjects with sealants, the odds of net cavitated caries incidence were 2.25 as high as for those without sealants. For females, the odds of net cavitated caries incidence were 2.04 times as high as among males. For subjects with cavitated caries incidence from 9 to 13, the odds of cavitated caries incidence were 2.05 times as high as for those without 9 to 13 incidence. For subjects who consumed foods predominant in fiber and natural sugar (AUC) for one additional day per week, the odds of cavitated caries incidence were 0.91 times as high as for those with lower frequency of consumption. For subjects who consumed solid foods with moderate presumed cariogenicity (AUC) for one additional day/week, the odds of cavitated caries incidence were 1.07 times as high as for those with lower frequency of consumption. For subjects who had sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC) for one additional day/week, the odds of cavitated caries incidence were 0.89 times as high as for those with lower frequency of consumption. For subjects who brushed for an additional time daily, the odds of cavitated caries incidence were 0.50 times as high as for those with lower daily brushing.

Table 4-44 Main effects model for logistic regression relating net cavitated caries incidence and independent variables

Parameter	Reference	Adjusted Beta coefficients	SE	95% CI	Chi-Square	P-Value	OR
Presence of Surface Zones with Sealants (Y/N)	Presence of Surface Zones Without Sealants	0.808	0.307	0.209, 1.408	6.97	0.009	2.25
Sex	Males	0.711	0.274	0.175, 1.247	6.75	0.01	2.04
Cavitated Caries Net-Incidence from 9 to 13	No Incidence	0.716	0.293	0.142, 1.290	5.98	0.02	2.05
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Days/week)	-	-0.100	0.042	-0.181, -0.019	5.81	0.02	0.91
Frequency of Consumption of Foods with Moderate Presumed Cariogenicity (AUC) (Days/week)	-	0.066	0.023	0.022, 0.110	8.56	0.01	1.07
Frequency of Consumption of Sugar-Free Beverages (AUC) (Days/Week)#	-	-0.119	0.046	-0.207, -0.030	6.89	0.01	0.89
Frequency of Daily Brushing (AUC) (Days/Week)	-	-0.692	0.276	-1.232, -0.152	6.29	0.02	0.50

#Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself

Logistic Regression Analyses: Two-Way Interactions

Table 4-45 summarizes the logistic regression results for two-way interaction effects tested individually on top of the main effects model relating net cavitated caries incidence to the independent variables in Table 4-44. Each two-way interaction effect was tested for addition to the base model with main effects of presence of surface zones with sealants, net cavitated caries incidence (Y/N) from 9 to 13, frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), frequency of consumption of foods predominant in added sugar (AUC) (days/week), frequency of consumption of foods with moderate presumed cariogenicity (AUC) (days/week), frequency of consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC) and daily tooth brushing frequency (AUC), respectively. Various combinations of types of variables, e.g., continuous with dichotomous, and dichotomous with dichotomous variables, were used in the analyses. In order to test the interaction effects, the variables frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), frequency of consumption of with moderate presumed cariogenicity (AUC) (days/week), and daily tooth brushing frequency (AUC) were dichotomized and categorized into new variables of frequency of foods predominant in natural sugar and fiber (AUC) (dichotomized as less than or equal to 5 days/week vs. more than 5 days/week), frequency of consumption of foods with moderate presumed cariogenicity (AUC) (dichotomized as 5 days/week or less vs. more than 5 days/week) and frequency of daily tooth brushing (AUC) (dichotomized as brushing twice daily or less vs. more than twice daily). Only the two-way interaction of presence of surface zones with sealants and sex was statistically significant at the $p<0.05$ level.

Table 4-45 Two-way interaction results of logistic regression model for cavitated caries incidence as the outcome variable

Variable 1	Reference	Variable 2	Reference	Estimate	SE	95% CI	Chi-Square	P-Value
Frequency of Daily Tooth Brushing (AUC) (Continuous)	-	Sex	0	-0.697	-0.547	1.768, 0.375	1.63	0.21
Presence of Surface Zones with Sealants	0	Sex	0	1.439	0.621	0.223, 2.655	5.38	0.03*
Sex	0	Cavitated Caries Incidence from 9 to 13	0	0.785	0.598	-0.388, 1.956	1.72	0.19
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/Week)	-	Sex	0	-0.105	0.077	-0.256, 0.046	1.87	0.18
Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Continuous)	-	Sex	0	-0.048	0.040	-0.125, 0.030	1.49	0.23
Frequency of Consumption of Sugar-Free Beverage (AUC) (Continuous) (Servings/ week)	-	Sex	0	-0.0003	0.010	-0.181, 0.181	0.00	1.00
Frequency of Daily Tooth Brushing (AUC) (Continuous)	-	Presence of Surface Zones with Sealants	0	0.101	0.583	-1.041, 1.243	0.03	0.87
Presence of Surface Zones with Sealants	0	Cavitated Caries Incidence from 9 to 13	0	-0.555	0.731	-1.987, 0.877	0.58	0.45

Variable 1	Reference	Variable 2	Reference	Estimate	SE	95% CI	Chi-Square	P-Value
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/Week)	-	Presence of Surface Zones with Sealants	0	0.074	0.097	-0.116, 0.264	0.58	0.45
Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Continuous)	-	Presence of Surface Zones with Sealants	0	-0.005	0.049	-0.100, 0.100	0.01	0.93
Frequency of Consumption of Sugar-Free Beverage (AUC) (Continuous) (Servings/ week)	-	Presence of Surface Zones with Sealants	0	0.124	0.128	-0.127, 0.374	0.93	0.34
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/Week)	-	Cavitated Caries Incidence from 9 to 13	0	0.006	0.079	-0.149, 0.160	0.00	0.95
Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Continuous)	-	Cavitated Caries Incidence from 9 to 13	0	-0.009	0.044	-0.094, 0.078	0.04	0.85
Frequency of Consumption of Sugar-Free Beverage (AUC) (Continuous) (Servings/ week)	-	Cavitated caries Incidence from 9 to 13	0	0.043	0.099	-0.151, 0.236	0.19	0.67

Variable 1	Reference	Variable 2	Reference	Estimate	SE	95% CI	Chi-Square	P-Value
Frequency of Daily Tooth Brushing (AUC) (Continuous)	-	Cavitated Caries Incidence from 9 to 13	0	-0.031	0.626	-1.257, 1.197	0.00	0.97
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/Week)	-	Frequency of Daily Tooth Brushing (AUC) (Dichotomized as brushing twice daily or less vs. more than twice daily)	0	0.017	0.055	-0.091, 0.124	0.09	0.77
Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Continuous)	-	Frequency of Daily Tooth Brushing (AUC) (Dichotomized as brushing twice daily or less vs. more than twice daily)	0	0.008	0.016	-0.024, 0.038	0.21	0.66
Frequency of Consumption of Sugar-Free Beverage (AUC) (Continuous) (Servings/ week)	-	Frequency of Daily Tooth Brushing (AUC) (Dichotomized as brushing twice daily or less vs. more than twice daily	0	0.048	0.094	-0.137, 0.231	0.25	0.62
Frequency of Daily Tooth Brushing (AUC) (Continuous)	-	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Dichotomized as 5 days/week or less vs. more than 5 days/week))	0	0.221	0.227	-0.224, 0.666	0.95	0.34

Variable 1	Reference	Variable 2	Reference	Estimate	SE	95% CI	Chi-Square	P-Value
Frequency of Daily Tooth Brushing (AUC) (Continuous)	-	Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Dichotomized as less than or equal to 25 days/week vs. more than 25 days /week)	0	-0.019	0.233	-0.048, 0.438	0.01	0.94
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (days/week)	-	Cavitated Caries Incidence from 9 to 13	0	0.006	0.079	-0.149, 0.160	0.00	0.95
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (days/week)(AUC) (Continuous)	-	Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Dichotomized as less than or equal to 25 days/week vs. more than 25 days /week)	0	0.014	0.055	-0.094, 0.121	0.06	0.81
Frequency of Consumption of Foods with Presumed Modified Cariogenicity (AUC) (Continuous)	-	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Dichotomized as 5 days/week or less vs. more than 5 days/week)	0	0.013	0.012	-0.019, 0.044	0.64	0.43

Variable 1	Reference	Variable 2	Reference	Estimate	SE	95% CI	Chi-Square	P-Value
Frequency of Consumption of Sugar-Free# Beverage (AUC) (Continuous) (Servings/ week)	-	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Dichotomized as 5 days/week or less vs. more than 5 days/week)	0	0.123	0.077	-0.029, 0.273	2.54	0.12

*Interaction was significant at $p<0.05$.

Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself.

Multivariable Negative Binomial Regression Main Effects Results

Table 4-46 summarizes the results of multivariable negative binomial regression analyses relating independent variables to net cavitated caries increment count. The model began with a total of twelve variables, as they met the inclusion criterion for multivariable analyses, i.e., all the included variables had p<0.15 in the bivariate analyses. The variables included were daily fluoride intake from water (mg F/Day) (AUC), dental visit (AUC) (proportion of visits), three categories of socioeconomic status (low, middle, high), daily brushing frequency (AUC), frequency of consumption of beverages with added sugar (AUC) (servings/week), frequency of consumption of milk (AUC) (servings/week), frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), frequency of high cariogenicity solid food consumption (AUC) (days/week), frequency of consumption of foods predominant in added sugars (AUC) (days/week), presence of surface zones with sealants, baseline age (age 13) (decimal years), and net cavitated caries increment count from 9 to 13.

The backward elimination technique was used to remove the least significant variables. Variables eliminated sequentially from each step of the model were frequency of consumption of high cariogenicity category foods (AUC) (days/week) (p=0.52), frequency of beverages with added sugar (AUC) (p=0.88), frequency of consumption of milk (AUC) (p=0.30), socioeconomic status categories (low, middle, high) (p=0.11), dental visit (AUC) (p= 0.17), and daily brushing frequency (AUC) (p=0.10). The trimmed model comprised of six variables.

The main effects regression model found net cavitated caries increment count was related to daily fluoride intake from water (AUC) (mg F/day), presence of surface zones with sealants (Y/N), baseline age (age 13 in decimal years), cavitated caries increment count from 9 to 13, frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), and frequency of consumption of foods predominant in added sugar (AUC) (days/week). For subjects with one additional mg of daily fluoride intake from water, the surface level net cavitated caries incidence rate was 0.50 times as high as for those with lower daily fluoride intake from water (mg F/day). For subjects with sealants, the surface level net cavitated caries incidence rate was 2.35 times as high as for those without sealants. For subjects who were one year older at the baseline exam, the surface level net cavitated caries incidence rate was 1.50 times as high as for those with lower baseline age. For subjects with one additional surface of net cavitated caries increment from 9 to 13, the surface level net cavitated caries incidence rate from 13 to 17 was 1.18 times as high as for those with lower increment from 9 to 13. For subjects who consumed foods predominant in natural sugar and fiber (AUC) for one additional day/week, the surface level net cavitated caries incidence rate was 0.94 times as high as for those with lower consumption. For subjects who consumed foods predominant in added sugar (AUC) one additional day/week, the surface level net cavitated caries incidence rate was 1.11 times as high as for those with lower frequency of consumption

Table 4-46 Main effects model for negative binomial regression relating net cavitated caries increment count and independent variables

Parameter	Adjusted Beta Coefficients	SE	95% CI	Chi-Square	P-Value	IRR
Daily Fluoride Intake from Water	-0.6953	2.578	-1.283, -0.108	5.38	0.03*	0.50
Presence of Surface Zones of Sealants	0.8525	0.228	0.407, 1.299	14.05	0.002*	2.35
Baseline Age	0.4517	0.192	0.076, 0.828	5.54	0.02*	1.50
Cavitated Caries Net-Increment from 9 to 13	0.1695	0.051	0.071, 0.268	11.38	0.0007*	1.18
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC)	-0.0686	0.029	-0.125, -0.013	5.68	0.02*	0.94
Frequency of Consumption of Foods Predominant in Added Sugar (AUC)	0.1043	0.035	0.037, 0.172	9.16	0.003*	1.11

*Association was significant at $p<0.05$.

Negative Binomial Regression-Two Way Interactions

Table 4-47 summarizes negative binomial model results of the two-way interaction effects tested individually on top of the main effects model relating net cavitated caries increment count to the independent variables in Table 4-46. Each two-way interaction effect of statistically significant main effects was tested separately for addition to the base model with the main effects shown in Table 4-46. Various combinations of types of variables, e.g., continuous and dichotomous and dichotomous and dichotomous variables, were used in the analyses.

In order to test interaction effects, the continuous variables of daily fluoride intake from water (mg F/day) (AUC), baseline age (age 13) (decimal years), frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week) and frequency of consumption of foods predominant in added sugar (AUC) (days/week) were dichotomized into new variables such as daily fluoride intake from water (AUC) (dichotomized as ≤ 3.0 vs. 3.0 or more) baseline age (age 13) (dichotomized 13.2 or less vs. greater than 13.2), frequency of intake of foods predominant in natural sugar and fiber (AUC) (dichotomized as less than or equal to 5 days/week vs. more than 5 days/week) and frequency of consumption of foods predominant in added sugar (AUC) (dichotomized as 5 days/week or less vs. more than 5 days/week).

Only the interaction effects of frequency of consumption of foods predominant in added sugar (AUC) (continuous) (days/week) and net cavitated caries incidence from 9 to 13 as a dichotomous outcome (0 vs. 1+) and baseline age and cavitated caries increment count from 9 to 13 as a dichotomous outcome (0 vs. 1+) were statistically significant at $p<0.05$.

Table 4-47 Two-way interaction results of negative binomial regression model for net cavitated caries increment count as the outcome variable

Variable 1	Ref.	Variable 2	Ref.	Estimates	SE	95% CI	Chi-Square	P-Value
Baseline Age (Decimal years)	-	Presence of Surface Zones with Sealants	0	-0.266	0.495	-1.235, 0.703	0.29	0.60
Net Cavitated Caries Increment from 9 to 13 (Count)	0	Presence of Surface Zones with Sealants	0	-0.011	0.152	-0.307, 0.287	0.00	0.95
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/week)	-	Presence of Surface Zones with Sealants	0	0.034	0.080	-0.122, 0.189	0.18	0.68
Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Continuous) (Days/week)	-	Presence of Surface Zones with Sealants	0	-0.071	0.078	-0.223, 0.083	0.81	0.37
Baseline Age (Decimal years)	-	Frequency of Consumption of foods Predominant in Added Sugar (AUC) (Dichotomized as less than or equal to 5 days/week vs. more than 5 days/week)	0	-0.031	0.024	-0.076, 0.016	1.70	0.20
Baseline Age (Decimal years)	-	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Dichotomized as 5 days/week or less vs. more than 5 days/week)	0	0.019	0.021	-0.023, 0.060	0.78	0.38

Variable 1	Ref.	Variable 2	Ref.	Estimates	SE	95% CI	Chi-Square	P-Value
Cavitated Caries Increment from 9 to 13 (Count)	-	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Dichotomized as 5 days/week or less vs. more than 5 days/week)	0	-0.026	0.103	-0.223, 0.176	0.06	0.81
Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Continuous) (Days/week)	0	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Dichotomized as 5 days/week or less vs. more than 5 days/week)	0	0.064	0.044	-0.023, 0.150	2.10	0.15
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/week)	-	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Dichotomized as less than or equal to 5 days/week vs. more than 5 days/week)	0	-0.010	0.041	-0.090, 0.071	0.06	0.82
Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (AUC) (Continuous) (Days/week)	-	Cavitated Caries Increment from 9 to 13 as a Dichotomous Outcome (0 vs 1+)	0	0.062	0.040	-0.017, 0.140	2.37	0.13
Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Dichotomized as less than or equal to 5 days/week vs. more than 5 days/week)	0	Cavitated Caries Increment from 9 to 13 (Count)	0	0.020	0.098	-0.173, 0.212	0.04	0.85

Variable 1	Ref.	Variable 2	Ref.	Estimates	SE	95% CI	Chi-Square	P-Value
Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Continuous) (Days/week)	-	Cavitated Caries Increment from 9 to 13 as a Dichotomous Outcome (0 vs 1+)	0	0.087	0.041	0.007, 0.167	4.48	0.04*
Baseline Age (Decimal years)	-	Cavitated Caries Increment from 9 to 13 as a Dichotomous Outcome (0 vs 1+)	0	0.055	0.020	0.016, 0.094	7.72	0.006*
Baseline Age (Dichotomized as 13.2 or less vs. greater than 13.2)	0	Cavitated Caries Increments from 9 to 13 (Count)	-	0.065	0.102	-0.135, 0.264	0.40	0.53
Baseline Age (Dichotomized as 13.2 or less vs. greater than 13.2)	0	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Continuous) (Days/week)	-	0.067	0.042	-0.015, 0.148	2.58	0.11
Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	-	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Dichotomized as less than or equal to 5 days/week vs. more than 5 days/week)	0	0.106	0.284	-0.450, 0.660	0.14	0.72
Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Dichotomized as less than or equal to 5 days/week vs. more than 5 days/week	0	0.291	0.308	-0.314, 0.894	0.89	0.35

Variable 1	Ref.	Variable 2	Ref.	Estimates	SE	95% CI	Chi-Square	P-Value
Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	Cavitated Caries Increment from 9 to 13 as a Dichotomous Outcome (0 vs 1+)	0	0.131	0.318	-0.493, 0.754	0.17	0.69
Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	Cavitated Caries Increment from 9 to 13 (Count)	-	0.028	0.110	-0.189, 0.244	0.06	0.81
Baseline Age (Decimal years)	-	Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mgF/day)	-	0.014	0.022	-0.028, 0.057	0.41	0.53
Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	Presence of Surface Zones with Sealants	-	0.358	0.290	-0.210, 0.924	1.53	0.22
Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Continuous) (Days/Week)	0	Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	0.023	0.402	-0.057, 0.101	0.30	0.59
Baseline Age (Dichotomized as 13.2 or less vs. greater than 13.2)	0	Frequency of Consumption of Foods Predominant in Fiber and Natural Sugar (Continuous) (AUC)	0	0.066	0.039	-0.010, 0.141	2.90	0.09
Frequency of Consumption of Foods Predominant in Added Sugar (Continuous) (AUC) (Days/Week)	-	Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	0.039	0.046	-0.050, 0.128	0.74	0.40

Variable 1	Ref.	Variable 2	Ref.	Estimates	SE	95% CI	Chi-Square	P-Value
Daily Fluoride Intake from Water (AUC) (mg F/day)	-	Presence of Surface Zones with Sealants	0	0.813	0.829	-0.810, 2.436	0.96	0.33
Daily Fluoride Intake from Water (AUC) (mg F/day)	-	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Dichotomized as less than or equal to 5 Days/Week vs. more than 5 days/week)	-	0.103	0.506	-0.889, 1.095	0.04	0.84
Daily Fluoride Intake from Water (AUC) (mg F/day)	-	Frequency of Consumption of Foods Predominant in Natural Sugar and Fiber (AUC) (Dichotomized as less than or equal to 5 days/week vs. more than 5 days/week)	0	0.231	0.52	-0.782, 1.243	0.20	0.66
Daily Fluoride Intake from Water (AUC) (mg F/day)	-	Baseline Age (Decimal ears)	0	0.568	0.50	-0.410, 1.544	1.30	0.26
Daily Fluoride Intake from Water (AUC) (mg F/day)	-	Cavitated Caries Increment from 9 to 13 as a Dichotomous Outcome (0 vs 1+)	0	0.290	0.55	-0.783, 1.362	0.28	0.60
Fluoride Intake from Water (AUC) (Dichotomized as 3.0 or less vs. greater than 3.0)(mg F/day)	0	Baseline Age (Dichotomized as 13.2 or less vs. greater than 13.2)	0	0.360	0.28	-0.183, 0.894	1.67	0.20

*Interaction significant at p<0.05

Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself

Negative Binomial Regression-Three Way Interactions

Table 4-48 summarizes negative binomial model results of the three-way interaction effects tested individually on top of the main effects model relating net cavitated caries increment count to the independent variables in Table 4-47 and the significant two-way interaction effects. Each three-way interaction effect was tested on top of the main effects model variables in Table 4-46 and the significant two-way interactions of frequency of consumption of foods predominant in added sugar (AUC) (continuous) (days/week) and net cavitated caries increment from 9 to 13 as a dichotomous outcome (0 vs. 1+) and baseline age in decimal years and net cavitated caries increment count from 9 to 13 as a dichotomous outcome (0 vs. 1+).

Various combinations of variables, e.g., continuous and dichotomous, and dichotomous and dichotomous variables, were used in the analyses. In order to test interaction effects, the continuous variables such as daily fluoride intake from water (AUC) (mg F/day), baseline age (age 13) (decimal years), frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week) and frequency of consumption of foods predominant in added sugar (AUC) (days/week) were dichotomized to new variables of daily fluoride intake from water (AUC) (dichotomized as $\leqslant$ 3.0 vs. greater than 3.0), baseline age (dichotomized 13.2 or less vs. greater than 13.2), frequency of consumption of foods predominant in natural sugar and fiber (AUC) (dichotomized as less than or equal to 5 days/week vs. more than 5 days/week) and frequency of consumption of foods predominant in added sugar (AUC) (dichotomized as 5 days/week or less vs. more than 5 days/week), respectively. None of the three-way interactions was statistically significant at $p<0.05$.

Table 4-48 Three-way interaction results of negative binomial regression model for net cavitated caries increment count as the outcome variable

Variable 1	Ref.	Variable 2	Ref.	Variable 3	Ref.	Beta	SE	95% CI	Chi-Square	P-Value
Baseline Age (Decimal years)	-	Cavitated Caries Increment from 9 to 13 as a dichotomous outcome (0 vs 1+)	0	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Dichotomized as less than equal to 5 vs. more than 5) (days/week)	0	-0.023	0.038	-0.094, 0.053	0.30	0.59
Baseline Age (Decimal years)	-	Cavitated Caries Increment from 9 to 13 as a Dichotomous Outcome (0 vs 1+)	0	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Continuous) (days/week)	0	0.021	0.078	-0.132, 0.172	0.07	0.80
Baseline Age (Dichotomized as 13.2 or less vs. greater than 13.2)	-	Cavitated Caries Increment from 9 to 13 as a dichotomous outcome (0 vs 1+)	0	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Continuous) (days/week)	0	0.023	0.055	-0.085, 0.130	0.16	0.69
Baseline Age (Dichotomized as 13.2 or less vs. greater than 13.2)	-	Cavitated Caries Increment from 9 to 13 as a dichotomous outcome (0 vs 1+)	0	Frequency of Consumption of Foods Predominant in Added Sugar (AUC) (Dichotomized as less than equal to 5 vs. more than 5) (days/week)	0	0.058	0.460	-0.957, 0.841	0.02	0.90

*Interaction significant at $p<0.05$

Multivariable Logistic Regression: Final Model

Table 4-49 summarizes the results for the multivariable logistic regression analyses, with adjusted regression coefficients and p-values for the significant main effects and 2-way interactions related to net cavitated caries incidence. This model was built upon the trimmed model shown in Table 4-44 with added interaction effects and so is comprised of the five main effects and one significant two-way interaction. The variables in the final model were sex (p=0.48), daily brushing frequency (AUC), (p=0.02), presence of surface zones with sealants (p=0.80), net cavitated caries incidence from 9 to 13 (p=0.0093), frequency of consumption of foods predominant in natural sugar and fiber (AUC) (p=0.03), frequency of consumption of foods with moderate presumed cariogenicity category (AUC)(p=0.0043), frequency of consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC) (p=0.0092), and the interaction effect between presence of surface zones with sealants and sex (p= 0.0204).

Table 4-49 Final model for multivariable logistic regression analyses for net cavitated caries incidence

Parameter	Reference	Adjusted Regression Coefficient Estimates	SE	95% CI	Chi-Square	P-Value	OR
Sex	Male	-0.3894	0.548	-1.463, 0.684	0.51	0.48	0.68
Daily Brushing Frequency (AUC)	-	-0.7139	0.282	-1.266, -0.163	6.45	0.02*	0.49
Presence of Surface Zones with Sealants	No sealants	0.1084	0.423	-0.721, 0.938	0.07	0.80	1.12
Net Cavitated Caries Incidence From 9 to 13 (Yes/No)	No	0.7767	0.299	0.192, 1.362	6.77	0.01*	2.18
Frequency of Consumption (AUC) of Foods Predominant in Natural Sugar and Fiber	-	-0.0969	0.042	-0.180, -0.015	5.34	0.03*	0.91
Frequency of Consumption (AUC) of Foods with Moderate Presumed Cariogenicity Category	-	0.0650	0.023	0.021, 0.110	8.15	0.005*	1.07
Frequency of Consumption (AUC) of Sugar-Free Beverages	-	-0.1181	0.046	-0.207, -0.030	6.78	0.01*	0.89
Interaction Of Sex with Presence of Surface Zones with Sealants	No sealants	1.4382	0.621	0.223, 2.655	5.38	0.02*	-

*Association was statistically significant at p<0.05

#Sugar-free beverage category is defined as beverages without added sugar, including 100% juice, but no water by itself.

Table 4-50 summarizes the probabilities of events involved in the interaction of sex with presence of surface zones with sealants. The predicted probability that males without sealants had caries incidence was 0.57, and the probability that males with sealants had caries incidence was 0.59. The probability that females without sealants had caries incidence was 0.47, and the probability that females with sealants had caries incidence was 0.81. The method of obtaining probabilities is described later (Appendix L). The derived odds ratio can be interpreted as follows: the odds of caries incidence among females with sealants were 4.70 times the odds of caries incidence among females without sealants. The odds of caries incidence among males with sealants were 1.12 times the odds of caries incidence among males without sealants. The odds of caries incidence among females with sealants were 2.86 times the odds of caries incidence among males with sealants. The odds of caries incidence among females without sealants were 0.68 times the odds of caries incidence among males without sealants.

Explaining the interaction: The interaction effect shows that, for males with presence of sealants at the baseline exam, the probability of net cavitated caries incidence was greater (0.59) than among males without any sealants (0.57). However, this difference was very small. In contrast, for females with presence of sealants at the baseline exam, the probability of net cavitated caries incidence was much greater (0.81) than among females without sealants (0.47).

Among males, there was a modest difference between the probabilities of net cavitated caries incidence among subjects with and without any sealants- indicating that having sealants did not substantially alter the probability of cavitated caries incidence from 13 to 17. In contrast, among females, the probability of net cavitated caries incidence from 13 to 17 for those with sealants was almost twice (1.73 times) as high- indicating that, for females, having sealants was associated with significantly increased probability of net cavitated caries incidence from 13 to 17.

The reparametrization analyses showed that females with sealants were more likely to have cavitated caries incidence from 13 to 17 when compared with females without sealants (coefficient = 1.5322, p=0.0008). In addition, it was found that there was no statistically significant effect of presence of sealants in males (coefficient = 0.1231, p=0.7712), indicating the likelihood of cavitated caries incidence from 13 to 17 was not significantly different for males with sealants and those without sealants. It also indicated that the slope for the effect of males with sealants was close to zero and for females with sealants was strongly positive, as seen in Figure 4-1

Table 4-50 Probability values for caries incidence among male and female subjects with and without sealants.

Sex	Sealants	
	No	Yes
Males	0.57	0.59
Females	0.47	0.81

Figure 4-1 shows a graphical representation of the interaction effect for sex and presence of surface zones with sealants.

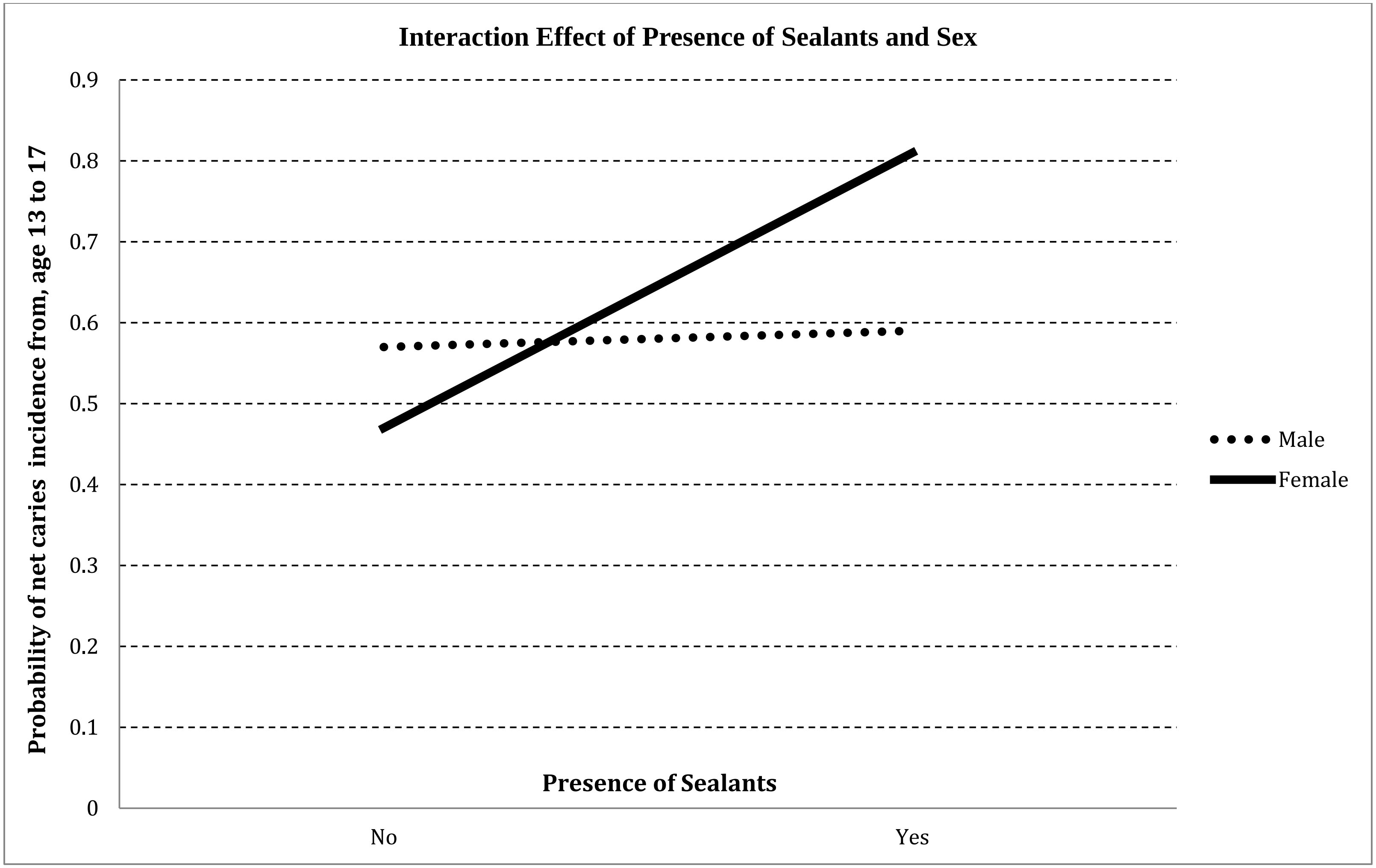


Figure 4-1 Interaction effect for sex and presence of surface zones with sealants

Multivariable Negative Binomial Regression with Interaction Effect: Final Model

Table 4-51 summarizes negative binomial model results for the final model relating net cavitated caries increment count to the independent variables in Table 4-46. The significant two-way interaction effects were tested using backward stepwise elimination on top of the main effects of daily fluoride intake from water (mg F/day) (AUC), presence of surface zones with sealants (Y/N), baseline age (age 13) (decimal years), net cavitated caries increment count from 9 to 13, frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week), and frequency of consumption of foods predominant in added sugar (AUC). The interaction effects between net cavitated caries incidence from 9 to 13 and frequency of consumption of foods predominant in added sugar (AUC) (days/week) (p=0.84) and the main effect of daily fluoride intake from water (AUC) (mg F/day) (p=0.14) lost significance and were removed sequentially, resulting in the final model with five variables and one significant interaction effect.

The variables in the final model were presence of surface zones with sealants (p=0.0006), baseline age (age 13) (decimal years) (p=0.07), increment count from 9 to 13 (p=0.67), frequency of consumption of foods predominant in natural sugar and fiber (AUC) (days/week) (p=0.03), frequency of consumption of foods predominant in added sugar (p=0.007) (AUC) (days/week) and the interaction between baseline age in decimal years and dichotomized net cavitated caries incidence from 9 to 13 (Y/N) (p=0.002).

Table 4-51 Final model for multivariable negative binomial regression for cavitated caries increment count as the outcome

Parameter	Reference	Regression Coefficient Estimates	SE	95% CI	Chi-Square	P-Value	IRR
Presence of Surface Zones with Sealants (Y/N)	No Surface Zones with Sealants	0.7743	0.23	0.334, 1.214	11.89	0.0006*	2.17
Baseline Age (Decimal years)	-	0.3538	0.19	-0.020, 0.728	3.45	0.07	1.42
Net Cavitated Caries Increment Count from 9 to 13	-	0.0268	0.06	-0.094, 0.148	0.19	0.67	1.03
Frequency of Consumption of Solid Foods with Natural Sugar and Fiber (AUC)	-	-0.0651	0.03	-0.121, -0.010	5.27	0.03*	0.94
Frequency of Consumption of Solid Foods with Added Sugar (AUC)	-	0.0923	0.04	0.026, 0.159	7.40	0.007*	1.10
Interaction between Baseline Age and Net Cavitated Caries Incidence from 9 to 13	Positive Net Cavitated Caries Incidence from 9 to 13	0.0623	0.02	0.025, 0.101	10.24	0.002*	-

*Association was statistically significant at p<0.05.

Table 4-52 summarizes the results for multivariable negative binomial regression analyses for the estimates of net cavitated caries increment count from 13 to 17 for minimum and maximum values of baseline age. The estimates are the result of the interaction effect seen between the variables net cavitated caries incidence from 9 to 13 and baseline age (AUC).Figure 4-2 shows a graphical representation of the interaction effect between baseline age and 9 to 13 incidence.

Explanation of the interaction effect: For subjects with cavitated caries incidence from 9 to 13 and with lower baseline age, the surface level net cavitated caries increment count estimates were greater (0.67) than the surface level net cavitated caries increment count estimates among subjects without cavitated caries incidence from 9 to 13 (0.31). However, this difference was relatively small. In contrast, for subjects with net cavitated caries incidence from 9 to 13 and with higher baseline age, the net cavitated caries increment count estimate was much greater (1.90) than the net cavitated caries increment count estimate among subjects without cavitated caries incidence from 9 to 13 (0.73).

Among those with lower baseline age (12.4 years), there was a modest difference between net cavitated caries increment count estimates from 13 to 17 for the subjects with and without cavitated caries incidence from 9 to 13—indicating that with lower baseline age, having positive 9 to 13 net cavitated caries incidence did not substantially alter the number of net cavitated caries increments from 13 to 17. In contrast, for those with higher baseline age (14.9) the difference between net cavitated caries increment count estimate from 13 to 17 for subjects with and without cavitated caries incidence from 9 to 13 were much greater, indicating that with higher baseline age, having positive

9 to 13 net cavitated caries incidence was substantially more strongly associated with increased severity of net cavitated caries from age 13 to 17.

The reparametrization analyses showed that the effect of age was statistically significant and positive for subjects with and without net cavitated caries incidence from 9 to 13, confirming that greater baseline age was associated with greater net cavitated caries increment count. However, when tested, the main effect of baseline age on subjects with cavitated caries incidence from 9 to 13 was higher (coefficient=0.4649, p=0.0115) than the main effect of baseline age on subjects without cavitated caries incidence from 9 to 13 (coefficient=0.4071, p=0.0275). It also showed that the slopes were not the same and lines not parallel for the effect of greater baseline age, for those with and without cavitated caries incidence from 9 to 13, respectively, indicating a difference in the two effects. While both the slopes for effect of greater baseline age were positive, the slope was steeper for those with net cavitated caries incidence from 9 to 13 when compared with those without net cavitated caries incidence from 9 to 13.

Table 4-52 Negative binomial regression results for estimates of cavitated caries incidence for range of baseline age

Cavitated Caries Incidence from 9 to 13	Baseline age	
	Minimum Age	Maximum Age
No	0.31	0.73
Yes	0.67	1.90

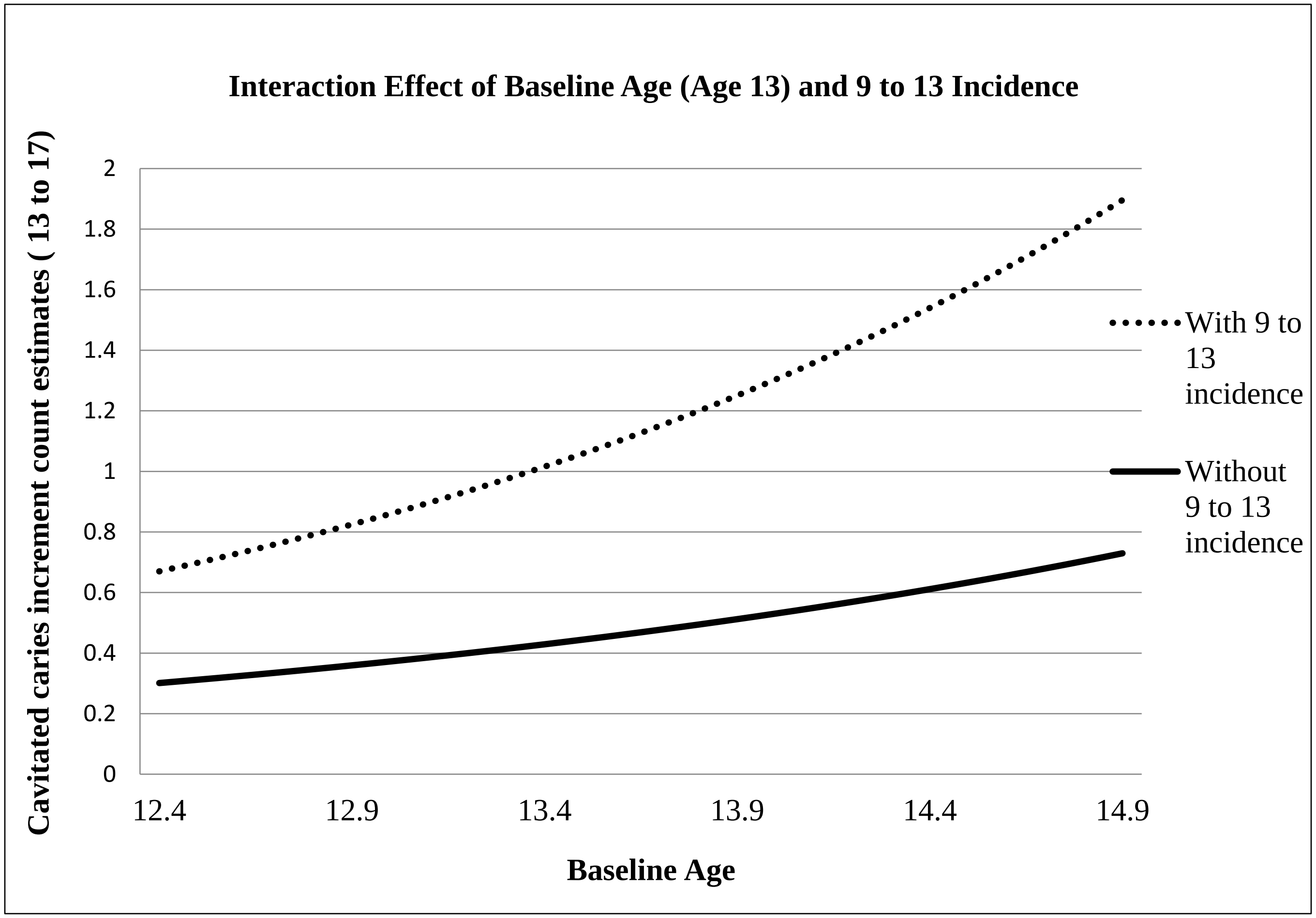


Figure 4-2 Interaction effect for baseline age and 9 to 13 incidence

CHAPTER 5

DISCUSSION

Introduction

Dental caries among adolescents has been an issue of concern in the United States for a long time. From 1999-2004, the National Health and Nutrition Examination Survey (NHANES) showed a 59% prevalence of caries experience among 12 to 19 year old adolescents and that 20% had untreated decay. The effects of dental caries on oral health quality of life and systemic health of adolescents have also been documented (Biazevic et al, 2008). The impact of dental caries in adolescents, coupled with high caries prevalence, makes it essential to understand the risk factors associated with cavitated caries in the U.S. adolescent population. Various studies have sought to investigate risk factors for caries in adolescents. However, due to the cross-sectional nature of these studies, causality cannot be determined. Studies on longitudinal associations of risk factors and dental caries in adolescents are rare and the findings provide inconsistent results, due in part to differences in analytical designs, age distributions of the subjects, study populations, risk factor definitions, periods of observation and outcome definitions. The purpose of this study was to assess risk factors for cavitated caries in adolescents from age 13 to age 17 by conducting secondary analyses of the Iowa Fluoride Study data.

Iowa Fluoride Study

The Iowa Fluoride Study is a longitudinal study that recruited a birth cohort in 1992-95 from hospital postpartum wards and has continued to follow them into early adulthood. During its early stages, the primary aim of the study was to determine fluoride intake of participants and the associations with dental fluorosis, after which the focus broadened to include dental caries patterns and examination of risk factors for dental caries, including in adolescence. The data for the study were collected prospectively as subjects were examined to assess disease prevalence at ages 5, 9, 13 and 17. The prospective design of the cohort study has enabled assessment of incidence and possibly causal risk factors due to the temporal sequence between risk factor exposures and outcomes. Another advantage of the study is the nature of data collected. The IFS dietary data were collected using three-day food and beverage diaries initially and then using validated semi-annual Iowa Fluoride Study questionnaires, from age 9 onwards. These data assessed longitudinal exposures of risk factors such as fluoride intake and dietary intake (foods and beverages) in detail and also enabled in-depth assessments of exposure to in-office and at home use of topical fluorides, dental visits, and oral hygiene habits such as frequency and duration of brushing. Rarely has such detailed data on risk factors been collected.

Limitations of the IFS

In spite of several advantages, there are certain limitations to the study. The IFS study subjects are a relatively homogeneous group with mostly non-Hispanic White subjects belonging to middle and high SES backgrounds based mostly in Iowa, thus limiting the generalizability of the study findings. As the baseline caries levels were low in this sample, the findings cannot be generalized to those with extremely high caries risk or low SES children from vulnerable and disadvantaged populations. The present study failed to collect data on upstream determinants such as neighborhood, or community level influences, e.g., presence of community prevention programs, unmet dental need in the community or other dental care system characteristics, social environment, and social capital. The study did not use radiographs to assess caries measures, specifically for proximal surfaces; therefore, it is probable that the caries levels among IFS subjects were underestimated. In spite of the advantages of the longitudinal nature of the study, there was loss to follow-up and missing responses in the questionnaire data and the subjects having variation in the actual exam ages. Also, data on salivary flow, S.*mutans* and other bacteria and plaque levels were not collected.

Iowa Fluoride Study Questionnaires

For the present analyses, the data were collected from the validated Iowa Fluoride Study Questionnaires (IFS questionnaire) and Block Kids Food Frequency Questionnaires (Block questionnaire). The present study used data collected from semi-annual IFS questionnaires to estimate fluoride intake from water, beverages, selected foods with added water, dietary fluoride supplements, and dentifrices, as well as fluoride mouthrinse at home/school, respectively, along with dental visit histories, history of professional fluoride application, multivitamin supplement intake, and oral hygiene behaviors of brushing frequency and duration.

The advantages of using the IFS questionnaires were that extensive and detailed information was collected over a period of up to 22 years for actively participating subjects of the study. In addition, investigators could not identify the diseased vs. non-diseased subjects who were exposed vs. unexposed to risk factors beforehand; thus, the extent of information collected was the same for both groups, leading to prevention of information bias. While frequent and detailed data collection through the semi-annual IFS questionnaires was possible, completing a substantial number of questionnaires was challenging, as subjects found it difficult to complete each questionnaire, thus leading to some missing responses. The IFS questionnaire also did not provide comprehensive information for consumption of solid foods because it was originally designed to assess dietary fluoride intake mostly from beverages.

Block Kids Food Frequency Questionnaire

The present study also used Block Kids Food Frequency questionnaire responses that were originally used to collect data on macronutrients, vitamin D (I.U.), calcium and other minerals (intakes of subjects enrolled in the Iowa Bone Development Study, an ancillary study to the IFS).

The Block questionnaire responses were divided into two parts- solid foods (65 items) and beverage (10 items) consumption, respectively. Based on their presumed cariogenicity and nutrient content, the sixty-five solid food items were categorized into seven discrete and mutually exclusive categories: low presumed cariogenicity based on protein and fat content, low presumed cariogenicity based on fiber and low natural sugar content, moderate presumed cariogenicity based on high natural sugar content, moderate presumed cariogenicity based on starch and protein content, moderate presumed cariogenicity based on starch content, high presumed cariogenicity based on both sugar and starch content, and high presumed cariogenicity based on added sugar content. The beverages were divided into three categories based on presumed cariogenicity: low for milk, moderate for 100% juice and high for sugared beverages.

Previous studies mostly assessed individual solid food item consumption in association with dental caries in adolescents (Clancy et al, 1977), or assessed relationships between caries incidence and food groups and food items simultaneously (Petridou et al, 1996). In rare cases, where categorizes of solid foods were defined, they were mainly based on percentage of sugar and percentage of starch in the foods (Campain et al, 2003), or nature of events, e.g., sugar event, starch event, confectionary event, along with total intake of sugar, starch and carbohydrates in gm/per day, respectively (Rugg-Gunn et al, 1984 and Beighton et al, 1996). Some studies also considered a common assessment of solid and beverage items, testing their associations with dental caries among adolescents (Rugg-Gunn et al, 1984; Campain et al, 2003) and some recent ones focused solely on systematic beverage categories (Chankanka et al, 2011 and Auad et al, 2009). The aims of the present categorization of solid food items were to map the intake of sugar and starch foods, as considered in previous studies, and to evaluate the intakes of food items predominant in other macronutrients such as protein and fats. The present analyses also considered frequency of intake of foods predominant in more than two macronutrient categories (fat and protein; protein and starch, starch and sugar, etc.). Another objective of the categorization of solid foods was to assess the presumed cariogenicity potential of these Block questionnaire solid food categories and to determine their relationships with caries incidence - an approach suggested by Palmer et al (2010) to study risk factors in severe early childhood caries. An advantage of this categorization was that it helped in understanding the differences in effects of frequency of consumption of foods predominant in added sugar and natural sugar, respectively. The approach for solid food categories has also been emphasized by Evans et al (2013) in a paper proposing the pediatric cariogenicity index. This approach was previously investigated with the IFS study subjects for early-childhood and pre-adolescent net cavitated caries analyses (Chankanka et al, 2011) with a focus on beverage categories, i.e., those with added sugar and those with natural sugar. Moreover, these analyses are some of the first to have a longitudinal approach in investigating the relationships between adolescent net cavitated caries incidence and systematically defined beverage and solid food categories along with other important demographic, oral hygiene, fluoride, dental visit, topical fluoride, sealant and previous caries incidence variables.

For the seven solid food categories, each category was comprised of many food items. The consumption of all of the food items in each discrete category was assessed in days per week; as a result, it was probable that the frequency of consumption for each presumed category of solid food could be greater than 7 days/week. Similarly, it was also possible that the frequency of consumption of beverages and combined categories of solid foods, respectively, as determined from the Block questionnaires, could be greater than 7 days/week.

Comparison of Beverage Intake from IFS and Block Questionnaires

In order to compare the frequency of consumption of beverages assessed with the Block questionnaire and the IFS questionnaire, the units for frequency of consumption of beverages from the IFS questionnaire were defined in servings/week. This was done so that the frequency of consumption of beverages assessed with Block questionnaires in days/week and the IFS questionnaires in servings/week, respectively, had “week” as a common denominator. The IFS questionnaire variables were reported in servings per week derived by multiplying the frequency per day (servings/day) by seven. It is appropriate that the values for frequency of consumption of beverages from IFS questionnaire could be greater than seven servings/week, as it was assumed that subjects could have more than one serving per day.

As reported earlier, frequency of consumption of Block questionnaire beverage and solid food variables was reported in number of days, and not number of servings. Thus, servings on separate days would count for greater frequency of consumption of beverages and solid foods in one given category than for the same number of servings all on a single day. Also, with a number of sub-categories in a given category, the overall frequency of consumption could be greater than 7 days/week, since the sub-categories were summed separately into the broader category. Thus, differences observed in the frequency of consumption of the Block questionnaire and beverage variables and IFS questionnaire beverage variables were due in part to the differences in the two questionnaires.

Inclusion Criteria

A major limitation was that the subjects in these analyses were required to complete at least 10 IFS questionnaires and 2 Block questionnaires during the observation period from age 13 to 17.5 years. This led to missing responses on some of the questionnaires. To account for these missing responses and to reduce resultant bias due to missing responses, a set of inclusion criteria were used for subjects to be included in these analyses. The subjects were required to have a given set of responses for age 13.0 to 17.5 year Iowa Fluoride Study questionnaires and 13 to 17 years Block questionnaire, respectively, to reflect the exposures and possible changes over time observed from age 12.5 to 17.5 years. With intent to include important information about the initial, middle and final phases of the observation period, the response period was divided into three sub-periods- early, middle and late, respectively. The advantages of these inclusion criteria were that the extent of information on exposures was roughly the same for all subjects and a broad range of exposure periods were covered. This enabled a better understanding of the exposure to risk and protective factors during given interval of time.

Area-Under-the-Curve

The trapezoidal method of area-under-the-curve (AUC) was used to obtain a weighted average for each of the following: fluoride intake from combined sources, fluoride intake from water, composite water fluoride level, duration and frequency of brushing, proportions of 6-month periods with topical fluoride application and dental visits, respectively, frequency of beverage consumption (both IFS and Block questionnaire), and frequency of solid food consumption (Block questionnaire). AUC estimates were divided by the time interval so the AUC for each of the continuous variables was the average exposure across the data points from about age 13.0 to 17.5 for the IFS questionnaires and age 13.0 to 17.0 for the Block questionnaires. A significant advantage of using AUC is that it enables deriving an estimate across the broader period encompassing the three response periods by joining the available time points. It should be remembered, however, that the AUC cannot assign or attribute a value to the missing response itself.

Sample Size

Parents of 1,882 children provided consent to participate in the study, of which 1,382 gave a response to the first IFS questionnaire. Of the subjects examined at the age 13 dental exam (550), 444 subjects also had the age 17 dental exam. The sample of 303 for these analyses represented 22% of the subjects in the IFS study (1,382) at age 6 months and 74% of those who had both age 13 and 17 exams (N=408). When assessed statistically, there were no significant differences among subjects included and excluded from the present analyses for levels of maternal education, family income or baseline exam (age 13) caries levels.

Outcome Variables

In the present study, the associations between net cavitated caries increment from age 13 to 17 and risk factors were examined using two sets of outcome variables, i.e., dichotomous person level net cavitated caries incidence (Y/N) and surface level net cavitated caries incidence (discrete count). This permitted the study of incidence of net cavitated caries and extent of net cavitated caries in the IFS study sample. The diagnosis of net cavitated caries was done as defined in criteria by Warren et al (2002), which are a modification of Pitts' criteria (Pitts and Fyffe, 1988, Pitts 1997). These criteria enabled more successful calibration of examiners to classify both net cavitated enamel and dentin lesions in a single combined category- substantially reducing the measurement bias.

Independent Variables

Demographic

The demographic variables were defined using the IFS demographic questionnaire responses collected in 2007. A rationale for using the responses from the IFS 2007 questionnaire was to use information that is more recent on levels of maternal education and family income when compared with those obtained at the time of recruitment (1992-95). Socioeconomic status category was a composite variable based on subjects' maternal education and family income level. It has been documented that socioeconomic status categories can be best defined by using individual-based measures (The Measurement of Socioeconomic Status for the Reporting of Nationally Comparable Outcomes of Schooling, Marks et al, 1983).

The use of this individual-based measure prevented misclassification bias and ecological fallacy that often surface with the use of area-based/group-based estimates. An advantage of defining socioeconomic status by considering both maternal education and family income was that it captured the overall aspect of economic background. However, the presence of the majority of subjects with higher maternal education and relatively higher family incomes resulted in varied numbers in the different categories, so the split was less favorable, thus limiting statistical power.

The variables baseline age (age ~13) and final age (age ~17) were defined as the chronological age at the time of age 13 and age 17 dental examinations, respectively. The median baseline age was 13.2 years and the range of baseline age was 12.4 to 14.9 years. The median final exam age was 17.5 years and the range was 16.8 to 18.5 years. The range of length of interval between the age 13 and age 17 exams was 3.0 to 5.0 years with median interval of 4.20 years.

Oral Hygiene Variables

Daily brushing frequency was defined as a continuous variable. The median daily brushing frequency was 1.78 times/day and most children brushed their teeth more than once per day. Although the effects of greater daily toothbrushing could be studied using this definition, it was not possible to separately compare the effects of once vs. twice vs. three times daily brushing on net cavitated caries incidence and increment, respectively, due to overall small sample size and lower power. Daily brushing duration was defined as a continuous variable from reported responses in minutes/day, which has been used earlier (Gallagher et al, 2009; Wainwright & Sheiham, 2014).

Fluoride Variables

Fluoride intake from water (AUC), total fluoride intake from combined sources (AUC) and composite water fluoride level (AUC) were defined as continuous variables and represented the weighted average estimates of intake of fluoride from water, the total fluoride intake from beverages and solid foods containing water, and the water fluoride level from all reported water sources, respectively. The variable fluoride intake from water (AUC) was defined as the weighted average of the amount of fluoride intake from water consumed. However, the present analyses did not consider fluoride intake from bottled water and tap water separately. Therefore, differences in the effects of fluoride intake from tap vs. bottled water on cavitated caries incidence and increments could not be evaluated. In addition, the present analyses did not separately assess the effect of fluoride intake from beverages (sugared and those containing natural sugar) and water or other sugar-free beverages. The fluoride mouthrinse use was defined as any vs. no use from the reported responses for the age 13.0 to 17.5 IFS questionnaires.

Dental Visit and Topical Fluoride Application Variables

The variables dental visit (AUC) and topical fluoride application (AUC) were defined as the proportion of 6-month periods with reported dental visits and with topical fluoride application, respectively. The objective was to determine the association between surface level and person level cavitated caries incidence and reported dental visits and topical fluoride applications across the four and one-half year observation period. The study analyses therefore, could assess differences between greater vs. lower proportions of periods with dental visits and fluoride applications, respectively, on a continuous scale.

Sealant Variables

Presence of sealants was defined as the presence of surface zones with sealants. The number of surface zones of teeth with sealants was also considered. While it can be argued that the majority of the effect of sealants was due to the presence of surface zones with sealants on molar surfaces, the effect of sealants on surface zones of canines and premolars were not considered separately in these analyses.

Dietary Variables: Beverages and Solids

The dietary variables for both beverages and solid foods were defined as continuous variables averaged using area-under-the-curve estimates. The beverage variables used were defined separately from the responses obtained in the IFS questionnaire and the Block Kids Food Frequency questionnaire, respectively, as described in earlier parts of the Discussion (pages 3-4). While the present analyses had the ability to detect the effects of frequency of consumption of solid foods and beverages of low, moderate and high presumed cariogenicity, they were unable to detect the effects of amount of intake of these dietary components. In addition, the present analyses were unable to distinguish between the effects of consumption of solid foods and beverages at different times of the day, e.g., effects of during meals vs. between meals consumption of sugar-sweetened beverages. Such patterns of intake have been identified and studied as a key component of dental caries etiology in some studies of younger age groups (Marshall et al, 2005).

The frequency of consumption of beverage and solid food items, as assessed from Block questionnaire, was calculated in days/week. The assumption was that the number of days a food item or beverage was consumed per week was synonymous with number of days with exposures. While this unit is not the amount consumed or frequency of consumption per day, it acts as an estimate of the patterns of weekly consumption of specific solid and beverage items listed in the Block questionnaire.

An alternative approach would be to use amount of solid or beverage consumed per day which would be obtained using the product of the number of days food/beverage was consumed in a week and the amount consumed each day, divided by seven. However, in doing so, the individuals who had small servings of food at more frequent different times and large servings of foods at fewer times would fall in the same category. For instance, a subject who consumed 3-4 cookies in one day would be in the same category as the subject who had one cookie each day for three to four days. In actuality, these subjects could be at different risk levels, therefore, requiring separate analyses. It was decided that the best strategy would be to use a method that allowed investigators to count the number of days with an exposure of solid food or beverage item. This enabled differentiation of subjects who consume solid foods fewer days in a week vs. those who consume solid foods a greater number of days in a week. It can be justified that use of the variable frequency of consumption of solid foods and beverages in days/week also gives a snapshot of weekly frequency of consumption of these dietary components from the reported response. It is clear that using this variable enables the discrimination between frequent daily consumers vs. relatively infrequent daily consumers of solid foods and beverages.

Rationale for using Logistic Regression Approach

In the present analyses, the risk factors for dental caries in adolescents were determined by assessing associations between risk factors and person level incidence of net cavitated caries and number of net cavitated caries increment count, respectively. Bivariate and multivariable logistic regression analyses were conducted to determine the associations of person level cavitated caries incidence with independent variables. An alternative approach to use the log-binomial model for binary outcomes along with derivation of the relative risk among those exposed vs. non-exposed, when tried in the present analyses, failed to converge. A possible explanation is the range of zero to infinity that is used with this modelling approach. Because the net cavitated caries incidence was a binary outcome variable modelled on a real number scale for logistic regression, it seemed ideal to model the probability of the outcome variable in this way.

Rationale for Using Negative Binomial Regression Approach

Negative binomial regression modeling was used to assess the relationships between net cavitated caries increment count and the independent variables. It was found that the underlying distribution of the outcome count did not follow a bell-shaped curve, i.e., was not normally distributed, hence related approaches were not considered. The count data did not contain an excessive number of zeros so negative binomial regression seemed the right approach, when compared to zero inflated negative binomial regression. Additionally, as there was greater deviation of the data from the mean, negative binomial modelling seemed appropriate when compared to Poisson modelling. Additional comparisons of the different types of models were made using AIC and the log likelihood estimates. The negative binomial regression models had the lowest values of log-likelihood, and a difference of two or more between the log likelihood estimates found for the negative binomial and Poisson models was evidence of the model with a better fit.

Crude and adjusted estimates for the surface level net cavitated caries incidence rates were assessed in bivariate and multivariable regression, while the incidence rate ratio as a measure of association was calculated by exponentiation of the crude and adjusted beta estimates obtained in the bivariate and multivariable regression models. Also, as it was necessary in negative binomial modeling to have equal intervals between examinations, the differences between intervals were accounted for by using the "log offset" command in SAS. Both the logistic regression and negative binomial regression analyses were used as types of generalized linear models and hence, "PROC GENMOD" was used in the SAS analyses code for both.

The backward stepwise elimination procedure was used in the regression modelling and the main effects models were developed with the requirement that variables be significant at $p<0.05$ for both types of regression analyses. The findings in the present study could be limited somewhat due to the choice of modelling procedure itself, i.e., the backward elimination procedure does not guarantee the “optimal model”. This was due to lack of analyses based on largest R^2 of any set of candidate models and could not have represented the “best set of predictors”. A different approach would be to use a “full-model” keeping even the non-significant variables, however, that would add to the noise in the model and would also limit its predictive ability (Whittingham et al, 2006). Alternatively, modelling procedures such as “Best Subsets Model” and “Sequential Variable Block” considering all possible models with one or more predictors or a specific set of predictors to define the most significant models, could have been used. “Best Subsets” was not available for these analyses conducted using SAS. The present analyses did not utilize the sequential variable blocks approach, but in future such analyses it could be worthwhile.

Descriptive Statistics

The means and medians were used to describe the central tendency, while variability was determined from the ranges, percentiles and standard deviations of the variables. The sample size in the present analyses was 303 of which 142 were males and 161 were females. Most subjects were non-Hispanic whites from middle to high SES backgrounds (low SES = 21%, middle SES= 16% and high SES = 63%). The mean ages at the age 13 and age 17 dental exams were 13.3 and 17.5 years, respectively, and the average interval between exams was 4.18 years. The mean net cavitated caries experience scores at age 13 were lower (1.20) when compared to age 17 exams (3.50) while the mean net cavitated caries increment count was 2.31. About 64% of subjects were caries-free at age 13 dental exams, which declined to 38% of subjects at age 17. Of the total 303 subjects, 45% (N=136) had no net cavitated caries incidence, while 55% had positive net cavitated caries incidence (N= 167). The mean daily brushing frequency was 1.64 times/day.

As the frequency of beverage and solid food item consumption from Block questionnaire was calculated in days/week, the overall frequency of consumption for each category with a given set of solid food items and beverages was likely to exceed seven days per week. Of beverage categories as defined from the IFS questionnaires, the highest mean frequency of consumption in servings/week was found for milk consumption (9.68), followed by frequency of sugared beverage consumption (6.97), sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself)) consumption (3.37) and 100% juice consumption (1.94). For frequency of beverage consumption assessed using the Block questionnaires, a similar trend was reported, with greatest mean frequency of consumption (days/week) for milk (9.47), followed by sugared beverage consumption (4.68) and 100% juice consumption (2.36). For the seven solid food categories, mean frequency of consumption of solid foods as assessed from Block questionnaires was greatest (days/week) for foods predominant in starch (11.24), followed by frequency of consumption of foods predominant in sugar and starch (11.03), fat and protein (9.45), starch and protein (8.94), low natural sugar and fiber (5.6), added sugar (5.31) and high natural sugar (4.85). Among the combined categories of solid foods, the mean frequency (days/week) was greatest for solid foods with moderate presumed cariogenicity (25.00). It was followed by high cariogenicity solid foods (16.35) and low cariogenicity solid foods (15.00). There was good inter-examiner reliability among examiners for both age 13 and age 17, reducing the chances of bias. The reliability was tested for some vs. no cavitated caries experience for age 13 and age 17 by person level agreement and simple kappa measures for agreement between examiners. The scores for person level agreement for age 13 and age 17 were 86% and 78% respectively, and the simple kappa scores were 0.59 and 0.58, respectively.

Correlation Analyses

The collinearity between variables was assessed using spearman rank order correlation analyses. Strong correlations were found between frequency of consumption of sugared beverages (AUC) from IFS (servings/day) and from Block questionnaire (days/week), and between frequency of consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) (AUC) (servings/week) and 100% juice (AUC) (servings/week), both measured from the IFS questionnaires. Moderate correlations were found between frequency of milk (AUC) (servings/week) consumption from the IFS (servings/week) and Block questionnaires (days/week), and between frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption (AUC) from the IFS (servings/week) and Block questionnaires (days/week). Overall, most of the correlations were modest to moderate, with few very high. The strength of correlations among Block and IFS questionnaire beverage variables were high as expected. This was because the tools intended to measure the same variables, given the differences in definitions alluded to earlier. The strength of correlation among Block questionnaire solid food variables was also moderate to high. This should not be surprising because caloric requirements increase substantially in adolescence, leading to patterns of frequent snacking, and increased consumption of carbohydrates, proteins and beverages. The high correlation therefore, can be attributed in part to the fact that adolescents are more likely to have a frequent and comprehensive dietary intake comprised of foods categorized as having low, moderate and high-presumed cariogenicity.

Bivariate Regression Analyses

Bivariate logistic and negative binomial regression analyses were conducted separately to assess the unadjusted effects of independent variables on net cavitated caries incidence and net cavitated caries increments from age 13 to 17. These results showed that subjects with low SES, lower daily brushing frequency (AUC) (times/day), higher frequency of consumption of foods predominant in added sugars (AUC), lower frequency of consumption of foods predominant in natural sugar and fiber (AUC), presence of surface zones with sealants (Y/N), greater net cavitated caries increment count from 9 to 13, and higher baseline age, respectively, were more likely to have person-level cavitated caries incidence and greater surface level net cavitated caries increments.

The results also showed that subjects with no fluoride mouthrinse use, lower frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself)consumption (days/week), greater frequency of 100% juice, greater frequency of consumption of foods predominant in starch and protein (AUC) (days/week), greater frequency of intake of combined category solid foods with moderate cariogenicity (AUC) (days/week), greater number of surface zones with sealants, positive 9 to 13 net cavitated caries incidence, and who were females were more likely to have net cavitated caries incidence. These variables, however, were not associated with net cavitated caries increment count in the bivariate negative binomial regression analyses. Except for variable presence of sealants, number of surface zones with sealants and frequency of 100% juice consumption, the findings for all the variables were in the predicted direction, as stated in the respective hypothesis.

For bivariate logistic regression analyses, the variables 100% juice consumption, number of surface zones with sealants, and 9 to 13 net cavitated caries increment count were excluded from the multivariable modeling in order to avoid any issues with multicollinearity.

The bivariate negative binomial analyses results also showed that greater daily fluoride intake from water (AUC) (mg F/day), greater proportion of periods with dental visits (AUC), lower frequency of consumption of beverages with added sugar (AUC) (servings/week), lower frequency of consumption of milk (AUC) (servings/week), and greater frequency of consumption of foods with high cariogenicity (AUC) (days/week), respectively, were associated with greater net cavitated caries increment count only and were not associated with net cavitated caries incidence at $p<0.15$. Except for the variables proportion of periods with dental visits (AUC), presence of sealants (Y/N), frequency of consumption of milk (AUC), the findings for all the variables were in the predicted direction, as stated in the respective hypothesis.

The Block questionnaire variables frequency of sugared beverage consumption (AUC) and frequency of milk consumption (AUC) were the Block beverage variables that were associated with net cavitated caries increment count. The variable frequency of sugared beverage consumption (AUC) (Block) was highly correlated with frequency of sugared beverage consumption (AUC) (IFS), while frequency of milk consumption (AUC) (Block) moderately correlated with frequency of milk consumption (AUC) (IFS). Therefore, these Block beverage variables were excluded from inclusion in the negative binomial multivariable modeling due to collinearity issues.

Overall, it was observed that the statistically significant variables in the bivariate logistic regression analyses and negative binomial regression analyses were mostly different. This observed difference was probably a result of differences in the outcome variables used in the analyses, the underlying distributions, and the nature of the modelling methods.

Multivariable Regression Analyses

In the multivariable logistic regression, greater daily brushing frequency (AUC), greater frequency of consumption of foods containing natural sugar and fiber (AUC) and greater frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself)consumption (AUC) were negatively associated with net cavitated caries incidence. In contrast, presence of surface zones with sealants (Y/N), positive net cavitated caries incidence from 9 to 13 and greater frequency of moderate presumed cariogenicity food consumption (AUC) were positively associated with net cavitated caries incidence.

In multivariable negative binomial regression analyses, presence of surface zones with sealants (Y/N), greater baseline age, greater surface level net cavitated caries increment from 9 to 13, and greater frequency of consumption of solid foods with added sugar (AUC) were positively and significantly associated with net cavitated caries increment count. The frequency of consumption of solid foods predominant in natural sugar and fiber (AUC) was negatively associated with net cavitated caries increment count

For both the logistic and negative binomial regression analyses, there was one statistically significant interaction. The interaction effect between sex and presence of surface zones with sealants was significant for multivariable logistic regression analyses, while the interaction between baseline age and net cavitated caries incidence from age 9 to 13 was significant for the negative binomial regression analyses. The observed interaction effect was with the default reparametrization approach used in the analyses.

Overall, the results showed that the statistically significant variables and interaction effects in the different types of regression analyses were substantially different. These differences probably are due to differences in the underlying distribution of the data (negative binomial vs. bernoulli), the definition of outcome variable used (count vs. dichotomous) and the respective analyses approaches used (negative binomial vs. logistic regression). This emphasizes the need to observe associations for variables beyond incidence outcomes. The unit of analysis/observation in incidence measure is “person level” incidence. In such cases, important information for risk factors can be lost, i.e., by using only person-level incidence outcomes, subjects with one carious surface and several carious surfaces are combined into a single group and cannot be studied separately. This approach could also result in type-II errors as researchers may accept the null, and observe lack of significant associations due to the definition of outcome of disease (person level vs. surface level), which in turn is likely to affect the validity of the model.

Possible Reasons for the Observed Significant Findings

The study found a strong significant positive association between net cavitated caries increment count and presence of sealants in the negative binomial regression analyses. A possible reason for this finding was that the factor (presence of sealants) did not precede the outcome of interest (net cavitated caries incidence from 13 to 17). It is also likely that subjects with sealants were already at high risk for cavitated caries and would as a result have higher loss of sealant retention (Oulis and Berouses, 2009). It is also worth emphasizing that, as these subjects were from high SES background, they could easily afford dental care. While females were more likely to have net cavitated caries incidence in the bivariate and multivariable logistic regression main effects model, the significant interaction effect observed between sex and presence of sealants in the final model revealed that net cavitated caries incidence among females significantly differed depending on sealant status. Unlike males, where the sealant status did not make a significant difference in net cavitated caries incidence, females with sealants were significantly more likely to have net cavitated caries incidence than those without sealants.

It can be attributed to the relatively early physical maturation of females when compared to males, which has been documented previously (Lukacs et al, 2006). Positive association between cavitated caries incidence and females found in this study is also consistent with the findings from other studies (Ditmyer et al, 2008 and Ditmyer et al, 2010). Lukacs et al (2006) have reasoned that the biochemical composition and flow rate of saliva differed among males and females, with females having lower flow; thus reducing the removal of food residue from teeth and increasing the likelihood of developing caries. Another possible explanation provided by Lukacs et al (2006) is that reduced salivary flow among females is subject to hormonal fluctuations during puberty and pregnancy, making the oral environment significantly more cariogenic for females than males. Lukacs (2006) also argued that earlier eruption patterns seen among females result in longer periods of exposure to cariogenic substances in the oral environment (Lukacs et al, 2006). Besides, it can also be attributed to the fact that females are more likely to seek dental treatment for caries, which could contribute substantially to the filled component and overall higher $D_{2-3}FS$ incidence in females.

The negative association of greater tooth brushing frequency with net cavitated caries incidence has been further confirmed in the present longitudinal study. This finding is consistent with the evidence published by Chestnutt et al (2003), Petridou et al (1996) and Mascarenhas et al (1998), and more recently by Chankanka et al (2011). In the present study, the majority of subjects used fluoridated toothpaste, and greater tooth brushing with fluoridated toothpaste was a protective factor against net cavitated caries incidence.

In logistic and negative binomial regression models, greater frequency of consumption of foods predominant in natural sugar and fiber was significantly associated with lower net cavitated caries incidence and lower increment, respectively. The foods predominant in natural sugar and fiber were mainly vegetables and were classified as foods with low presumed cariogenicity. More recently, their non-cariogenic/low-cariogenic potential has been hypothesized by Palmer et al (2010), while a negative association between intake of vegetable items and net caries incidence was found by Petridou et al (1996). The protective effect of vegetables could be attributed in part to the high fiber content stimulating greater salivary flow, which in turn, could lead to increased resistance to the effects of lower intrinsic sugars in vegetables. This could have led to its decreased cariogenic potential, when compared with other solid foods. In addition, vegetables have been shown to have polyphenols (Manach et al, 2004). These polyphenols have shown to influence activity of S. mutans and plaque formation (Kashket et al, 1985; Oshima et al 1993). In addition, the protective effect of greater intake of vegetables could be reflective of adolescents' preference for positive behaviors. For instance, in the present analyses, a negative correlation was found between consumption of solid foods predominant in fiber and natural sugar and frequency of consumption of sugared beverages.

The present study also found a significant positive association between increased frequency of consumption of foods predominant in added sugars and net cavitated caries increment count in the negative binomial regression analyses. The food items included in this category were sweets, chocolate candy, sauce, pudding, raisins, fruit roll-ups and dried fruits, which are to a great degree processed foods. The positive association between caries and sugar consumption has been reported previously (Gustaffson et al 1954; Rugg-Gunn et al 1984). Moynihan and Kelly (2014), in their systematic review, have provided evidence that greater free sugar consumption is associated with caries (Moynihan and Kelly, 2014). The increased cariogenicity of the foods predominant in added sugar is likely due to the high sugar intake and low processed starch content of these food items that have also been previously hypothesized to have greater cariogenic potential (Marshall et al, 2005). In addition, increase in the demand for caloric requirements could lead to more carbohydrate consumption overall with frequent consumption of foods predominant in added sugar (Brown et al, 1999*, Pediatric Dentistry*, 1999). This is because adolescents are likely to identify with the taste of sugar much more than the recognition of dangers associated with consumption (Freeman and Sheiham, 1997). In addition, adolescents are likely to have patterns of irregular meals and frequent snacking, as well as a tendency to skip meals, which further complicate the effects of solid foods predominant in added sugar on net cavitated caries increments in adolescents. Among the combined solid food categories, the present study also reported significant positive associations between net cavitated caries incidence and frequency of consumption of solid foods with presumed moderate cariogenicity. The solid foods in the presumed moderate cariogenicity category included those that were predominant in natural sugars (fruits: both raw and canned), protein and processed starch (e.g., meat sandwiches, beef-noodles, etc.) and processed starch (e.g., tortillas). Previously, greater cariogenicity of highly processed starches (tortillas, buns, fried potatoes, french fries, etc.) has been hypothesized by Marshall et al (2005) and have been documented by Decker & Loveren (2003), while the tendency of longer retention of foods predominant in starch has been documented by Kashket et al (1996). The presence of highly fermentable starch foods has been known to enhance the retention rate of sugars, leading to lower plaque pH (Lingstrom and Birkhed, 1993) and could have led to increased cariogenic potential of the solid foods predominant in starch. It can be argued that the combined effects of intrinsic sugars (sucrose, fructose and/or glucose) in non-canned fruits and intrinsic and extrinsic sugars in canned foods would be cariogenic

Among beverage variables, the present study also found a significant negative association between greater frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) consumption and net cavitated caries incidence, but not with net cavitated caries increment count. The beverages in this category were comprised mostly of beverages with no added sugar or natural sugars and 100% juice. The protective effect could, therefore, be in part due to the sugar substitute (aspartame, acesulfame potassium, and sucralose) content in the sugar-free beverages. These sugar-substitutes are non-cariogenic in nature, as they cannot be hydrolyzed by the cariogenic bacteria in the oral environment (Marshall et al, 2013; Roberts and Wright, 2012 and Ly et al, 2006). The sugar-free beverage category (i.e., beverages without added sugar, including 100% juice, but no water by itself) in the present study also included some beverages made using water (powdered beverages) and other beverages that are likely to act as carriers for topical and systemic fluoride, which in turn can be protective in nature. Although the sugar-free beverage category (i.e., beverages without added sugar, including 100% juice, but no water by itself) included 100% juice, which has natural sugars but no added sugars, the effect of drinking the sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself) was protective as a whole. This was observed because frequency of sugar-free beverage (i.e., beverages without added sugar, including 100% juice, but no water by itself) intake was negatively correlated with frequency of beverages with added sugar intake, although this was not significant at $p < 0.05$, indicating that at least some subjects with increased sugar-free (i.e., beverages without added sugar, including 100% juice, but no water by itself)beverage consumption were likely to have fewer sugared beverages, which could have led to protection from caries due to consumption of beverages with added sugars.

The present study also found that age 9 to 13 net cavitated caries incidence was significantly and positively associated with the person level and surface level net cavitated caries incidence from age 13 to 17, respectively. Previous net cavitated caries incidence is a clear reflection of caries activity in the past and projects an individual's tendency to be at certain level of caries risk. While some studies have used cavitated caries experience and prevalence estimates as a measure of previous caries experience (Alm et al, 2012), it can be argued that the variable 9 to 13 net cavitated caries incidence serves as an efficient surrogate representing the effects of risk factors (exposures and behaviors) during or before the periods from 9 to 13. It is suggested that the continued tendency for subjects to have net cavitated caries could be reflective of the lack of their ability to adopt protective behaviors or healthier lifestyles. In the negative binomial regression analyses, however, the relationship between net cavitated caries incidence from 9 to 13 and net cavitated caries increment count from 13 to 17 was complex. It was found that the effect of positive net cavitated caries incidence from 9 to 13 varied depending on the baseline age. Overall, for those without net cavitated caries incidence from 9 to 13, the net cavitated caries increment count was lower in comparison to those with net cavitated caries incidence from 9 to 13. However, this effect was further modified depending on the baseline age of the subject. For those with net cavitated caries incidence from 9 to 13, the estimates for net cavitated caries increment count from age 13 to 17 were substantially greater for those with higher baseline age (14.9 years) when compared with those who had lower baseline age (12.4 years). This was confirmed in the reparametrization analyses. Even for subjects without age 9 to 13 net cavitated caries incidence, greater net cavitated caries increment count estimates were seen for subjects with higher baseline age when compared to those with lower baseline age, as confirmed from reparametrization analyses. It can be believed that the observed interaction effect between net cavitated caries incidence from 9 to 13 and baseline age is due to two reasons. Those who had previous caries incidence are likely to have more caries in the future due to a possible tendency to resist protective behaviors, lack of awareness about healthy behaviors and genetic or other predisposition. Those with higher baseline age, on the other hand, have longer post-eruption phases such that the tooth surfaces are at risk to caries for a longer duration of time (exposed for a longer time to cariogenic foods, beverages, etc.) than those with lower baseline age. Thus, when both these conditions are true, i.e., when subjects with greater net cavitated caries incidence rate from 9 to 13 also have higher baseline age, the overall effect leads to greater net cavitated caries increment count from 13 to 17.

Possible Reasons for the Lack of Significant Findings

The variables eliminated in the main multivariable negative binomial regression model using backward elimination procedure were, frequency of consumption of high cariogenicity category foods (AUC) (days/week) (p= 0.52), frequency of beverages with added sugar (AUC) (p=0.88), frequency of consumption of milk (AUC) (p=0.30), socioeconomic categories (low, middle and high) (p=0.11), dental visit (AUC) (p= 0.17), and daily brushing frequency (AUC) (p=0.10). The variables eliminated in the logistic regression model using the backward elimination procedure were, frequency of consumption of foods predominant in starch (AUC) (p=0.83), fluoride mouthrinse use (Y/N) (p=0.41), frequency of consumption of foods predominant in added sugars (AUC) (p=0.18), socioeconomic status categories (low, middle, and high) (p=0.15) and baseline age (p=0.09).

When comparing the two models, socioeconomic status category (low, middle, and high) was the common variable in the two models that turned out to be non-significant. However, in both analyses, it was found that subjects classified in low socioeconomic categories were more likely to have caries when compared with subjects in moderate and high socioeconomic status categories, respectively. These results were consistent with earlier analyses done of IFS study subjects conducted by Chankanka et al, (2011). For negative binomial regression analyses, the lack of significant results between cavitated caries increment count and the non-significant variables was in part due to lack of sufficient variation/contrast among the subjects with and without net cavitated caries increment count. It was also true that the subjects had low exposure rates for some variables. When deriving the negative binomial trimmed model, frequency of consumption of foods predominant in starch, baseline age and frequency of foods predominant in added sugar were positively associated with net cavitated caries incidence in the bivariate analyses, however, these variables were eliminated due to lack of significance at $p<0.05$. Of these three variables, frequency of consumption of foods predominant in added sugar and baseline age were statistically and significantly associated with net cavitated caries increment count in the multivariable negative binomial regression analyses, indicating that the factors associated with the incidence and extent of cavitated caries could be different. It can be speculated that for negative binomial regression analyses variables such as frequency of consumption of high cariogenicity category foods (AUC) (days/week) (p = 0.52), frequency of consumption of beverages with added sugar (AUC) (p=0.88), frequency of consumption of milk (AUC) (p=0.30), could have lost significance due to overall low exposure, and lack of variation among subjects exposed when compared with the variables that were significant. It is also probable that the variables fell out due to lack of significance because they truly had a modest effect when compared with the variables that remained in the model. In addition, it can be considered generally that some variables could have lost significance due to relatively lower sample size.

The fluoride variables of fluoride intake from combined sources and composite water fluoride level were not significantly related in bivariate or multivariable analyses for both outcomes of net cavitated caries incidence and net-cavitated caries increment count, respectively. The findings are consistent with the findings of Chankanka et al (2011).

The variable fluoride intake from water was significant in the main effects model for negative binomial regression, but lost significance when the interaction between baseline age and net cavitated caries incidence from 9 to 13 was introduced in the model. It is likely that the significant interaction effect changed the statistical relationship between the main effect of fluoride intake from water and because the interaction variable baseline age*net cavitated caries incidence from 9 to 13 and the other independent variables in the model were stronger predictors of net cavitated caries incidence from 9 to 13. The multivariable negative binomial main effects model showed that daily fluoride intake from water was significantly associated with net cavitated caries increment count (p<0.03, coefficient = -0.6953) with IRR of 0.50. This result changed to being insignificant in the final model (p=.13 with coefficient = -0.4602) with addition of the interaction term. However, with IRR changing to 0.64, it was still suggestive of a negative association between daily fluoride intake from water and net cavitated caries increment count. The variable daily fluoride intake from water might have remained in the final model, if there had been adequate power and greater sample size. Even though these findings do not support those from the earlier study by Mariri et al (2003) that found fluoride intake from water to be significantly related to caries in a younger age group of IFS participants, they are suggestive of a negative tendency of association with caries incidence.

Implications of Dietary Findings

Based on the results, it is recommended that adolescents should have regular intake of foods predominant in fiber and natural sugar (i.e., vegetables) and minimal intake of foods predominant in processed starch and added sugar. The study findings also support recommendations to increase intake of sugar-free beverages and recommend drinking 100% juice in recommended amounts.

These recommendations are consistent with general guidelines for dietary practices for systemic health and the national recommendations issued by the United States Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (HHS) in 2010 (Dietary Guidelines for Americans 2010). According to these Guidelines, adolescents should increase intake of whole grains, vegetables and fruits, along with minimal intake of foods predominant in added sugar and processed starches. Refined grains are a common source of starch, and are added to other foods to stabilize and thicken the texture. The added sugars and added starches in foods provide energy (calories), but do not fulfill the nutrient requirements of the body; therefore, they should be consumed minimally. Children aged 2 to 18 years consume an average of 400 calories per day as beverages (Dietary Guidelines for Americans 2010), with soda pop intake being the most common beverage consumed among adolescents compared to energy and sports drinks, milk (whole, 2% ,1% and fat-free) and 100% juice and juice drinks. According to the Guidelines, it is essential to increase consumption of beverages with no added or natural sugars. If the diet includes juices, the Guidelines encourage drinking 100% juice only in recommended amounts and to have minimal consumption of beverages with added sugars.

Future Directions

The present study focused only on cavitated caries outcomes. Future studies on dental caries assessment in adolescents could look at the epidemiology of both net cavitated and non-cavitated caries and associated risk factors in detail. Additionally, a study of the etiology of pit and fissure vs. smooth surface caries, respectively, could also be conducted focusing on adolescent population. Future analyses could also be conducted with incidence density as one of the outcomes for net cavitated caries incidence and increment count. This approach would be worthwhile, as it will take into account the number of tooth surfaces at risk and the time period the surfaces are at risk of developing caries. It will also be worthwhile to consider additional analyses of the same dataset where beverage categories could be defined differently. For instance, the sugar-free beverage category could possibly be defined in two ways: all sugar-free beverages, including water by itself and 100% juice; and all sugar-free beverages, including water, but excluding 100% juice.

A future approach using radiographic techniques to assess proximal lesions could also be used (that were not assessed in this study) since studies without radiographs generally underreport the disease. A forthcoming study could be conducted investigating the effects of non-modifiable risk factors and comparing them with the effects of modifiable risk factors on cavitated and non-cavitated caries incidence in adolescents. Such a study could focus on determining the statistical significance of models with modifiable factors and those without modifiable factors and determine the most predictive of the two models or to propose a significant predictive model with both non-modifiable factors and modifiable factors.

It would also be worthwhile to consider the associations between characteristics and conditions such as BMI/obesity, *S. mutans*, plaque and salivary flow and cavitated and non-cavitated caries among adolescents, which were not assessed in the present analyses. The effects of fluoride intake from sugar-sweetened beverages and sugar-free beverages can also be assessed separately in future studies to determine the effects of fluoride intake in presence of sugar. Another approach would be to investigate the effects of timing of consumption of beverages and solid foods to highlight the difference between the effects of during meal and between meal consumption patterns on both cavitated and non-cavitated caries incidence. Due to limitations on the types of data available as mentioned earlier, the present study failed to assess the associations between upstream determinants. Future research can be conducted to assess associations between caries outcomes and distal determinants, such as SES trajectories across young adulthood, caries risk in parents and community level and dental care system characteristics.

CHAPTER 6

CONCLUSION

The main purpose of the present analyses was to determine risk factors associated with net incidence and cavitated caries increment by conducting secondary analyses of Iowa Fluoride Study data. In the process, the study sought to assess the adjusted effects of explanatory variables on the outcomes of net cavitated caries incidence and increment count from age 13 to 17. The explanatory variables used in the analyses were demographic variables (baseline exam age, i.e., age 13, sex, socioeconomic status category), oral hygiene variables (daily brushing frequency, duration of brushing), fluoride and dental visit variables (composite water fluoride level, daily fluoride intake from water; total fluoride intake from combined sources, use of fluoride mouthrinse; proportion of periods with topical fluoride application and dental visit, respectively); sealant variables (presence of sealants and number of surface zones with sealants). The explanatory dietary variables included beverage variables (frequency of consumption of beverages with added sugar, 100% juice, milk and sugar-free beverages, respectively) and solid food variables (frequency of consumption of foods predominant in fat and protein, fiber and low natural sugar, high natural sugar, starch and protein content, starch content, starch and sugar content and sugar content, respectively).

The findings for dichotomous net cavitated caries outcome support the hypotheses that subjects having age 9 to 13 net cavitated caries incidence, with greater frequency of consumption of moderate presumed cariogenicity solid foods and females were more likely to have age 13 to 17 net cavitated caries incidence. The results also showed that subjects with greater consumption of sugar-free beverages (i.e., beverages without added sugar, including 100% juice, but no water by itself), greater toothbrushing frequency, and greater frequency of consumption of foods predominant in natural sugar and fiber (vegetables) were more likely to have lower net cavitated caries incidence. The findings focused on net cavitated caries increment count support the hypotheses that subjects with higher baseline age (age 13), and greater frequency of consumption of solid foods predominant in added sugar were more likely to have higher net cavitated caries increment count from 13 to 17. The findings also showed that subjects with greater frequency of consumption of solid foods predominant in natural sugar and fiber were more likely to have lower net cavitated caries increment count from 13 to 17.

It is worth noting that non-modifiable factors in the present analyses, i.e., person level and surface level net cavitated caries increment count from 9 to 13, were positively and significantly associated with net cavitated caries incidence and net cavitated caries increment count from 13 to 17, respectively. This emphasizes the consistent evidence of positive association of caries with previous caries experience/baseline caries prevalence observed in adolescents (Alm et al, 2012; Haugejorden & Birkheland, 2007, Rise et al, 1982) and younger age groups. Another important finding was the negative association between the modifiable factor of frequency of foods predominant in fiber and natural sugar (vegetables) and both net cavitated caries incidence and net cavitated caries increment count, respectively. These findings are consistent with those by Petridou et al (1996). A possible reason for the finding is that vegetables have low intrinsic sugars and high amounts of fiber that lead to additional salivary stimulation, thus creating a relatively non-cariogenic environment. Vegetables have been found to be good sources of polyphenols (Manach et al, 2004), which in turn have been shown to hinder *S. mutans* activity and reduce plaque formation (Kashket et al, 1985; Oshima et al, 1993). Moreover, the increased intake of foods predominant in natural sugar and fiber was associated with lower sugared beverage consumption in the analyses.

Consistent positive associations between presence of sealants at the baseline exam and net cavitated caries incidence and net cavitated caries increment count, respectively, were found in the present analyses. It could be assumed that sealants were placed in high risk adolescents. These subjects might have had dietary, and/or other predispositions along with anatomic pit and fissure caries risk, leading to overall high caries risk and higher net cavitated caries increments when compared to others. In the logistic regression analyses, the positive association between net cavitated caries incidence and sealants was complex. The relationship could have been positive for the outcome of net cavitated caries incidence due to the observed interaction effect between sex and presence of sealants. It was found that females with sealants at baseline were much more likely to have net cavitated caries incidence from 13 to 17, whereas the presence of sealants among males did not significantly alter this probability, indicating that females who had sealants at baseline could be at high caries risk due to other negative behaviors. Also, the higher baseline caries risk was likely to result in greater loss of retention of sealants, leading to caries progression in the female subjects (Oulis and Berdouses, 2009). Additionally, it should be remembered that the majority of subjects were from high SES backgrounds where they were likely to be insured and could afford dental care.

The interaction between net cavitated caries incidence and baseline age (age 13) showed that the effect of presence or absence of net cavitated caries incidence from 9 to 13 on subjects was further modified depending on the baseline age (age 13) of the dental exam. Although the effect of higher baseline age was positive in subjects with and without caries, it was found that, with higher baseline age, the subjects who had net cavitated caries incidence from 9 to 13 were more likely to have greater net cavitated caries increment count from age 13 to 17 when compared to those of lower baseline age. This is probably because subjects with greater baseline age were more likely to have greater caries risk resulting from longer duration of exposure of at risk surfaces of teeth to the oral environment and from a tendency reflective of a lack of ability to adopt better dietary and oral hygiene behaviors, preventive practices, etc.

The present analyses were somewhat novel in terms of investigating risk factors for incidence and extent of surface level increment of cavitated caries among IFS adolescents. The focus was on conducting a retrospective analysis of prospective cohort study (IFS) data, an approach rarely used in studies—due to the more frequently available cross-sectional nature of data. The secondary analyses of the IFS data were conducted using the IFS and Block questionnaires to get a comprehensive assessment of variables related to oral hygiene, fluoride, dental visits, sealants, previous caries incidence, beverage and solid food intake, respectively, aiming to assess the effects of both modifiable and non-modifiable risk factors for cavitated caries incidence measures among IFS adolescents.

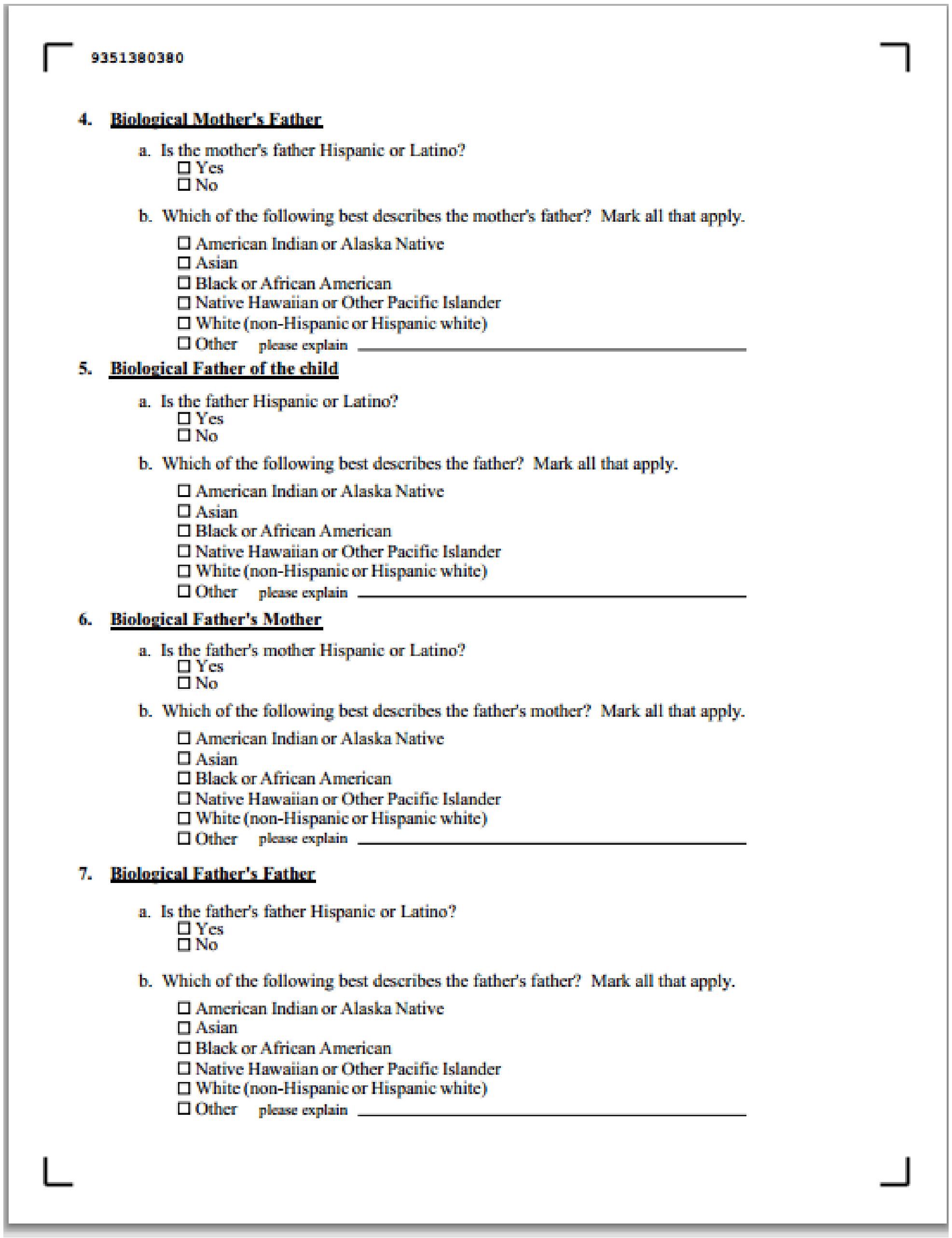
The inclusion criteria based on dental exams required subjects to have the proper interval between exams. The rule for inclusion based on IFS questionnaire required subjects to have the response for age 13 and 17.5 year IFS questionnaires, from the early and late sub-periods, with at least one response in the middle period. These criteria enabled the study of explanatory variable data for all three periods (i.e., early, middle and late) for IFS questionnaire variables. The differences in length of the interval between the baseline and final exam were accounted for by using the “log offset” in the negative binomial analyses. While the “best subsets model” and “sequential block” could have been alternative approaches to modelling, the manual backward elimination procedure was chosen as the best possible alternative for the given time frame for this project. The appropriate negative binomial regression approach for count outcomes and logistic regression approach for the dichotomous outcomes were carefully selected and were done so by assessing the AIC values and log likelihood values of the models.

The present analyses had some loss to follow-up and missing responses for the questionnaire data, which is common for longitudinal study designs. Despite this, the analyses had a considerable sample size, even with the stringent inclusion criteria. In order to account for missing responses, a trapezoidal area-under-the-curve method was used, as it had been used previously by the IFS investigators (Levy et al, 2001). This enabled the deriving of a weighted average of exposures and intakes over a given time period.

The present analyses were based on subjects who are mostly non-Hispanic whites from moderate to high SES, and this limits generalizability of its findings. As the study sample had relatively lower caries levels at baseline and was mostly higher SES, findings from the present study cannot be generalized to extremely high risk or vulnerable/low SES populations from diverse backgrounds. However, the present analyses are one of the first to be based on data about U.S. adolescents that has assessed the relationships between cavitated caries incidence and comprehensive solid food and beverage intakes, along with other important fluoride variables, dental visit variables, sealant variables and previous caries incidence variables. While the nature of the findings is significant, it must be remembered that these findings are not based on experimental designs and controlled trials that are likely to provide the most sound scientific evidence. However, the findings have the ability to contribute substantially to the current knowledge on risk factors for cavitated caries incidence and extent of surface increment among adolescents.

The study also highlights the significance of healthy eating and drinking habits and emphasizes the desirability of incorporating substantial vegetable intake as part of the daily diet, including the importance of consumption of sugar-free beverages along with recommended intake of 100% juice to prevent cavitated caries incidence in adolescents. The findings also support the importance of minimal consumption of beverages and foods predominant in added sugar and solid foods predominant in processed starch, which has been recommended as part of the Dietary Guidelines by the USDA and HHS (Dietary Guidelines for Americans 2010). The findings also reinforce the importance of greater daily brushing with fluoridated toothpaste as part of a regular oral hygiene regime. The present study findings show that previous caries incidence is a critical non-modifiable factor associated with both incidence and extent of cavitated caries in adolescents of the Iowa Fluoride Study. Therefore, special attention to earlier behaviors and adaptation of healthy behaviors is essential from the early years of life. The differences in findings for risk factors for cavitated caries incidence and increment count are due in part to the nature of the outcome variable, i.e., dichotomous vs. count. This signifies the need to consider both surface level and person level outcomes in future studies of adolescent caries.

APPENDIX A: FAMILY BACKGROUND ASSESSMENT QUESTIONNAIRE



9351380380

4. Biological Mother's Father

a. Is the mother's father Hispanic or Latino?
☐ Yes
☐ No

b. Which of the following best describes the mother's father? Mark all that apply.
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White (non-Hispanic or Hispanic white)
☐ Other please explain ____________________

5. Biological Father of the child

a. Is the father Hispanic or Latino?
☐ Yes
☐ No

b. Which of the following best describes the father? Mark all that apply.
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White (non-Hispanic or Hispanic white)
☐ Other please explain ____________________

6. Biological Father's Mother

a. Is the father's mother Hispanic or Latino?
☐ Yes
☐ No

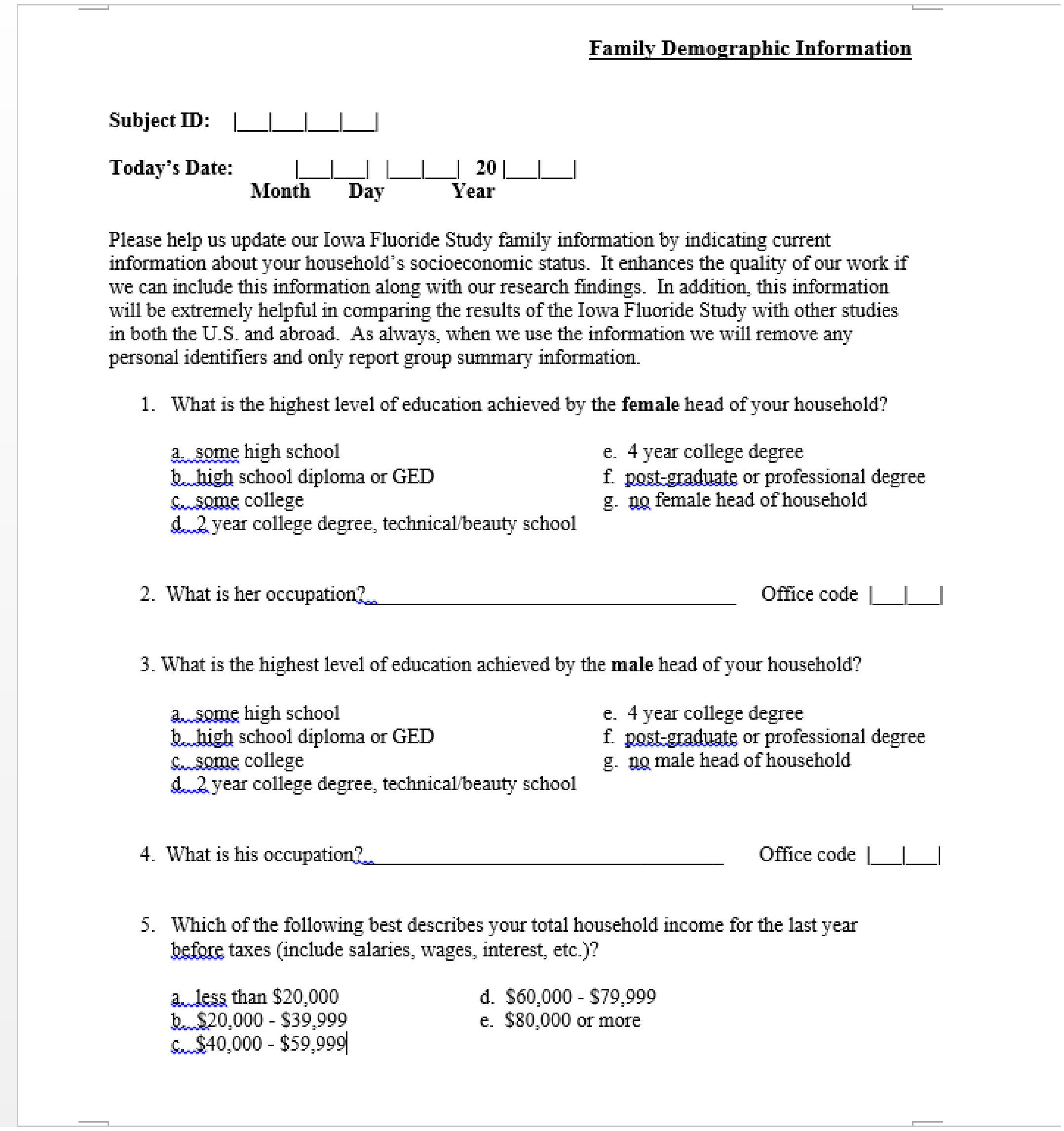
b. Which of the following best describes the father's mother? Mark all that apply.
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White (non-Hispanic or Hispanic white)
☐ Other please explain ____________________

7. Biological Father's Father

a. Is the father's father Hispanic or Latino?
☐ Yes
☐ No

b. Which of the following best describes the father's father? Mark all that apply.
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White (non-Hispanic or Hispanic white)
☐ Other please explain ____________________

APPENDIX B: FAMILY DEMOGRAPHIC INFORMATION QUESTIONNAIRE



Family Demographic Information

Subject ID: |___|___|___|___|

Today's Date: |___|___| |___|___| 20 |___|___|
Month Day Year

Please help us update our Iowa Fluoride Study family information by indicating current information about your household's socioeconomic status. It enhances the quality of our work if we can include this information along with our research findings. In addition, this information will be extremely helpful in comparing the results of the Iowa Fluoride Study with other studies in both the U.S. and abroad. As always, when we use the information we will remove any personal identifiers and only report group summary information.

1. What is the highest level of education achieved by the **female** head of your household?

a. some high school
b. high school diploma or GED
c. some college
d. 2 year college degree, technical/beauty school
e. 4 year college degree
f. post-graduate or professional degree
g. no female head of household

2. What is her occupation?___________________________________ Office code |___|___|

3. What is the highest level of education achieved by the **male** head of your household?

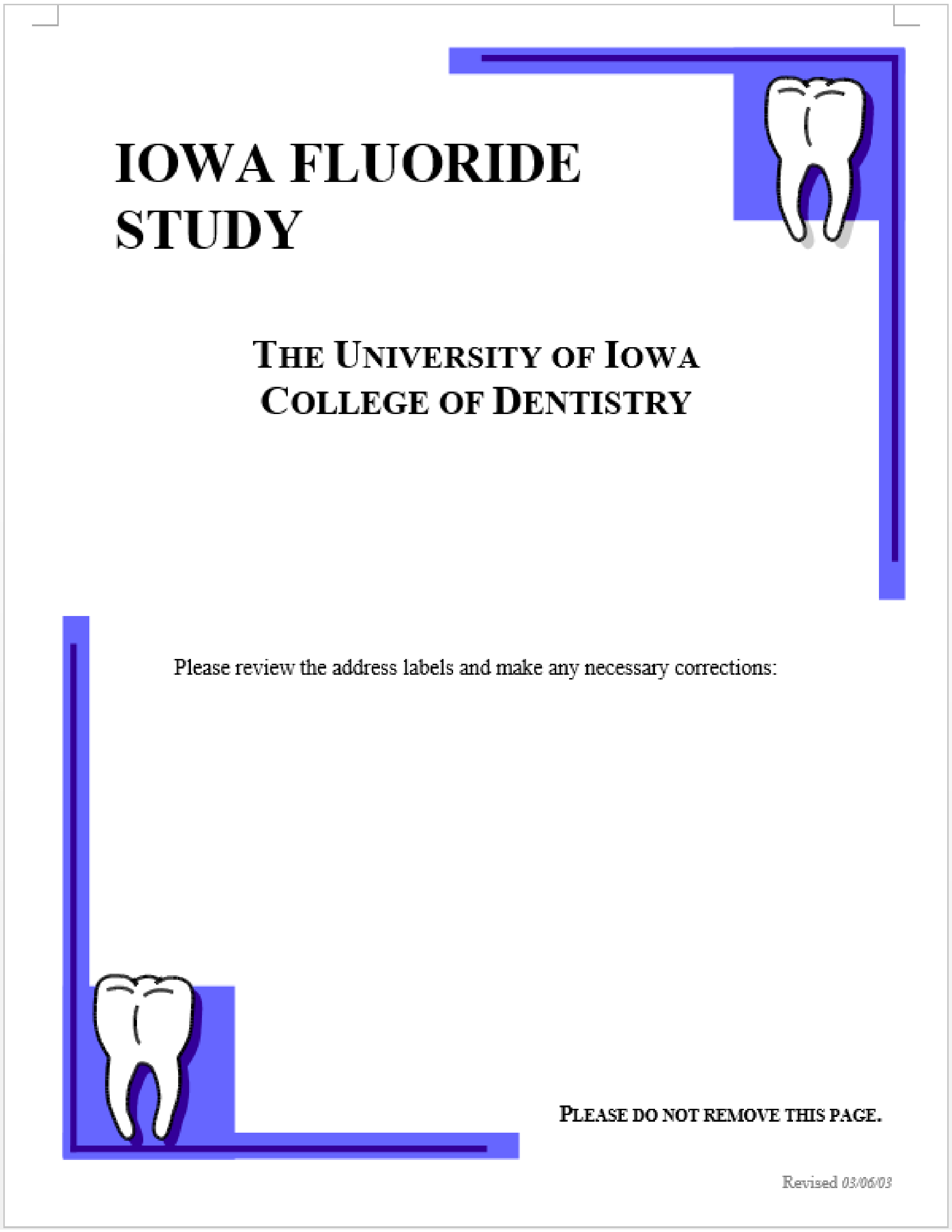
a. some high school
b. high school diploma or GED
c. some college
d. 2 year college degree, technical/beauty school
e. 4 year college degree
f. post-graduate or professional degree
g. no male head of household

4. What is his occupation?___________________________________ Office code |___|___|

5. Which of the following best describes your total household income for the last year before taxes (include salaries, wages, interest, etc.)?

a. less than $20,000
b. $20,000 - $39,999
c. $40,000 - $59,999
d. $60,000 - $79,999
e. $80,000 or more

APPENDIX C: MODIFIED IFS QUESTIONNAIRE AGE 9 YEARS



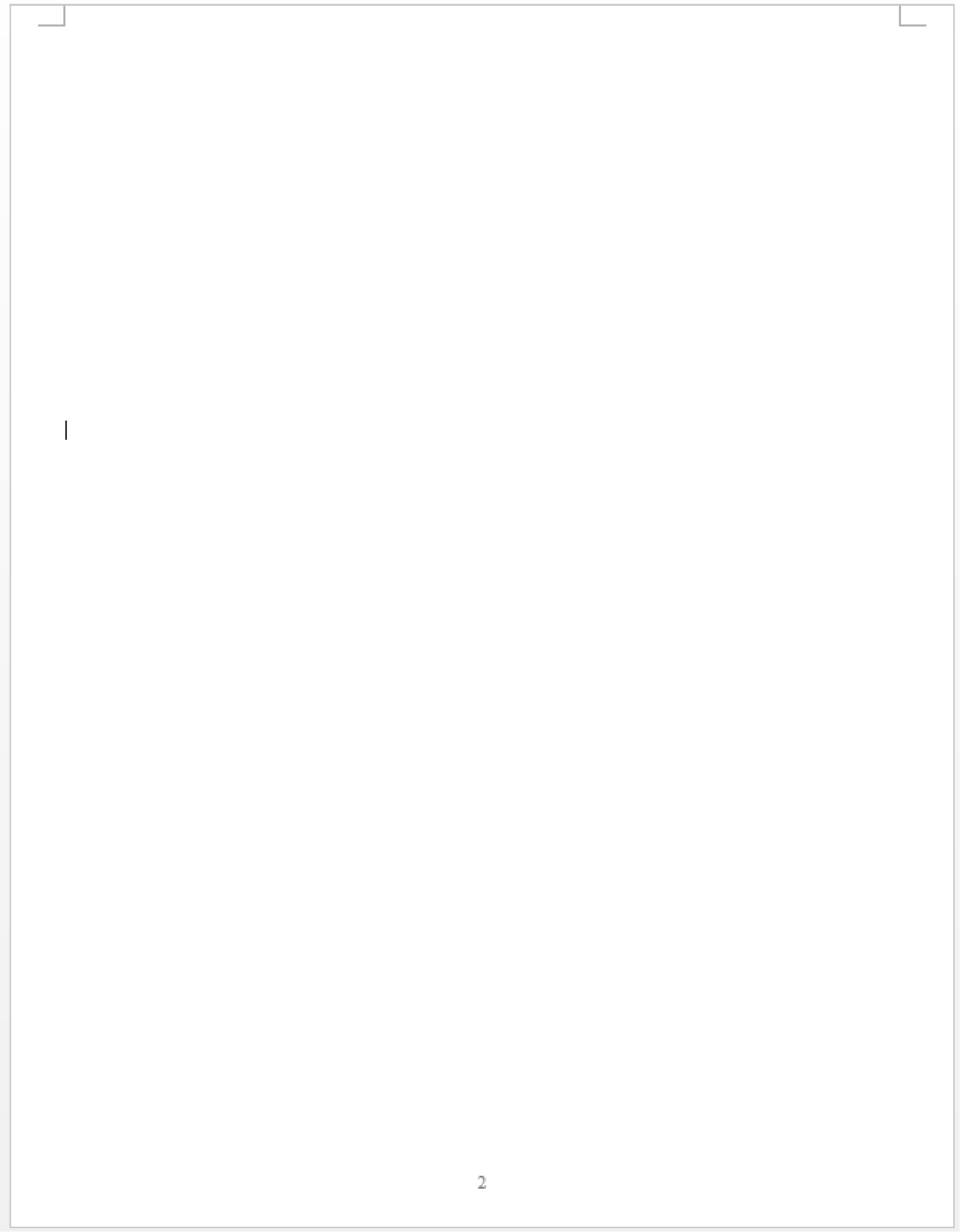
IOWA FLUORIDE STUDY

THE UNIVERSITY OF IOWA
COLLEGE OF DENTISTRY

Please review the address labels and make any necessary corrections:

PLEASE DO NOT REMOVE THIS PAGE.

Revised *03/06/03*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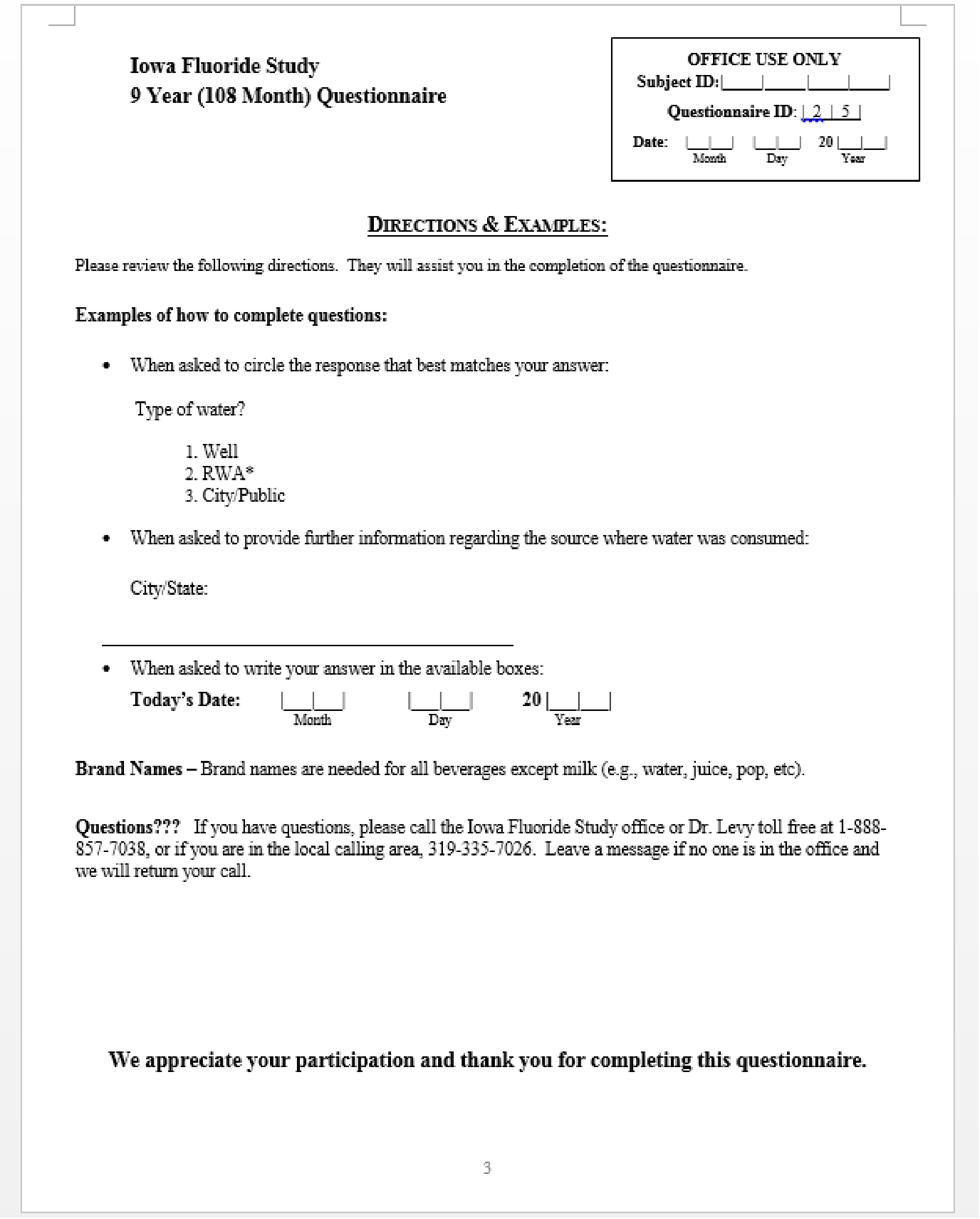


Iowa Fluoride Study
9 Year (108 Month) Questionnaire

OFFICE USE ONLY
Subject ID:|____|____|____|____|
Questionnaire ID: | 2 | 5 |
Date: |__|__| |__|__| 20 |__|__|
Month Day Year

DIRECTIONS & EXAMPLES:

Please review the following directions. They will assist you in the completion of the questionnaire.

Examples of how to complete questions:

- When asked to circle the response that best matches your answer:

Type of water?

1. Well
2. RWA*
3. City/Public

- When asked to provide further information regarding the source where water was consumed:

City/State:

____

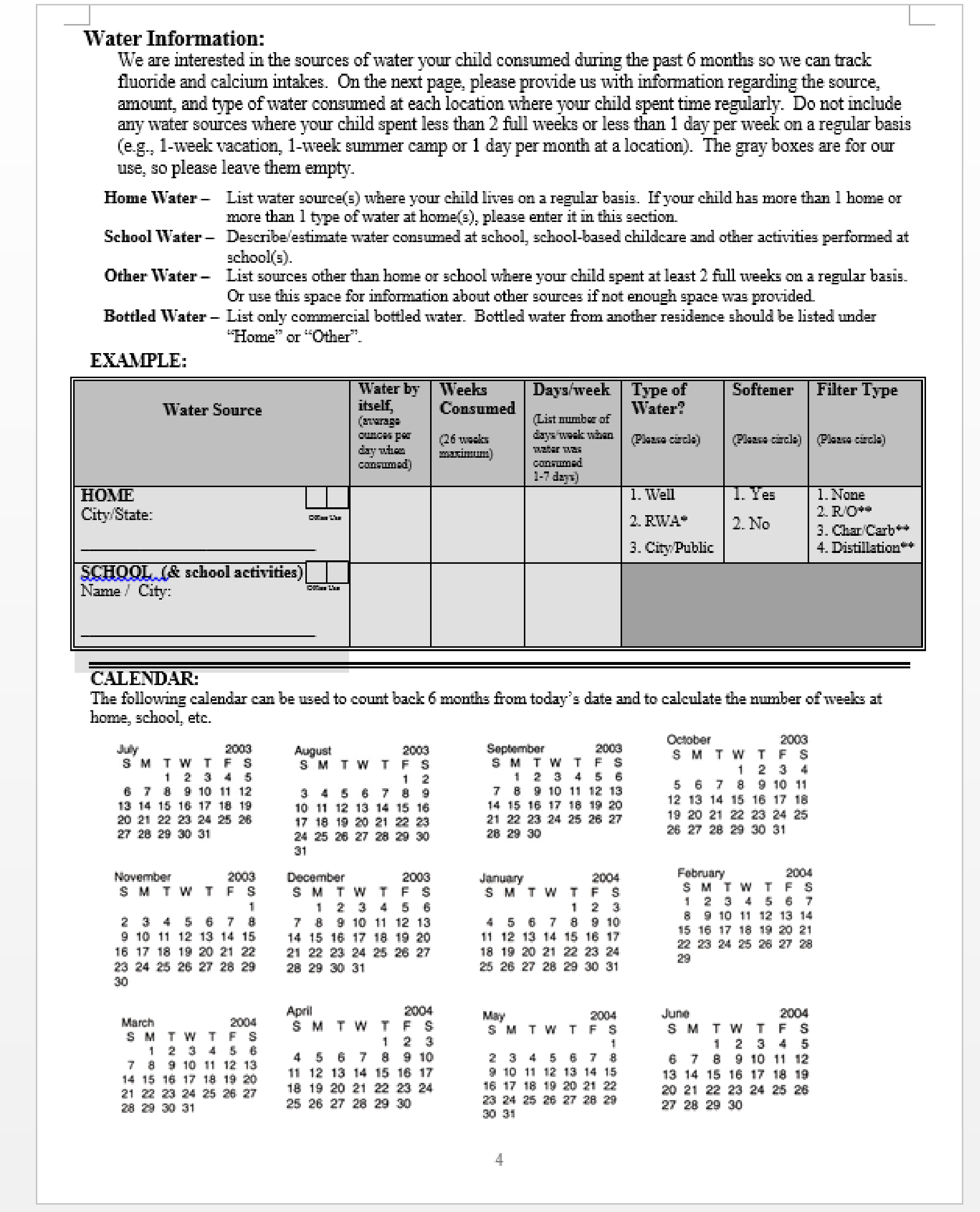
- When asked to write your answer in the available boxes:

Today's Date: |___|___| |___|___| **20** |___|___|
Month Day Year

Brand Names – Brand names are needed for all beverages except milk (e.g., water, juice, pop, etc).

Questions??? If you have questions, please call the Iowa Fluoride Study office or Dr. Levy toll free at 1-888-857-7038, or if you are in the local calling area, 319-335-7026. Leave a message if no one is in the office and we will return your call.

We appreciate your participation and thank you for completing this questionnaire.



Water Information:

We are interested in the sources of water your child consumed during the past 6 months so we can track fluoride and calcium intakes. On the next page, please provide us with information regarding the source, amount, and type of water consumed at each location where your child spent time regularly. Do not include any water sources where your child spent less than 2 full weeks or less than 1 day per week on a regular basis (e.g., 1-week vacation, 1-week summer camp or 1 day per month at a location). The gray boxes are for our use, so please leave them empty.

Home Water – List water source(s) where your child lives on a regular basis. If your child has more than 1 home or more than 1 type of water at home(s), please enter it in this section.

School Water – Describe/estimate water consumed at school, school-based childcare and other activities performed at school(s).

Other Water – List sources other than home or school where your child spent at least 2 full weeks on a regular basis. Or use this space for information about other sources if not enough space was provided.

Bottled Water – List only commercial bottled water. Bottled water from another residence should be listed under "Home" or "Other".

EXAMPLE:

Water Source	Water by itself, (average ounces per day when consumed)	Weeks Consumed (26 weeks maximum)	Days/week (List number of days/week when water was consumed 1-7 days)	Type of Water? (Please circle)	Softener (Please circle)	Filter Type (Please circle)
HOME ☐☐ Office Use City/State: ________________				1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
SCHOOL (& school activities) ☐☐ Office Use Name / City: ________________						

CALENDAR:

The following calendar can be used to count back 6 months from today's date and to calculate the number of weeks at home, school, etc.

July 2003

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

August 2003

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

September 2003

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

October 2003

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

November 2003

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

December 2003

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

January 2004

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

February 2004

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29						

March 2004

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April 2004

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

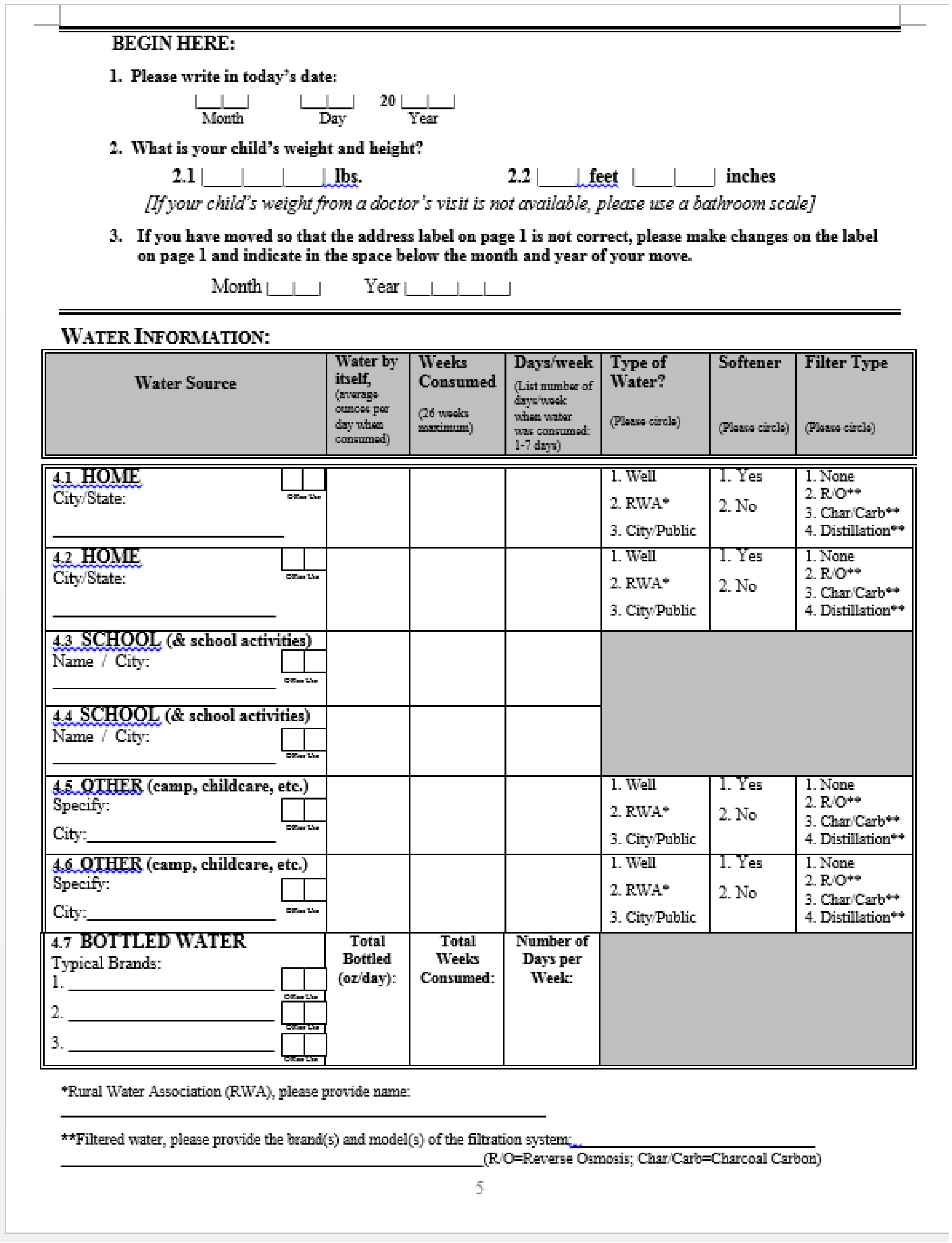
May 2004

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

June 2004

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

4



BEGIN HERE:

1. **Please write in today's date:**

|__|__| |__|__| 20 |__|__|
Month Day Year

2. **What is your child's weight and height?**

2.1 |___|___|___| **lbs.** **2.2** |___| **feet** |___|___| **inches**

[If your child's weight from a doctor's visit is not available, please use a bathroom scale]

3. **If you have moved so that the address label on page 1 is not correct, please make changes on the label on page 1 and indicate in the space below the month and year of your move.**

Month |__|__| Year |__|__|__|__|

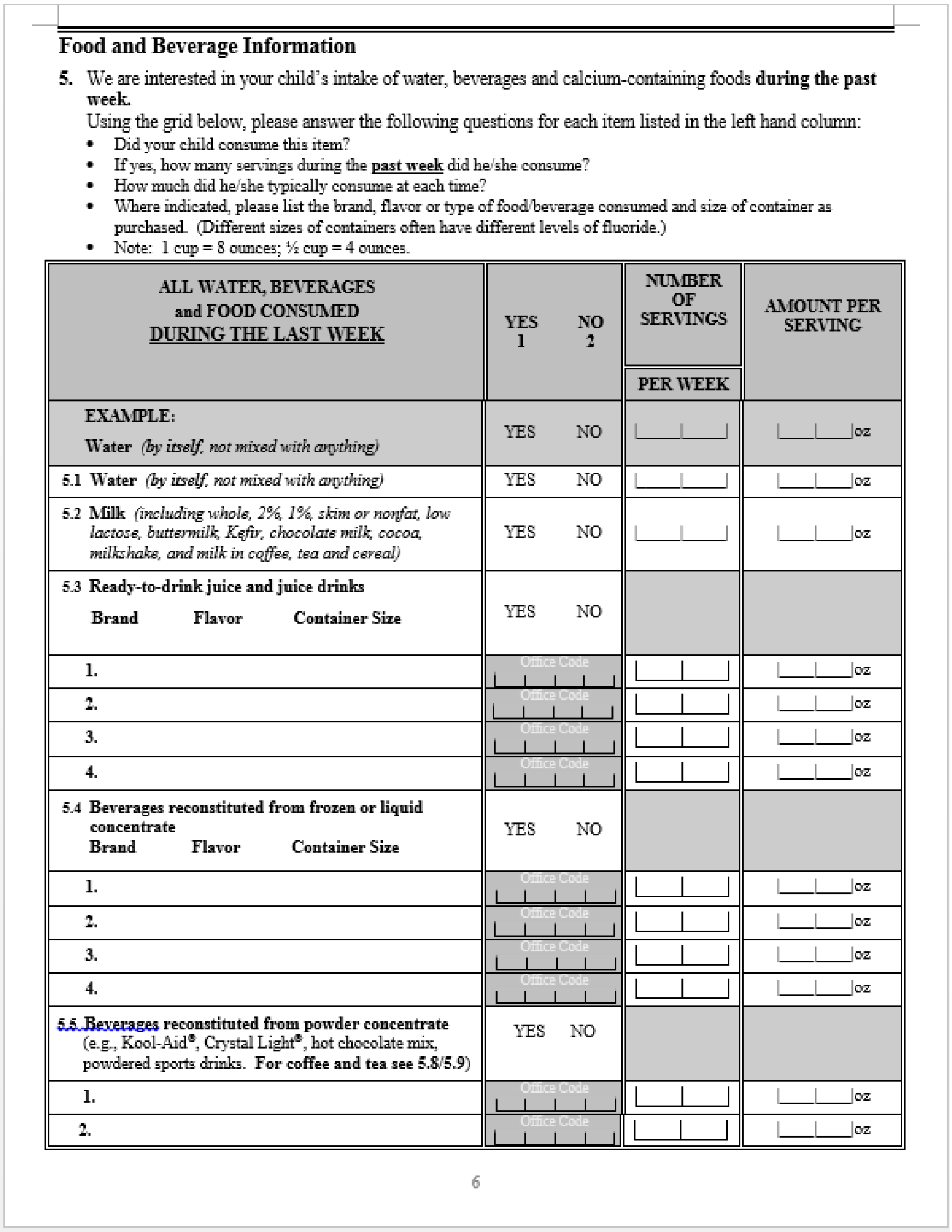
WATER INFORMATION:

Water Source	Water by itself, (average ounces per day when consumed)	Weeks Consumed (26 weeks maximum)	Days/week (List number of days/week when water was consumed: 1-7 days)	Type of Water? (Please circle)	Softener (Please circle)	Filter Type (Please circle)
4.1 HOME City/State: __________________ ☐☐ Office Use				1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.2 HOME City/State: __________________ ☐☐ Office Use				1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.3 SCHOOL (& school activities) Name / City: __________________ ☐☐ Office Use						
4.4 SCHOOL (& school activities) Name / City: __________________ ☐☐ Office Use						
4.5 OTHER (camp, childcare, etc.) Specify: City:________________ ☐☐ Office Use				1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.6 OTHER (camp, childcare, etc.) Specify: City:________________ ☐☐ Office Use				1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.7 BOTTLED WATER Typical Brands: 1. ________________ ☐☐ Office Use 2. ________________ ☐☐ Office Use 3. ________________ ☐☐ Office Use	**Total Bottled (oz/day):**	**Total Weeks Consumed:**	**Number of Days per Week:**			

*Rural Water Association (RWA), please provide name:
____

**Filtered water, please provide the brand(s) and model(s) of the filtration system:______________________
____________________________________(R/O=Reverse Osmosis; Char/Carb=Charcoal Carbon)

5



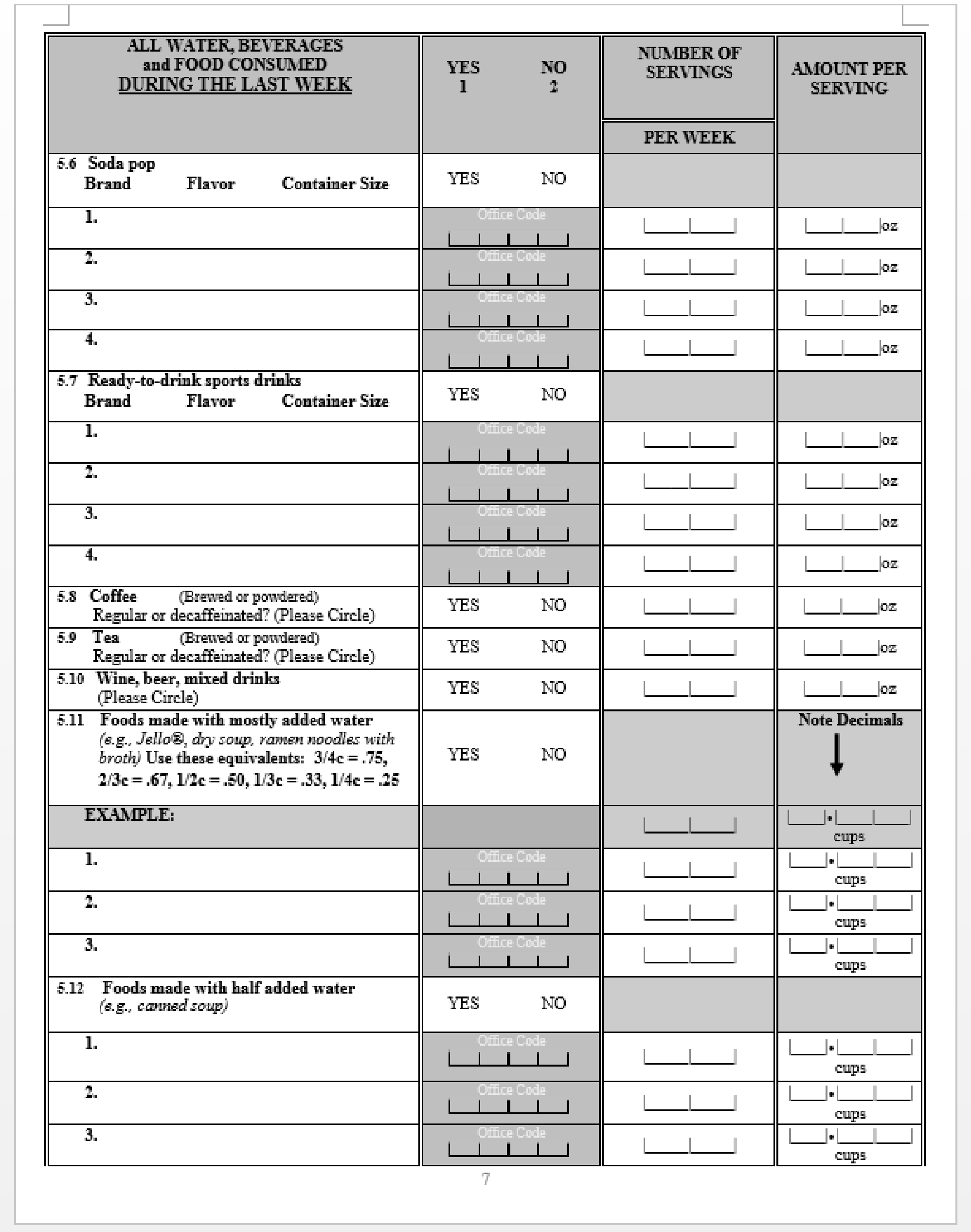
Food and Beverage Information

5. We are interested in your child's intake of water, beverages and calcium-containing foods **during the past week.**

Using the grid below, please answer the following questions for each item listed in the left hand column:

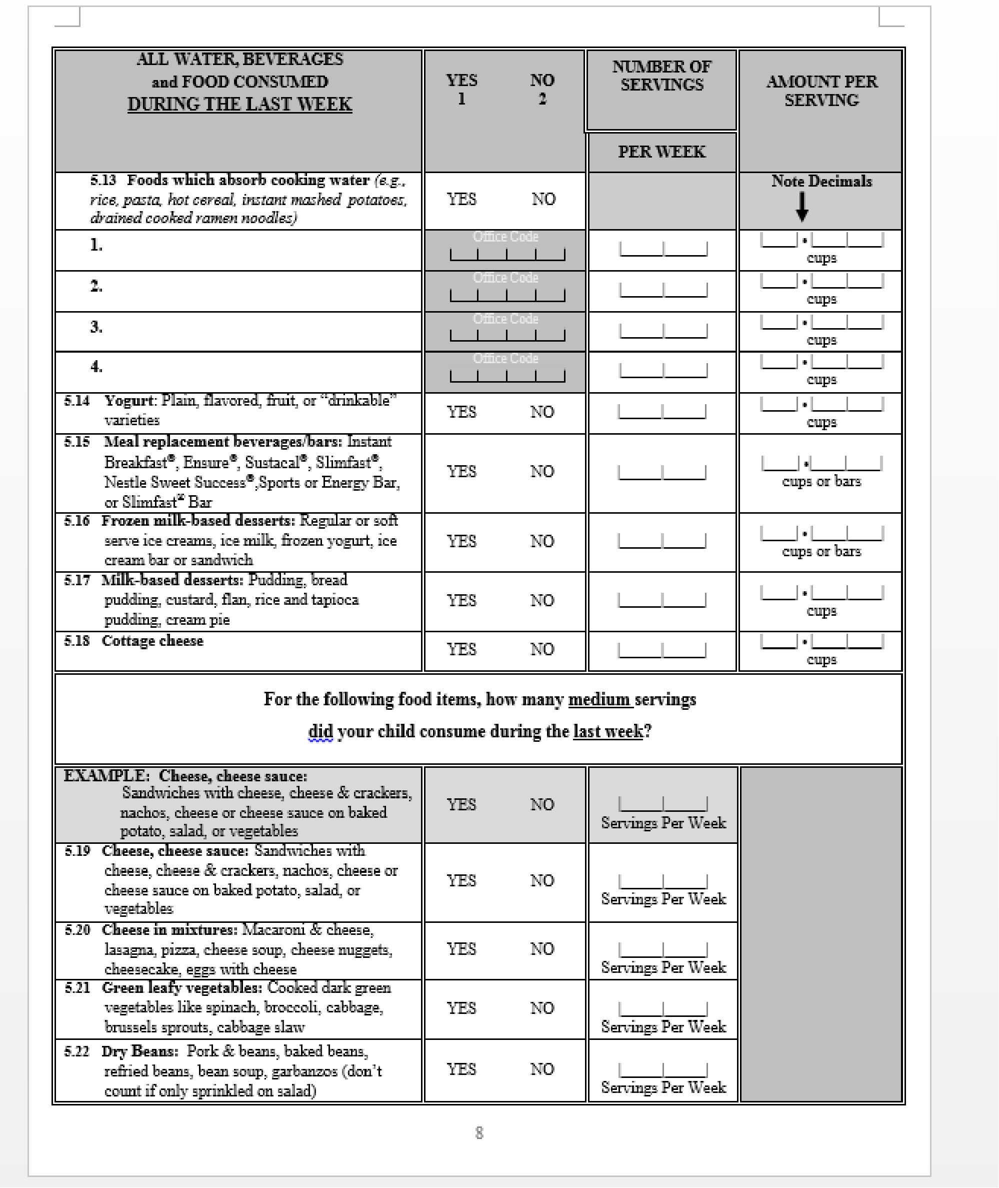
- Did your child consume this item?
- If yes, how many servings during the **past week** did he/she consume?
- How much did he/she typically consume at each time?
- Where indicated, please list the brand, flavor or type of food/beverage consumed and size of container as purchased. (Different sizes of containers often have different levels of fluoride.)
- Note: 1 cup = 8 ounces; ½ cup = 4 ounces.

ALL WATER, BEVERAGES and FOOD CONSUMED DURING THE LAST WEEK	**YES 1**	**NO 2**	**NUMBER OF SERVINGS PER WEEK**	**AMOUNT PER SERVING**
EXAMPLE: **Water** *(by itself, not mixed with anything)*	YES	NO		oz
5.1 **Water** *(by itself, not mixed with anything)*	YES	NO		oz
5.2 **Milk** *(including whole, 2%, 1%, skim or nonfat, low lactose, buttermilk, Kefir, chocolate milk, cocoa, milkshake, and milk in coffee, tea and cereal)*	YES	NO		oz
5.3 **Ready-to-drink juice and juice drinks** **Brand** **Flavor** **Container Size**	YES	NO		
1.	Office Code			oz
2.	Office Code			oz
3.	Office Code			oz
4.	Office Code			oz
5.4 **Beverages reconstituted from frozen or liquid concentrate** **Brand** **Flavor** **Container Size**	YES	NO		
1.	Office Code			oz
2.	Office Code			oz
3.	Office Code			oz
4.	Office Code			oz
5.5 Beverages reconstituted from powder concentrate (e.g., Kool-Aid®, Crystal Light®, hot chocolate mix, powdered sports drinks. **For coffee and tea see 5.8/5.9**)	YES	NO		
1.	Office Code			oz
2.	Office Code			oz



ALL WATER, BEVERAGES and FOOD CONSUMED DURING THE LAST WEEK	**YES 1 NO 2**	**NUMBER OF SERVINGS**	**AMOUNT PER SERVING**
		PER WEEK	
5.6 **Soda pop** **Brand Flavor Container Size**	YES NO		
1.	Office Code		oz
2.	Office Code		oz
3.	Office Code		oz
4.	Office Code		oz
5.7 **Ready-to-drink sports drinks** **Brand Flavor Container Size**	YES NO		
1.	Office Code		oz
2.	Office Code		oz
3.	Office Code		oz
4.	Office Code		oz
5.8 **Coffee** (Brewed or powdered) Regular or decaffeinated? (Please Circle)	YES NO		oz
5.9 **Tea** (Brewed or powdered) Regular or decaffeinated? (Please Circle)	YES NO		oz
5.10 **Wine, beer, mixed drinks** (Please Circle)	YES NO		oz
5.11 **Foods made with mostly added water** *(e.g., Jello®, dry soup, ramen noodles with broth)* **Use these equivalents: 3/4c = .75, 2/3c = .67, 1/2c = .50, 1/3c = .33, 1/4c = .25**	YES NO		**Note Decimals** ↓
EXAMPLE:			. cups
1.	Office Code		. cups
2.	Office Code		. cups
3.	Office Code		. cups
5.12 **Foods made with half added water** *(e.g., canned soup)*	YES NO		
1.	Office Code		. cups
2.	Office Code		. cups
3.	Office Code		. cups

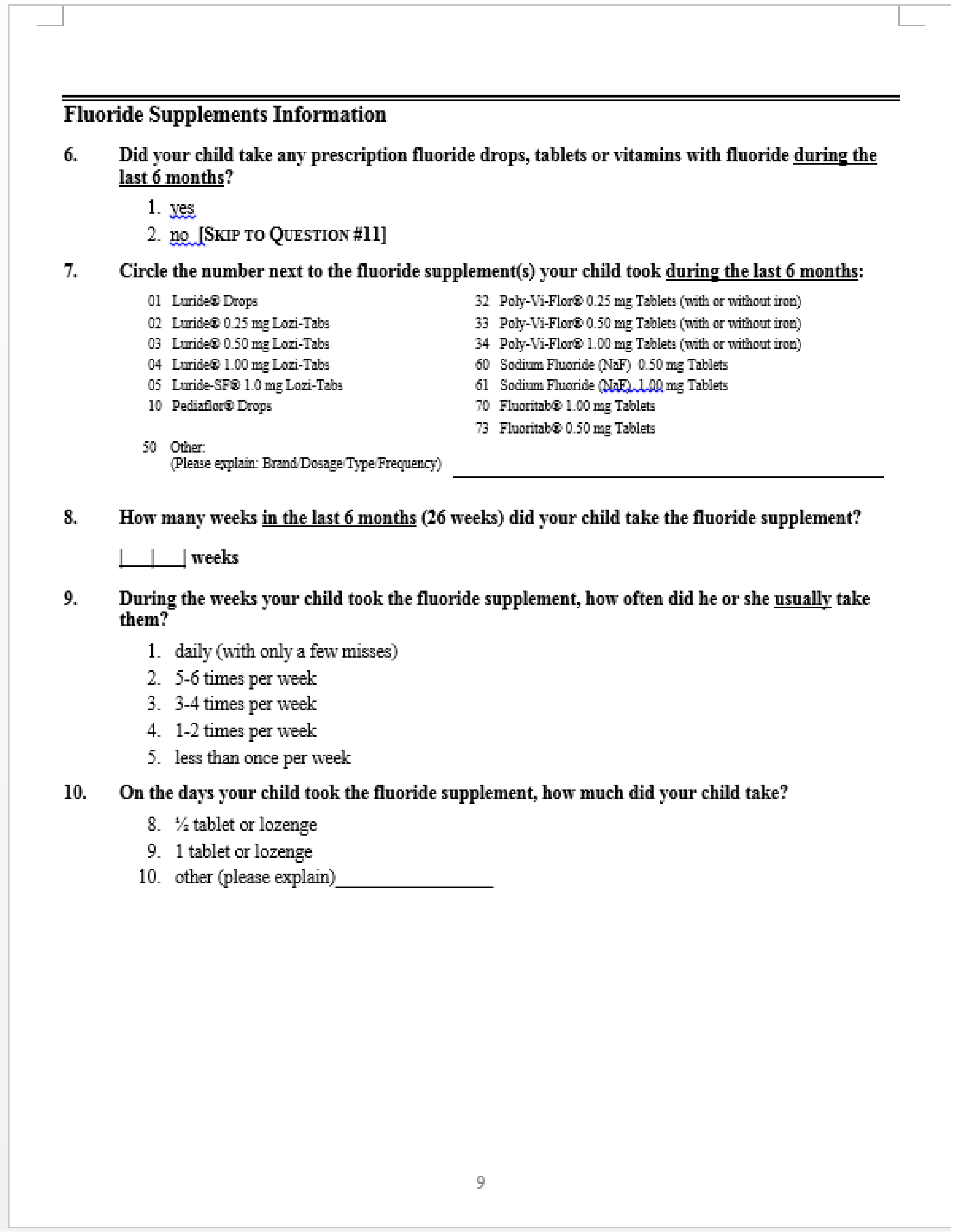
7



ALL WATER, BEVERAGES and FOOD CONSUMED **DURING THE LAST WEEK**	YES 1	NO 2	NUMBER OF SERVINGS	AMOUNT PER SERVING
			PER WEEK	
5.13 Foods which absorb cooking water *(e.g., rice, pasta, hot cereal, instant mashed potatoes, drained cooked ramen noodles)*	YES	NO		**Note Decimals** ↓
1.	Office Code ___ ___ ___ ___		___ ___	___ • ___ ___ cups
2.	Office Code ___ ___ ___ ___		___ ___	___ • ___ ___ cups
3.	Office Code ___ ___ ___ ___		___ ___	___ • ___ ___ cups
4.	Office Code ___ ___ ___ ___		___ ___	___ • ___ ___ cups
5.14 **Yogurt**: Plain, flavored, fruit, or "drinkable" varieties	YES	NO	___ ___	___ • ___ ___ cups
5.15 **Meal replacement beverages/bars:** Instant Breakfast®, Ensure®, Sustacal®, Slimfast®, Nestle Sweet Success®,Sports or Energy Bar, or Slimfast® Bar	YES	NO	___ ___	___ • ___ ___ cups or bars
5.16 **Frozen milk-based desserts:** Regular or soft serve ice creams, ice milk, frozen yogurt, ice cream bar or sandwich	YES	NO	___ ___	___ • ___ ___ cups or bars
5.17 **Milk-based desserts:** Pudding, bread pudding, custard, flan, rice and tapioca pudding, cream pie	YES	NO	___ ___	___ • ___ ___ cups
5.18 **Cottage cheese**	YES	NO	___ ___	___ • ___ ___ cups

For the following food items, how many medium servings did your child consume during the last week?

EXAMPLE: Cheese, cheese sauce: Sandwiches with cheese, cheese & crackers, nachos, cheese or cheese sauce on baked potato, salad, or vegetables	YES	NO	___ ___ Servings Per Week	
5.19 **Cheese, cheese sauce:** Sandwiches with cheese, cheese & crackers, nachos, cheese or cheese sauce on baked potato, salad, or vegetables	YES	NO	___ ___ Servings Per Week	
5.20 **Cheese in mixtures:** Macaroni & cheese, lasagna, pizza, cheese soup, cheese nuggets, cheesecake, eggs with cheese	YES	NO	___ ___ Servings Per Week	
5.21 **Green leafy vegetables:** Cooked dark green vegetables like spinach, broccoli, cabbage, brussels sprouts, cabbage slaw	YES	NO	___ ___ Servings Per Week	
5.22 **Dry Beans:** Pork & beans, baked beans, refried beans, bean soup, garbanzos (don't count if only sprinkled on salad)	YES	NO	___ ___ Servings Per Week	



Fluoride Supplements Information

6. **Did your child take any prescription fluoride drops, tablets or vitamins with fluoride during the last 6 months?**

1. yes
2. no [SKIP TO QUESTION #11]

7. **Circle the number next to the fluoride supplement(s) your child took during the last 6 months:**

01 Luride® Drops
02 Luride® 0.25 mg Lozi-Tabs
03 Luride® 0.50 mg Lozi-Tabs
04 Luride® 1.00 mg Lozi-Tabs
05 Luride-SF® 1.0 mg Lozi-Tabs
10 Pediaflor® Drops
32 Poly-Vi-Flor® 0.25 mg Tablets (with or without iron)
33 Poly-Vi-Flor® 0.50 mg Tablets (with or without iron)
34 Poly-Vi-Flor® 1.00 mg Tablets (with or without iron)
60 Sodium Fluoride (NaF) 0.50 mg Tablets
61 Sodium Fluoride (NaF) 1.00 mg Tablets
70 Fluoritab® 1.00 mg Tablets
73 Fluoritab® 0.50 mg Tablets

50 Other:
(Please explain: Brand/Dosage/Type/Frequency) ________________________________

8. **How many weeks in the last 6 months (26 weeks) did your child take the fluoride supplement?**

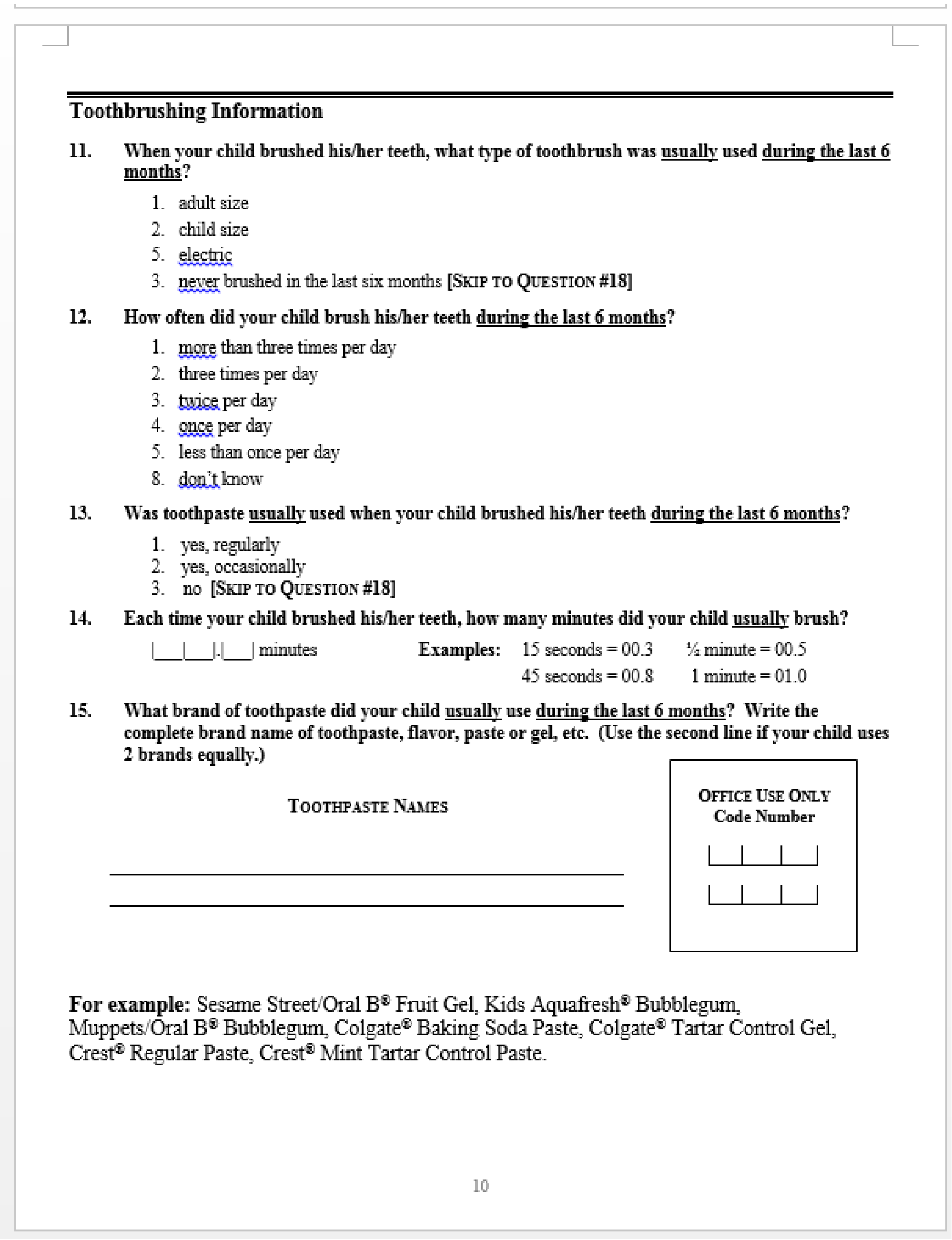
|___|___| weeks

9. **During the weeks your child took the fluoride supplement, how often did he or she usually take them?**

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

10. **On the days your child took the fluoride supplement, how much did your child take?**

8. ½ tablet or lozenge
9. 1 tablet or lozenge
10. other (please explain)________________



Toothbrushing Information

11. When your child brushed his/her teeth, what type of toothbrush was usually used during the last 6 months?

1. adult size
2. child size
5. electric
3. never brushed in the last six months [SKIP TO QUESTION #18]

12. How often did your child brush his/her teeth during the last 6 months?

1. more than three times per day
2. three times per day
3. twice per day
4. once per day
5. less than once per day
8. don't know

13. Was toothpaste usually used when your child brushed his/her teeth during the last 6 months?

1. yes, regularly
2. yes, occasionally
3. no [SKIP TO QUESTION #18]

14. Each time your child brushed his/her teeth, how many minutes did your child usually brush?

|___|___|.|___| minutes

Examples: 15 seconds = 00.3 ½ minute = 00.5
45 seconds = 00.8 1 minute = 01.0

15. What brand of toothpaste did your child usually use during the last 6 months? Write the complete brand name of toothpaste, flavor, paste or gel, etc. (Use the second line if your child uses 2 brands equally.)

TOOTHPASTE NAMES

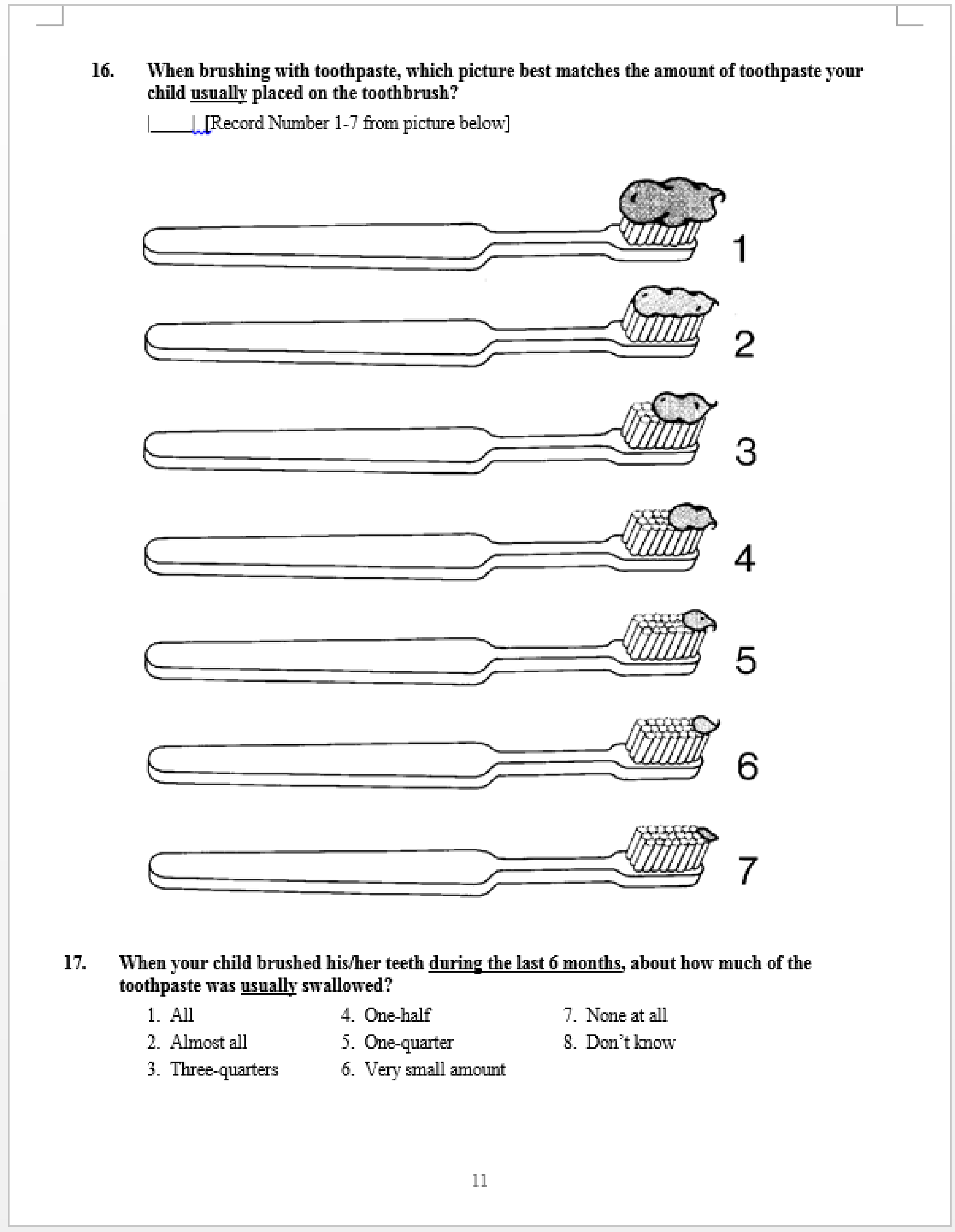
____

____

OFFICE USE ONLY
Code Number
|___|___|___|
|___|___|___|

For example: Sesame Street/Oral B® Fruit Gel, Kids Aquafresh® Bubblegum, Muppets/Oral B® Bubblegum, Colgate® Baking Soda Paste, Colgate® Tartar Control Gel, Crest® Regular Paste, Crest® Mint Tartar Control Paste.

10

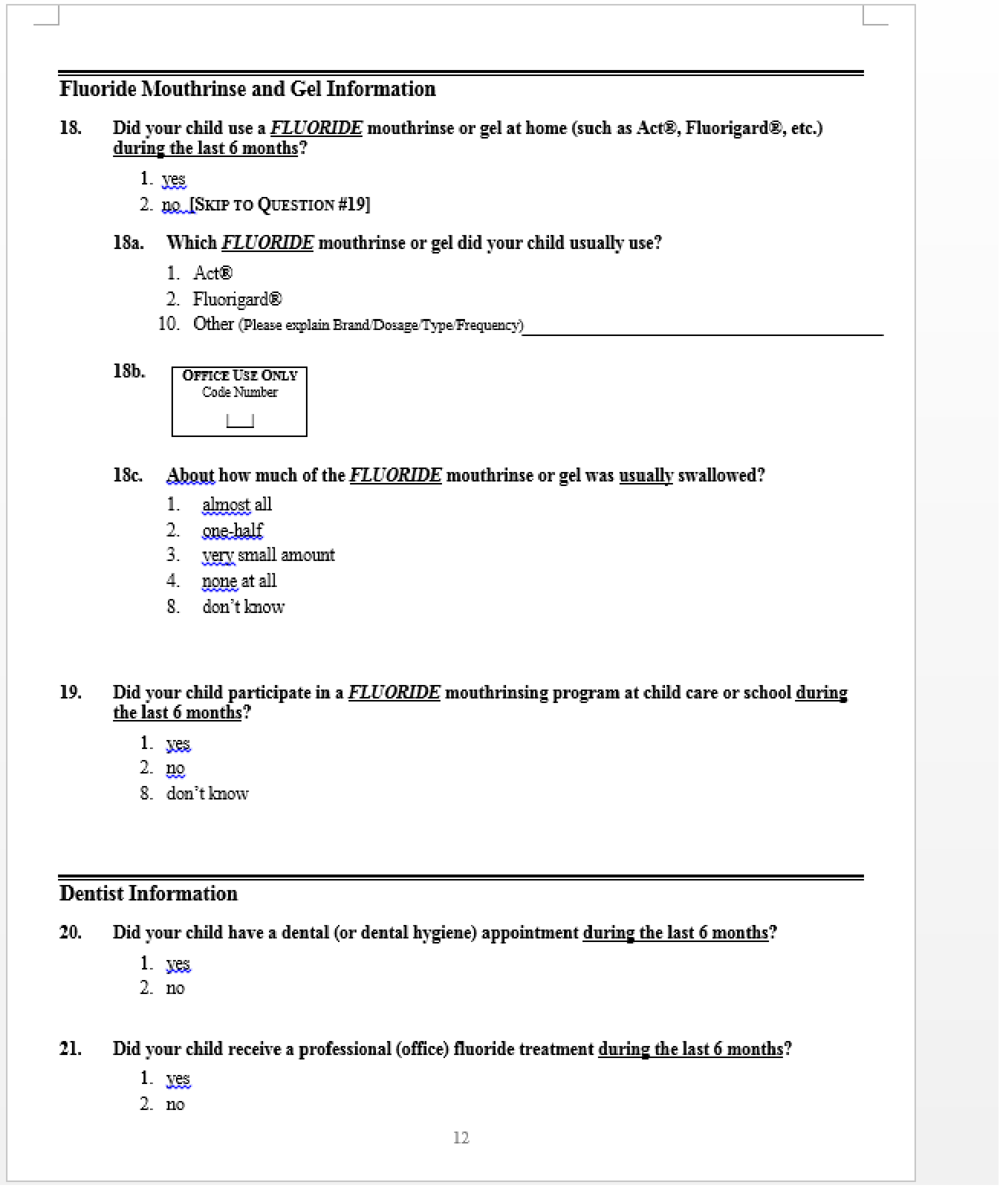


16. **When brushing with toothpaste, which picture best matches the amount of toothpaste your child usually placed on the toothbrush?**

|_____| [Record Number 1-7 from picture below]

17. **When your child brushed his/her teeth during the last 6 months, about how much of the toothpaste was usually swallowed?**

1. All
2. Almost all
3. Three-quarters
4. One-half
5. One-quarter
6. Very small amount
7. None at all
8. Don't know



Fluoride Mouthrinse and Gel Information

18. **Did your child use a *FLUORIDE* mouthrinse or gel at home (such as Act®, Fluorigard®, etc.) during the last 6 months?**

1. yes
2. no [SKIP TO QUESTION #19]

18a. **Which *FLUORIDE* mouthrinse or gel did your child usually use?**

1. Act®
2. Fluorigard®
10. Other (Please explain Brand/Dosage/Type/Frequency) ____________________

18b. OFFICE USE ONLY
Code Number
└─┘

18c. **About how much of the *FLUORIDE* mouthrinse or gel was usually swallowed?**

1. almost all
2. one-half
3. very small amount
4. none at all
8. don't know

19. **Did your child participate in a *FLUORIDE* mouthrinsing program at child care or school during the last 6 months?**

1. yes
2. no
8. don't know

Dentist Information

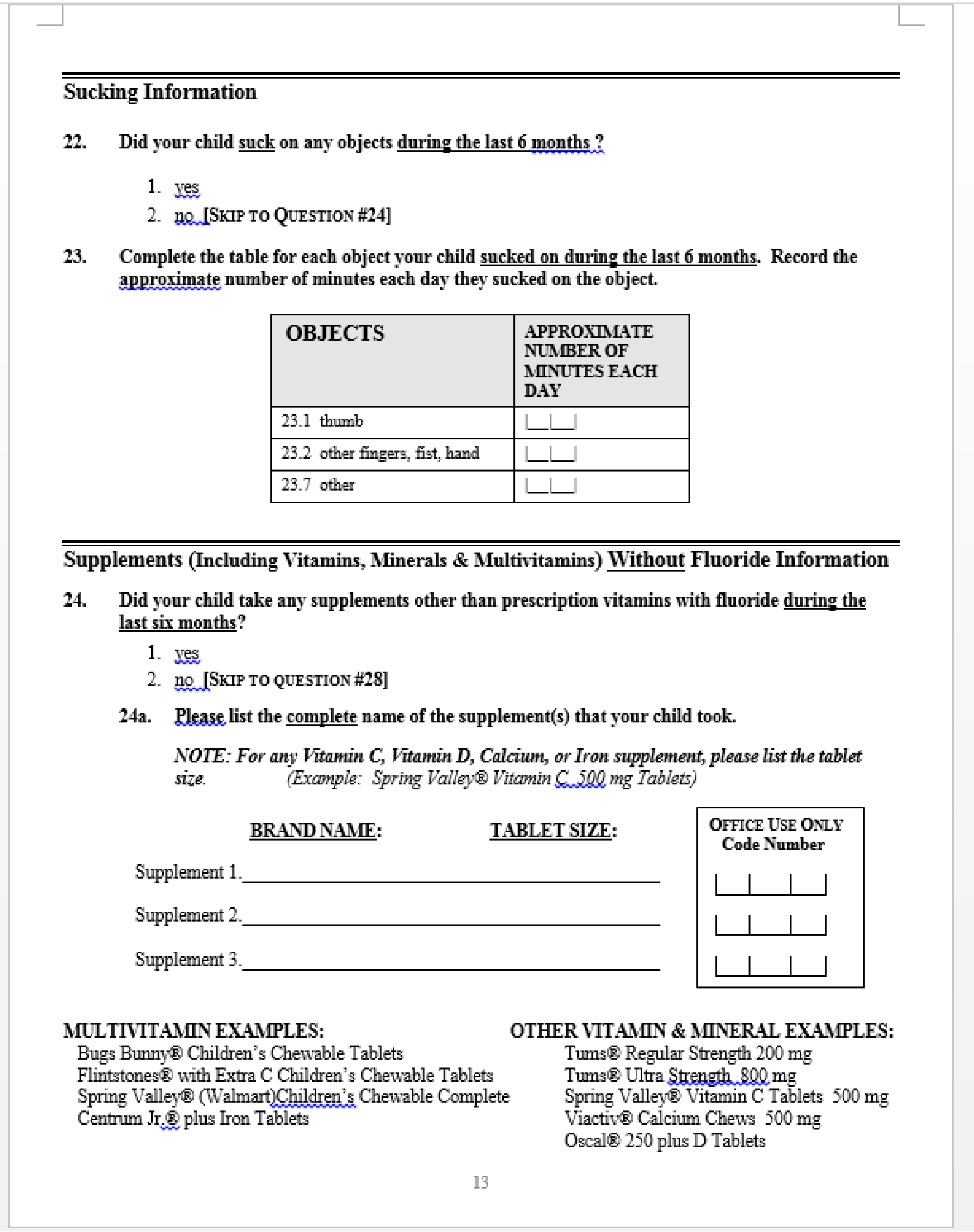
20. **Did your child have a dental (or dental hygiene) appointment during the last 6 months?**

1. yes
2. no

21. **Did your child receive a professional (office) fluoride treatment during the last 6 months?**

1. yes
2. no

12



Sucking Information

22. Did your child suck on any objects during the last 6 months ?

1. yes
2. no [SKIP TO QUESTION #24]

23. Complete the table for each object your child sucked on during the last 6 months. Record the approximate number of minutes each day they sucked on the object.

OBJECTS	APPROXIMATE NUMBER OF MINUTES EACH DAY
23.1 thumb	|__|__|
23.2 other fingers, fist, hand	|__|__|
23.7 other	|__|__|

Supplements (Including Vitamins, Minerals & Multivitamins) Without Fluoride Information

24. Did your child take any supplements other than prescription vitamins with fluoride during the last six months?

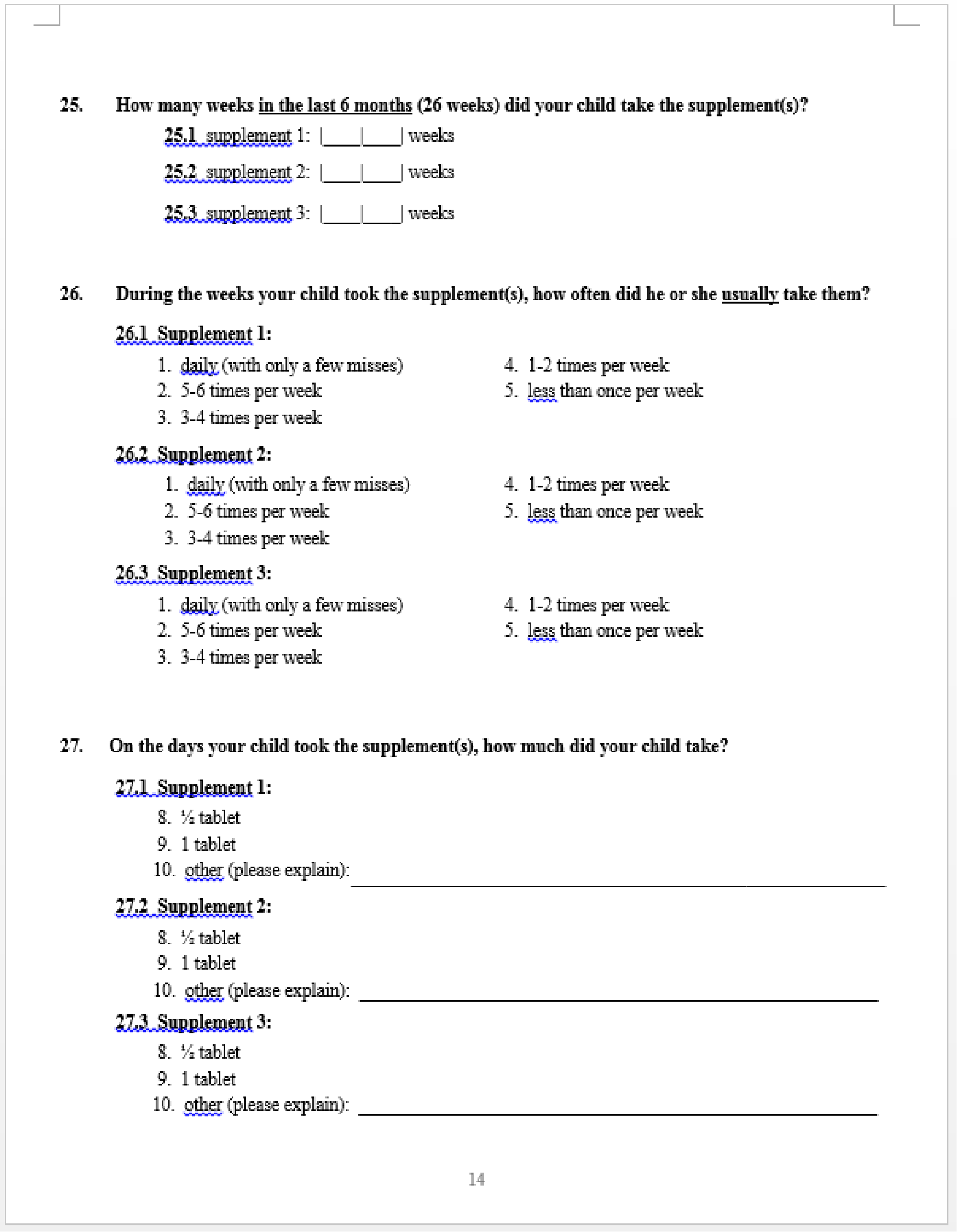
1. yes
2. no [SKIP TO QUESTION #28]

24a. Please list the complete name of the supplement(s) that your child took.

NOTE: For any Vitamin C, Vitamin D, Calcium, or Iron supplement, please list the tablet size. (Example: Spring Valley® Vitamin C 500 mg Tablets)

	BRAND NAME: TABLET SIZE:	OFFICE USE ONLY Code Number
Supplement 1.	________________________________	|__|__|__|
Supplement 2.	________________________________	|__|__|__|
Supplement 3.	________________________________	|__|__|__|

MULTIVITAMIN EXAMPLES:	OTHER VITAMIN & MINERAL EXAMPLES:
Bugs Bunny® Children's Chewable Tablets	Tums® Regular Strength 200 mg
Flintstones® with Extra C Children's Chewable Tablets	Tums® Ultra Strength 800 mg
Spring Valley® (Walmart)Children's Chewable Complete	Spring Valley® Vitamin C Tablets 500 mg
Centrum Jr.® plus Iron Tablets	Viactiv® Calcium Chews 500 mg
	Oscal® 250 plus D Tablets



25. **How many weeks in the last 6 months (26 weeks) did your child take the supplement(s)?**

25.1 supplement 1: |____|____| weeks

25.2 supplement 2: |____|____| weeks

25.3 supplement 3: |____|____| weeks

26. **During the weeks your child took the supplement(s), how often did he or she usually take them?**

26.1 Supplement 1:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

26.2 Supplement 2:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

26.3 Supplement 3:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

27. **On the days your child took the supplement(s), how much did your child take?**

27.1 Supplement 1:

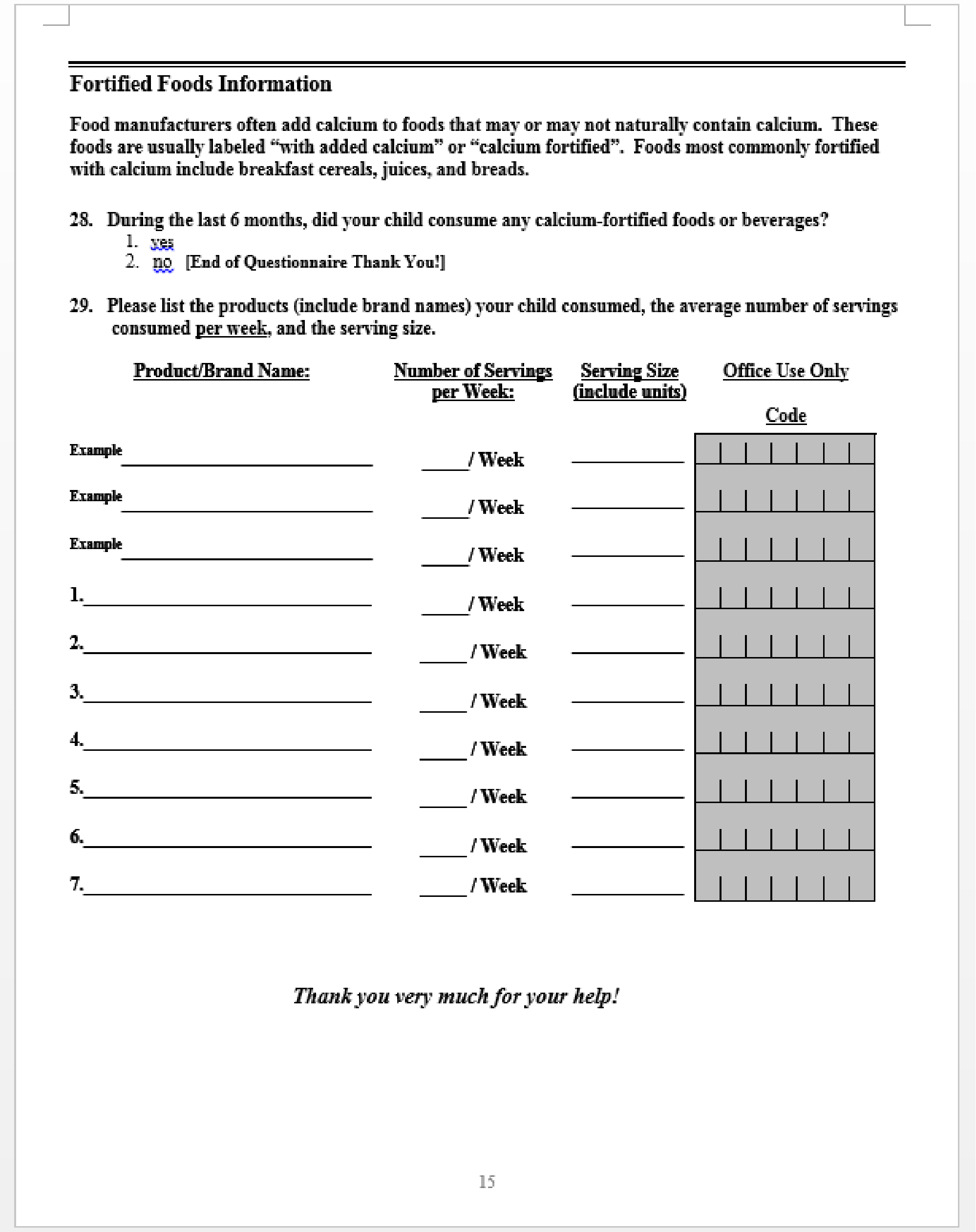
8. ½ tablet
9. 1 tablet
10. other (please explain): ____

27.2 Supplement 2:

8. ½ tablet
9. 1 tablet
10. other (please explain): ____

27.3 Supplement 3:

8. ½ tablet
9. 1 tablet
10. other (please explain): ____



Fortified Foods Information

Food manufacturers often add calcium to foods that may or may not naturally contain calcium. These foods are usually labeled "with added calcium" or "calcium fortified". Foods most commonly fortified with calcium include breakfast cereals, juices, and breads.

28. During the last 6 months, did your child consume any calcium-fortified foods or beverages?

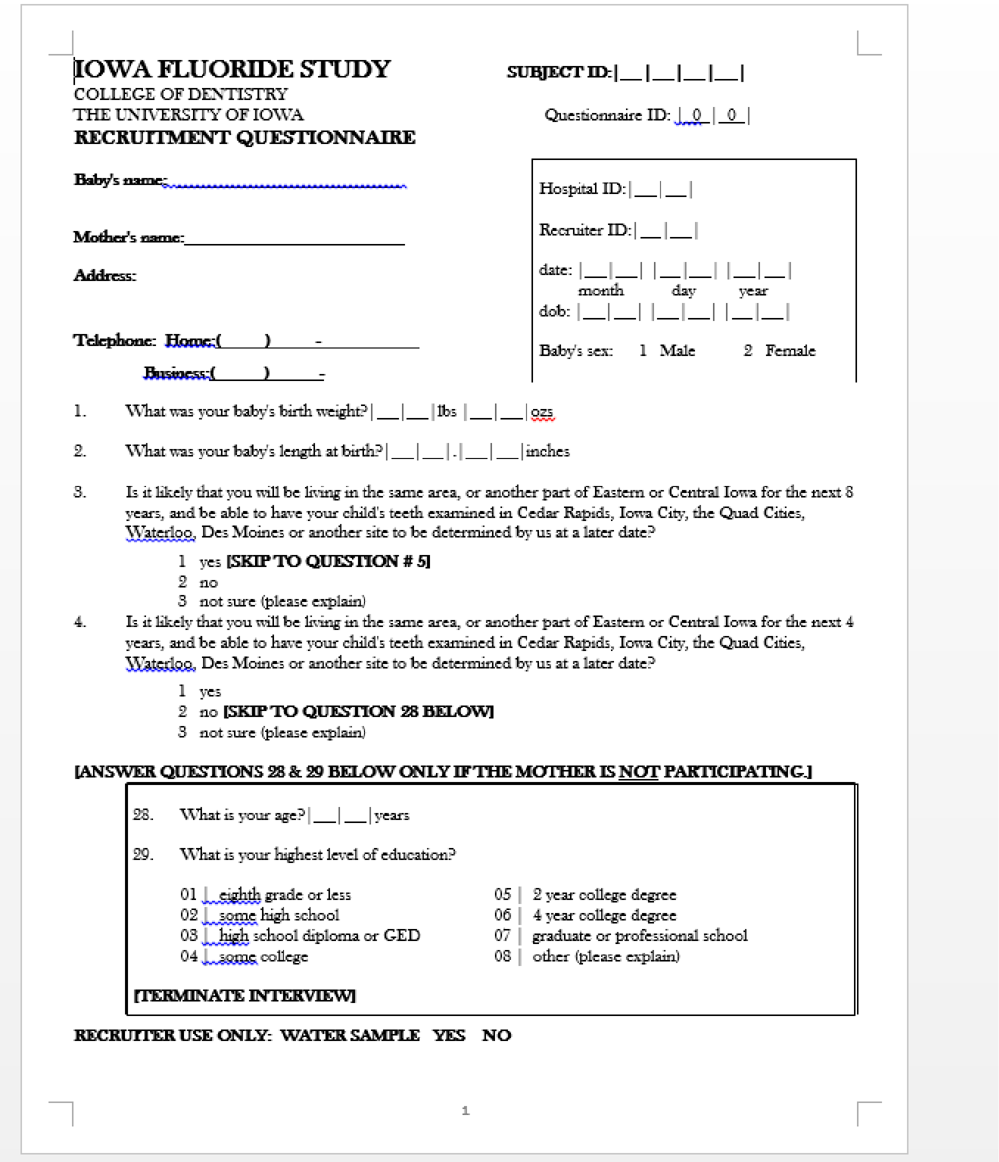
1. yes
2. no **[End of Questionnaire Thank You!]**

29. Please list the products (include brand names) your child consumed, the average number of servings consumed per week, and the serving size.

Product/Brand Name:	**Number of Servings per Week:**	**Serving Size (include units)**	Office Use Only Code
Example ____________	_____/ Week	________	
Example ____________	_____/ Week	________	
Example ____________	_____/ Week	________	
1. ____________	_____/ Week	________	
2. ____________	_____/ Week	________	
3. ____________	_____/ Week	________	
4. ____________	_____/ Week	________	
5. ____________	_____/ Week	________	
6. ____________	_____/ Week	________	
7. ____________	_____/ Week	________	

Thank you very much for your help!

APPENDIX D: IOWA FLUORIDE STUDY RECRUITMENT QUESTIONNAIRE



IOWA FLUORIDE STUDY
COLLEGE OF DENTISTRY
THE UNIVERSITY OF IOWA
RECRUITMENT QUESTIONNAIRE

SUBJECT ID:|__|__|__|__|

Questionnaire ID: |_0_|_0_|

Hospital ID:|___|___|

Recruiter ID:|___|___|

date: |___|___| |___|___| |___|___|
month day year
dob: |___|___| |___|___| |___|___|

Baby's sex: 1 Male 2 Female

Baby's name:

Mother's name:_______________________

Address:

Telephone: Home:(   )   -

Business:(   )   -

1. What was your baby's birth weight? |___|___| lbs |___|___| ozs

2. What was your baby's length at birth? |___|___|.|___|___| inches

3. Is it likely that you will be living in the same area, or another part of Eastern or Central Iowa for the next 8 years, and be able to have your child's teeth examined in Cedar Rapids, Iowa City, the Quad Cities, Waterloo, Des Moines or another site to be determined by us at a later date?
   1 yes **[SKIP TO QUESTION # 5]**
   2 no
   3 not sure (please explain)

4. Is it likely that you will be living in the same area, or another part of Eastern or Central Iowa for the next 4 years, and be able to have your child's teeth examined in Cedar Rapids, Iowa City, the Quad Cities, Waterloo, Des Moines or another site to be determined by us at a later date?
   1 yes
   2 no **[SKIP TO QUESTION 28 BELOW]**
   3 not sure (please explain)

[ANSWER QUESTIONS 28 & 29 BELOW ONLY IF THE MOTHER IS NOT PARTICIPATING.]

28. What is your age? |___|___| years

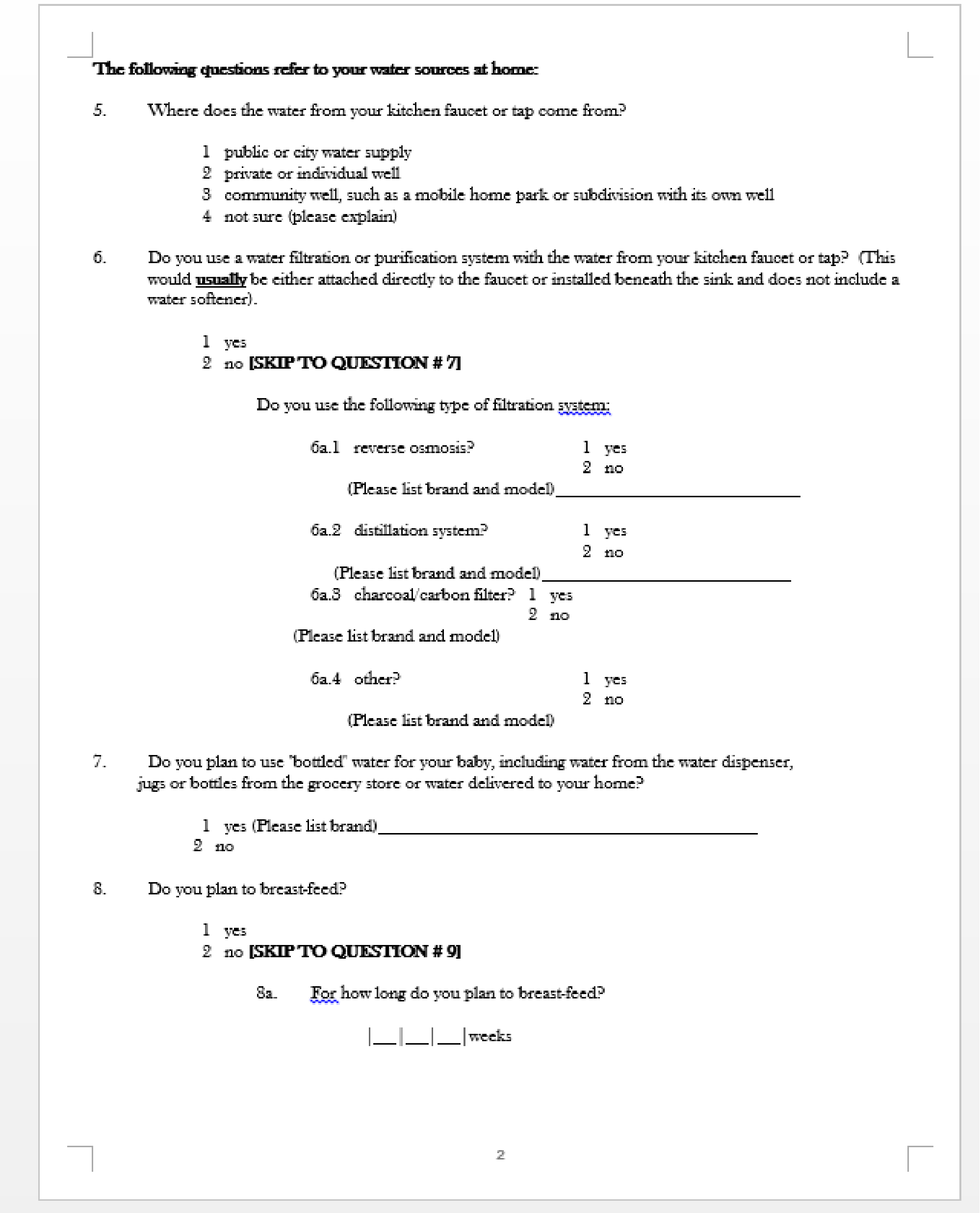
29. What is your highest level of education?

01 |__ eighth grade or less
02 |__ some high school
03 |__ high school diploma or GED
04 |__ some college
05 | 2 year college degree
06 | 4 year college degree
07 | graduate or professional school
08 | other (please explain)

[TERMINATE INTERVIEW]

RECRUITER USE ONLY: WATER SAMPLE YES NO

1



The following questions refer to your water sources at home:

5. Where does the water from your kitchen faucet or tap come from?

1 public or city water supply
2 private or individual well
3 community well, such as a mobile home park or subdivision with its own well
4 not sure (please explain)

6. Do you use a water filtration or purification system with the water from your kitchen faucet or tap? (This would **usually** be either attached directly to the faucet or installed beneath the sink and does not include a water softener).

1 yes
2 no **[SKIP TO QUESTION # 7]**

Do you use the following type of filtration system:

6a.1 reverse osmosis? 1 yes
2 no
(Please list brand and model)____________________________

6a.2 distillation system? 1 yes
2 no
(Please list brand and model)____________________________

6a.3 charcoal/carbon filter? 1 yes
2 no
(Please list brand and model)

6a.4 other? 1 yes
2 no
(Please list brand and model)

7. Do you plan to use "bottled" water for your baby, including water from the water dispenser, jugs or bottles from the grocery store or water delivered to your home?

1 yes (Please list brand)____
2 no

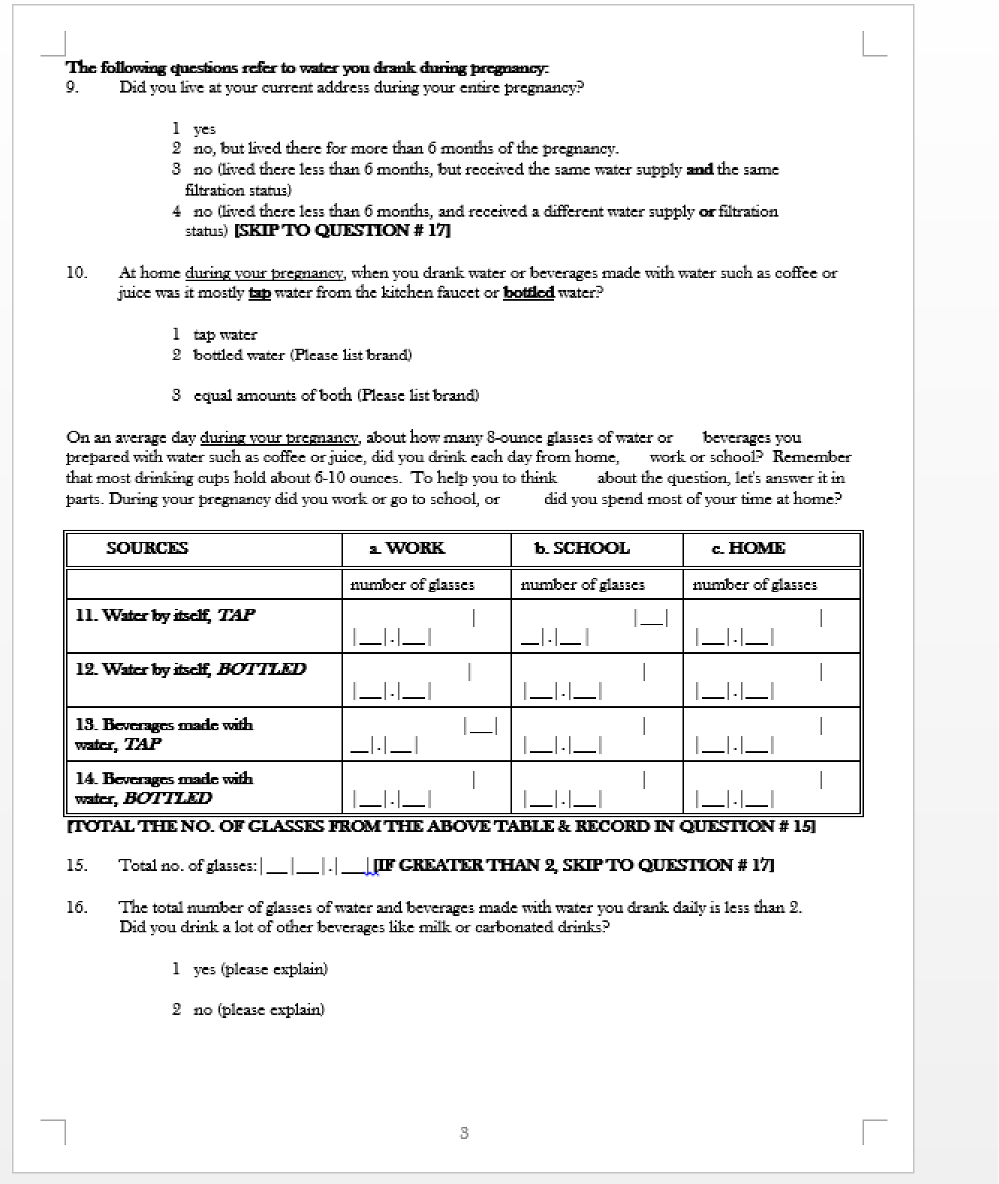
8. Do you plan to breast-feed?

1 yes
2 no **[SKIP TO QUESTION # 9]**

8a. For how long do you plan to breast-feed?

|___|___|___|weeks

2



The following questions refer to water you drank during pregnancy:

9. Did you live at your current address during your entire pregnancy?

1 yes
2 no, but lived there for more than 6 months of the pregnancy.
3 no (lived there less than 6 months, but received the same water supply **and** the same filtration status)
4 no (lived there less than 6 months, and received a different water supply **or** filtration status) **[SKIP TO QUESTION # 17]**

10. At home <u>during your pregnancy</u>, when you drank water or beverages made with water such as coffee or juice was it mostly **<u>tap</u>** water from the kitchen faucet or **<u>bottled</u>** water?

1 tap water
2 bottled water (Please list brand)

3 equal amounts of both (Please list brand)

On an average day <u>during your pregnancy</u>, about how many 8-ounce glasses of water or beverages you prepared with water such as coffee or juice, did you drink each day from home, work or school? Remember that most drinking cups hold about 6-10 ounces. To help you to think about the question, let's answer it in parts. During your pregnancy did you work or go to school, or did you spend most of your time at home?

SOURCES	**a. WORK**	**b. SCHOOL**	**c. HOME**
	number of glasses	number of glasses	number of glasses
11. Water by itself, *TAP*	| |__|.|__|	|__| __|.|__|	| |__|.|__|
12. Water by itself, *BOTTLED*	| |__|.|__|	| |__|.|__|	| |__|.|__|
13. Beverages made with water, *TAP*	|__| __|.|__|	| |__|.|__|	| |__|.|__|
14. Beverages made with water, *BOTTLED*	| |__|.|__|	| |__|.|__|	| |__|.|__|

[TOTAL THE NO. OF GLASSES FROM THE ABOVE TABLE & RECORD IN QUESTION # 15]

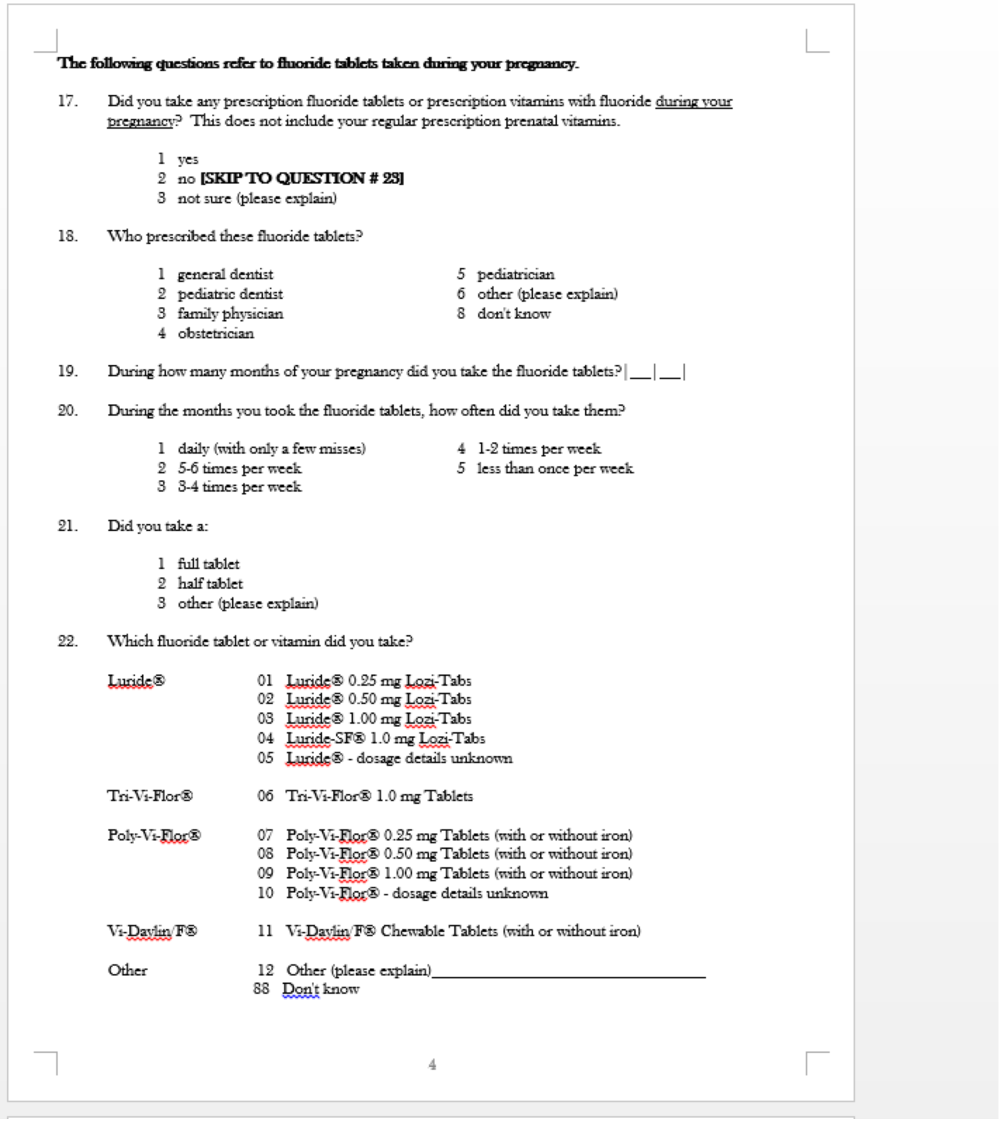
15. Total no. of glasses: |___|___|.|___| **[IF GREATER THAN 2, SKIP TO QUESTION # 17]**

16. The total number of glasses of water and beverages made with water you drank daily is less than 2. Did you drink a lot of other beverages like milk or carbonated drinks?

1 yes (please explain)

2 no (please explain)

3



The following questions refer to fluoride tablets taken during your pregnancy.

17. Did you take any prescription fluoride tablets or prescription vitamins with fluoride <u>during your pregnancy</u>? This does not include your regular prescription prenatal vitamins.

1 yes
2 no **[SKIP TO QUESTION # 23]**
3 not sure (please explain)

18. Who prescribed these fluoride tablets?

1 general dentist
2 pediatric dentist
3 family physician
4 obstetrician
5 pediatrician
6 other (please explain)
8 don't know

19. During how many months of your pregnancy did you take the fluoride tablets? |___|___|

20. During the months you took the fluoride tablets, how often did you take them?

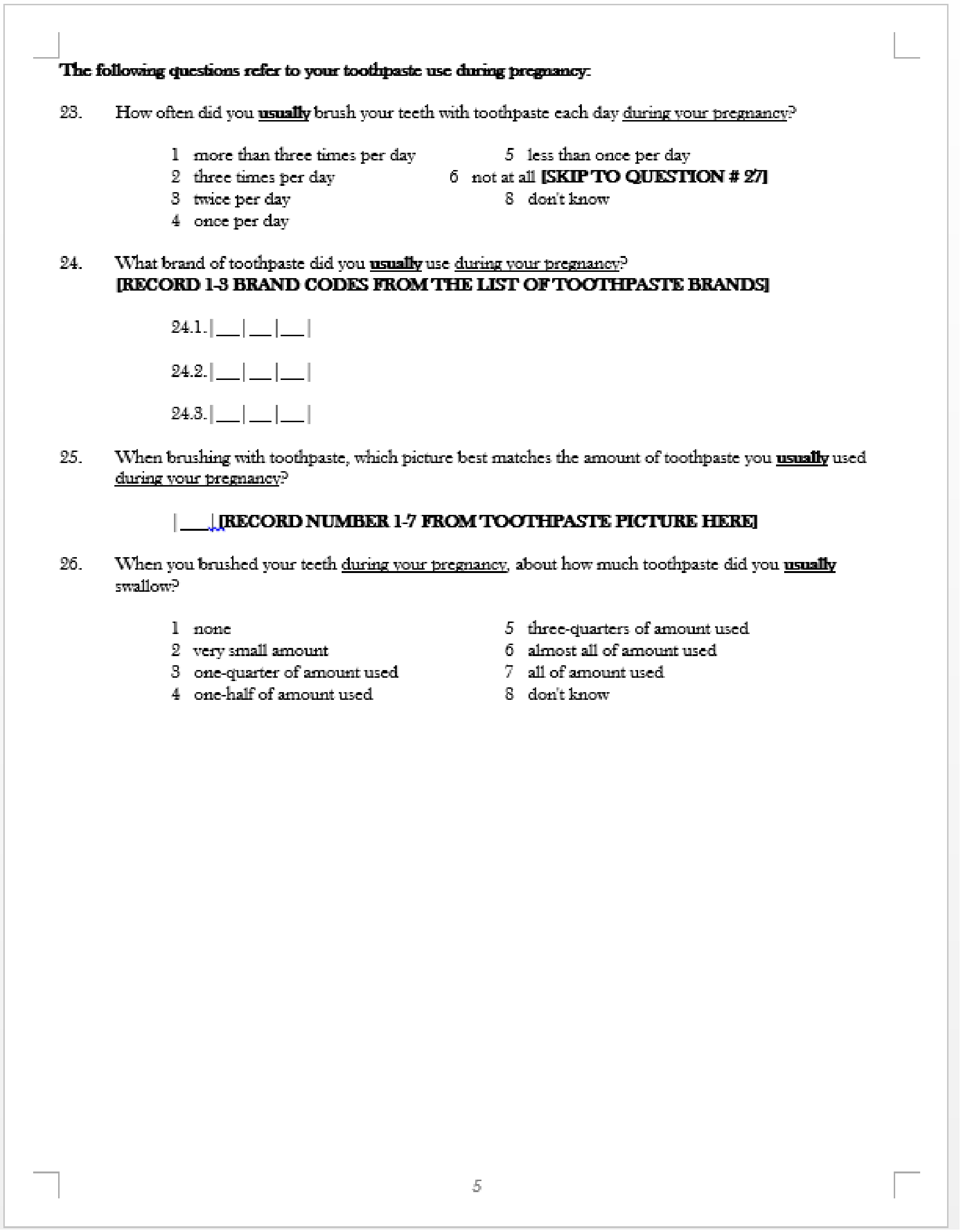
1 daily (with only a few misses)
2 5-6 times per week
3 3-4 times per week
4 1-2 times per week
5 less than once per week

21. Did you take a:

1 full tablet
2 half tablet
3 other (please explain)

22. Which fluoride tablet or vitamin did you take?

Luride®	01 Luride® 0.25 mg Lozi-Tabs 02 Luride® 0.50 mg Lozi-Tabs 03 Luride® 1.00 mg Lozi-Tabs 04 Luride-SF® 1.0 mg Lozi-Tabs 05 Luride® - dosage details unknown
Tri-Vi-Flor®	06 Tri-Vi-Flor® 1.0 mg Tablets
Poly-Vi-Flor®	07 Poly-Vi-Flor® 0.25 mg Tablets (with or without iron) 08 Poly-Vi-Flor® 0.50 mg Tablets (with or without iron) 09 Poly-Vi-Flor® 1.00 mg Tablets (with or without iron) 10 Poly-Vi-Flor® - dosage details unknown
Vi-Daylin/F®	11 Vi-Daylin/F® Chewable Tablets (with or without iron)
Other	12 Other (please explain)________________________________ 88 Don't know



The following questions refer to your toothpaste use during pregnancy:

23. How often did you **<u>usually</u>** brush your teeth with toothpaste each day <u>during your pregnancy</u>?

1 more than three times per day
2 three times per day
3 twice per day
4 once per day
5 less than once per day
6 not at all **[SKIP TO QUESTION # 27]**
8 don't know

24. What brand of toothpaste did you **<u>usually</u>** use <u>during your pregnancy</u>?
[RECORD 1-3 BRAND CODES FROM THE LIST OF TOOTHPASTE BRANDS]

24.1.|___|___|___|

24.2.|___|___|___|

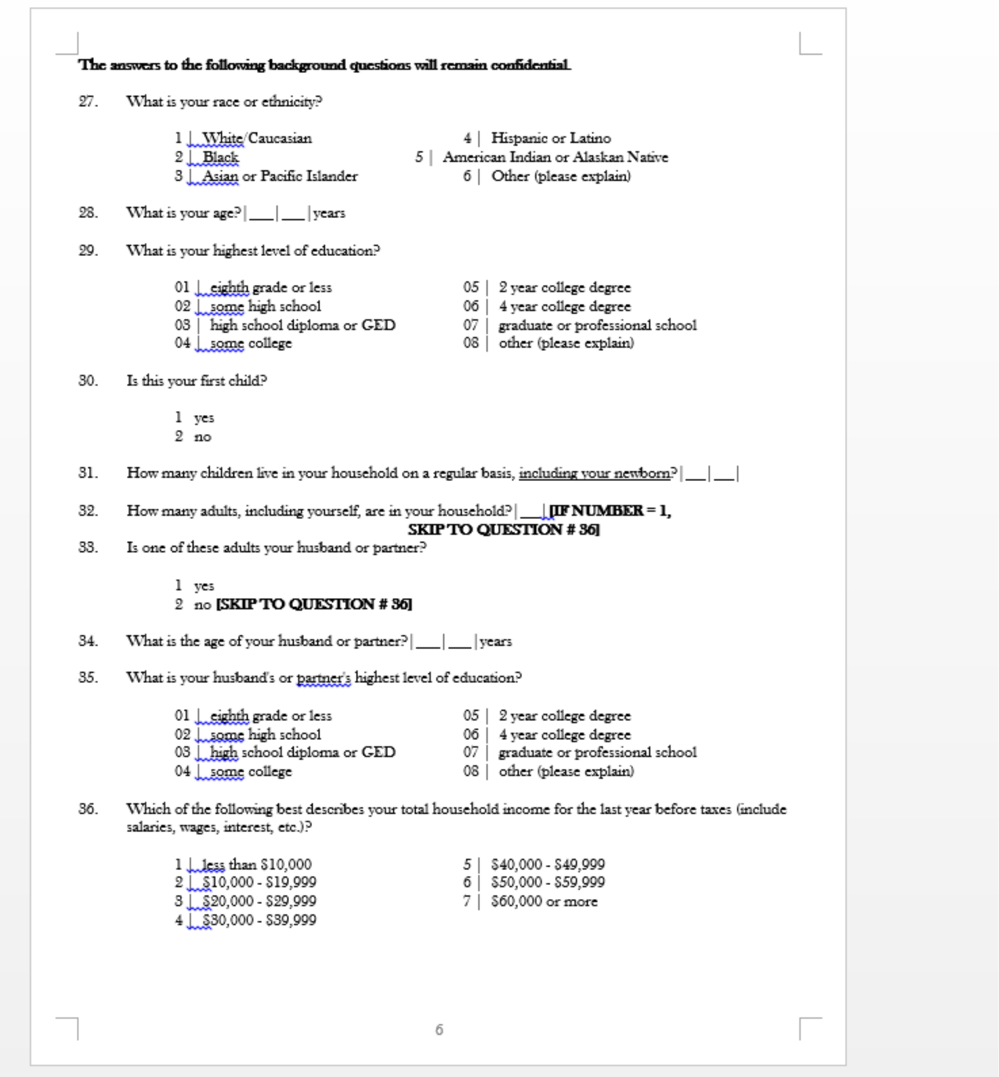
24.3.|___|___|___|

25. When brushing with toothpaste, which picture best matches the amount of toothpaste you **<u>usually</u>** used <u>during your pregnancy</u>?

|___| **[RECORD NUMBER 1-7 FROM TOOTHPASTE PICTURE HERE]**

26. When you brushed your teeth <u>during your pregnancy</u>, about how much toothpaste did you **<u>usually</u>** swallow?

1 none
2 very small amount
3 one-quarter of amount used
4 one-half of amount used
5 three-quarters of amount used
6 almost all of amount used
7 all of amount used
8 don't know



The answers to the following background questions will remain confidential.

27. What is your race or ethnicity?

1 | White/Caucasian
2 | Black
3 | Asian or Pacific Islander
4 | Hispanic or Latino
5 | American Indian or Alaskan Native
6 | Other (please explain)

28. What is your age? |___|___| years

29. What is your highest level of education?

01 | eighth grade or less
02 | some high school
03 | high school diploma or GED
04 | some college
05 | 2 year college degree
06 | 4 year college degree
07 | graduate or professional school
08 | other (please explain)

30. Is this your first child?

1 yes
2 no

31. How many children live in your household on a regular basis, <u>including your newborn</u>? |___|___|

32. How many adults, including yourself, are in your household? |___| **[IF NUMBER = 1, SKIP TO QUESTION # 36]**

33. Is one of these adults your husband or partner?

1 yes
2 no **[SKIP TO QUESTION # 36]**

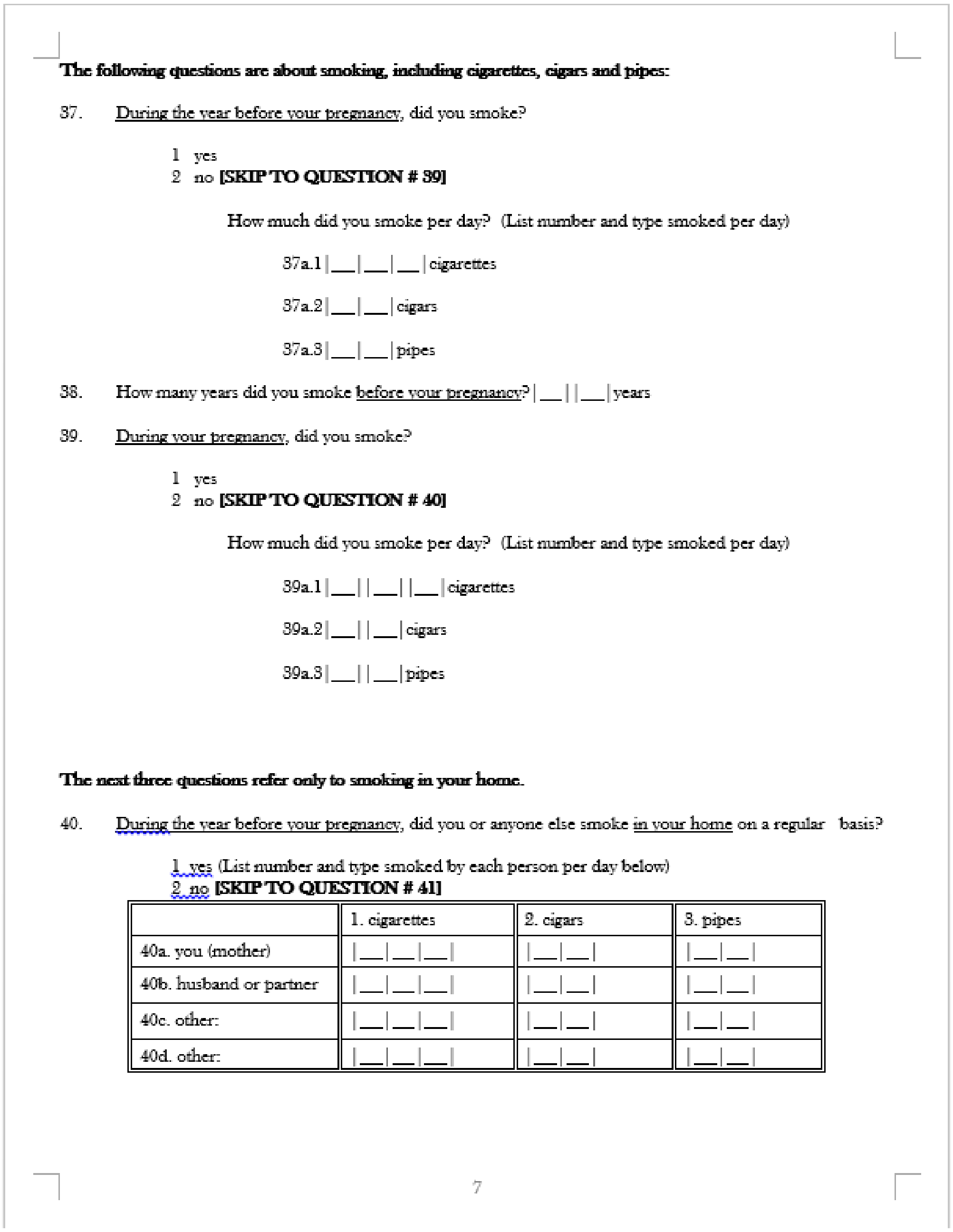
34. What is the age of your husband or partner? |___|___| years

35. What is your husband's or partner's highest level of education?

01 | eighth grade or less
02 | some high school
03 | high school diploma or GED
04 | some college
05 | 2 year college degree
06 | 4 year college degree
07 | graduate or professional school
08 | other (please explain)

36. Which of the following best describes your total household income for the last year before taxes (include salaries, wages, interest, etc.)?

1 | less than $10,000
2 | $10,000 - $19,999
3 | $20,000 - $29,999
4 | $30,000 - $39,999
5 | $40,000 - $49,999
6 | $50,000 - $59,999
7 | $60,000 or more



The following questions are about smoking, including cigarettes, cigars and pipes:

37. During the year before your pregnancy, did you smoke?

1 yes
2 no **[SKIP TO QUESTION # 39]**

How much did you smoke per day? (List number and type smoked per day)

37a.1 |___|___|___| cigarettes

37a.2 |___|___| cigars

37a.3 |___|___| pipes

38. How many years did you smoke before your pregnancy? |___| |___| years

39. During your pregnancy, did you smoke?

1 yes
2 no **[SKIP TO QUESTION # 40]**

How much did you smoke per day? (List number and type smoked per day)

39a.1 |___| |___| |___| cigarettes

39a.2 |___| |___| cigars

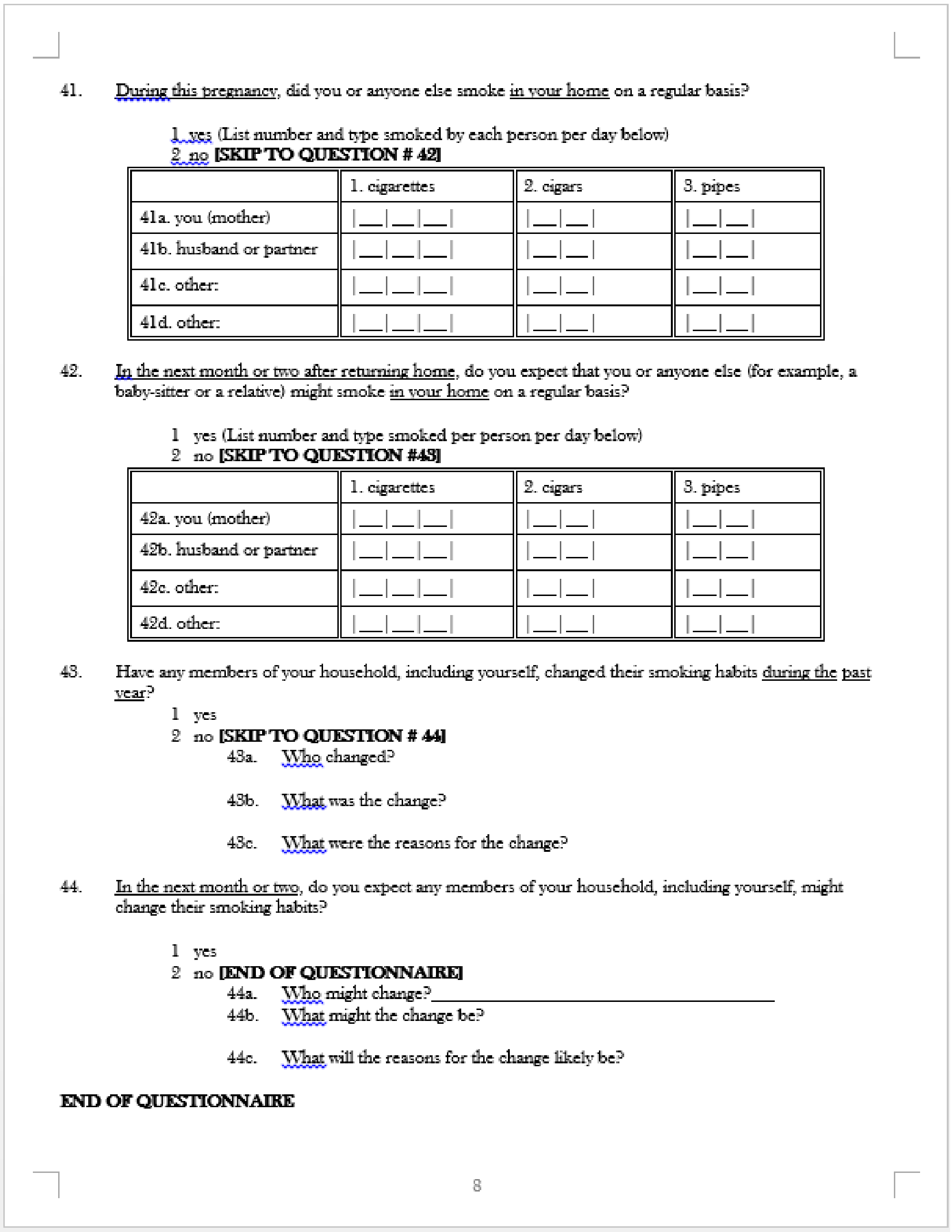
39a.3 |___| |___| pipes

The next three questions refer only to smoking in your home.

40. During the year before your pregnancy, did you or anyone else smoke in your home on a regular basis?

1 yes (List number and type smoked by each person per day below)
2 no **[SKIP TO QUESTION # 41]**

	1. cigarettes	2. cigars	3. pipes
40a. you (mother)	|___|___|___|	|___|___|	|___|___|
40b. husband or partner	|___|___|___|	|___|___|	|___|___|
40c. other:	|___|___|___|	|___|___|	|___|___|
40d. other:	|___|___|___|	|___|___|	|___|___|



41. During this pregnancy, did you or anyone else smoke in your home on a regular basis?

1 yes (List number and type smoked by each person per day below)
2 no **[SKIP TO QUESTION # 42]**

	1. cigarettes	2. cigars	3. pipes
41a. you (mother)	|__|__|__|	|__|__|	|__|__|
41b. husband or partner	|__|__|__|	|__|__|	|__|__|
41c. other:	|__|__|__|	|__|__|	|__|__|
41d. other:	|__|__|__|	|__|__|	|__|__|

42. In the next month or two after returning home, do you expect that you or anyone else (for example, a baby-sitter or a relative) might smoke in your home on a regular basis?

1 yes (List number and type smoked per person per day below)
2 no **[SKIP TO QUESTION #43]**

	1. cigarettes	2. cigars	3. pipes
42a. you (mother)	|__|__|__|	|__|__|	|__|__|
42b. husband or partner	|__|__|__|	|__|__|	|__|__|
42c. other:	|__|__|__|	|__|__|	|__|__|
42d. other:	|__|__|__|	|__|__|	|__|__|

43. Have any members of your household, including yourself, changed their smoking habits during the past year?

1 yes
2 no **[SKIP TO QUESTION # 44]**
43a. Who changed?

43b. What was the change?

43c. What were the reasons for the change?

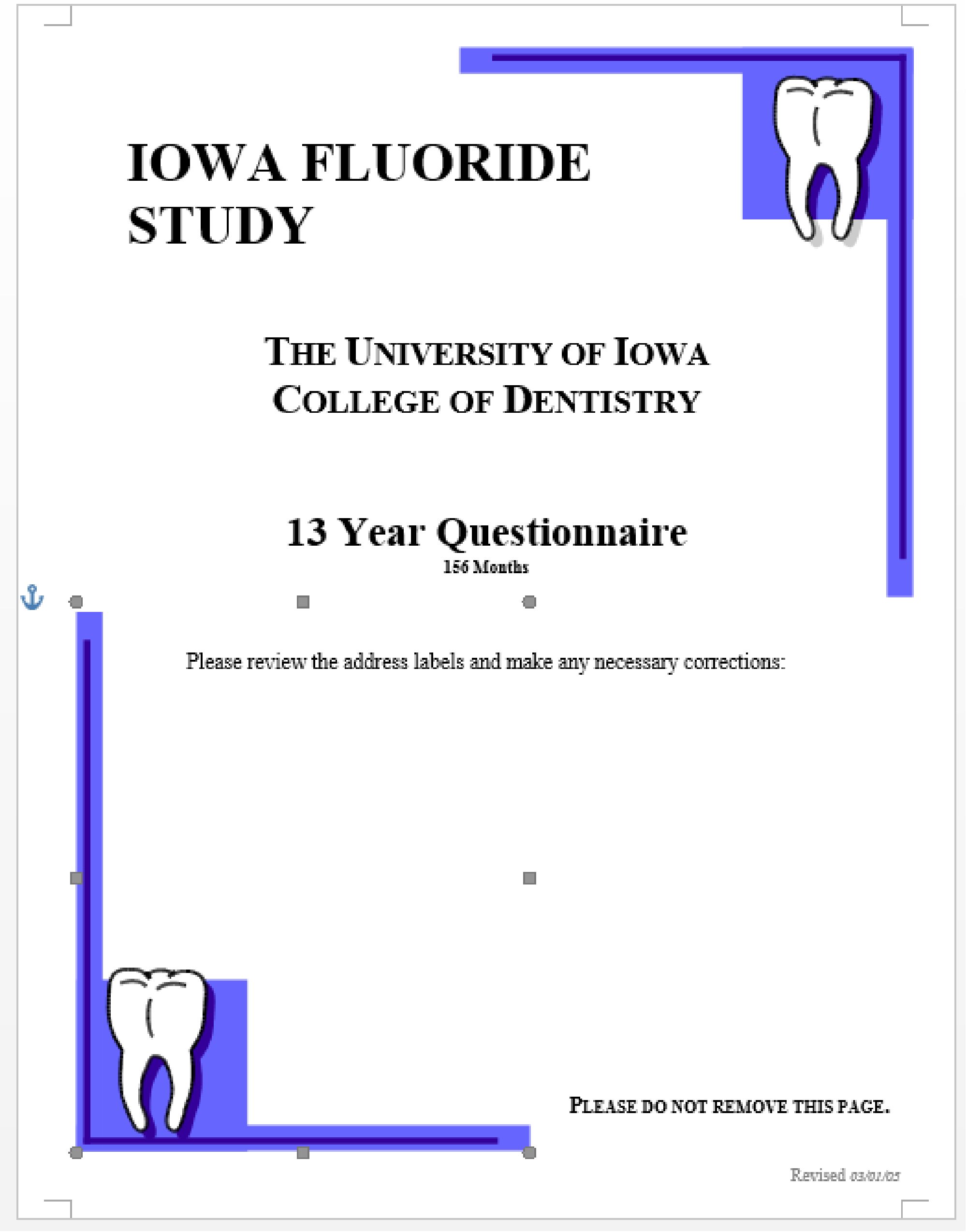
44. In the next month or two, do you expect any members of your household, including yourself, might change their smoking habits?

1 yes
2 no **[END OF QUESTIONNAIRE]**
44a. Who might change?______________________________
44b. What might the change be?

44c. What will the reasons for the change likely be?

END OF QUESTIONNAIRE

APPENDIX E: IOWA FLUORIDE STUDY 13 YEAR QUESTIONNAIRE



IOWA FLUORIDE STUDY

THE UNIVERSITY OF IOWA
COLLEGE OF DENTISTRY

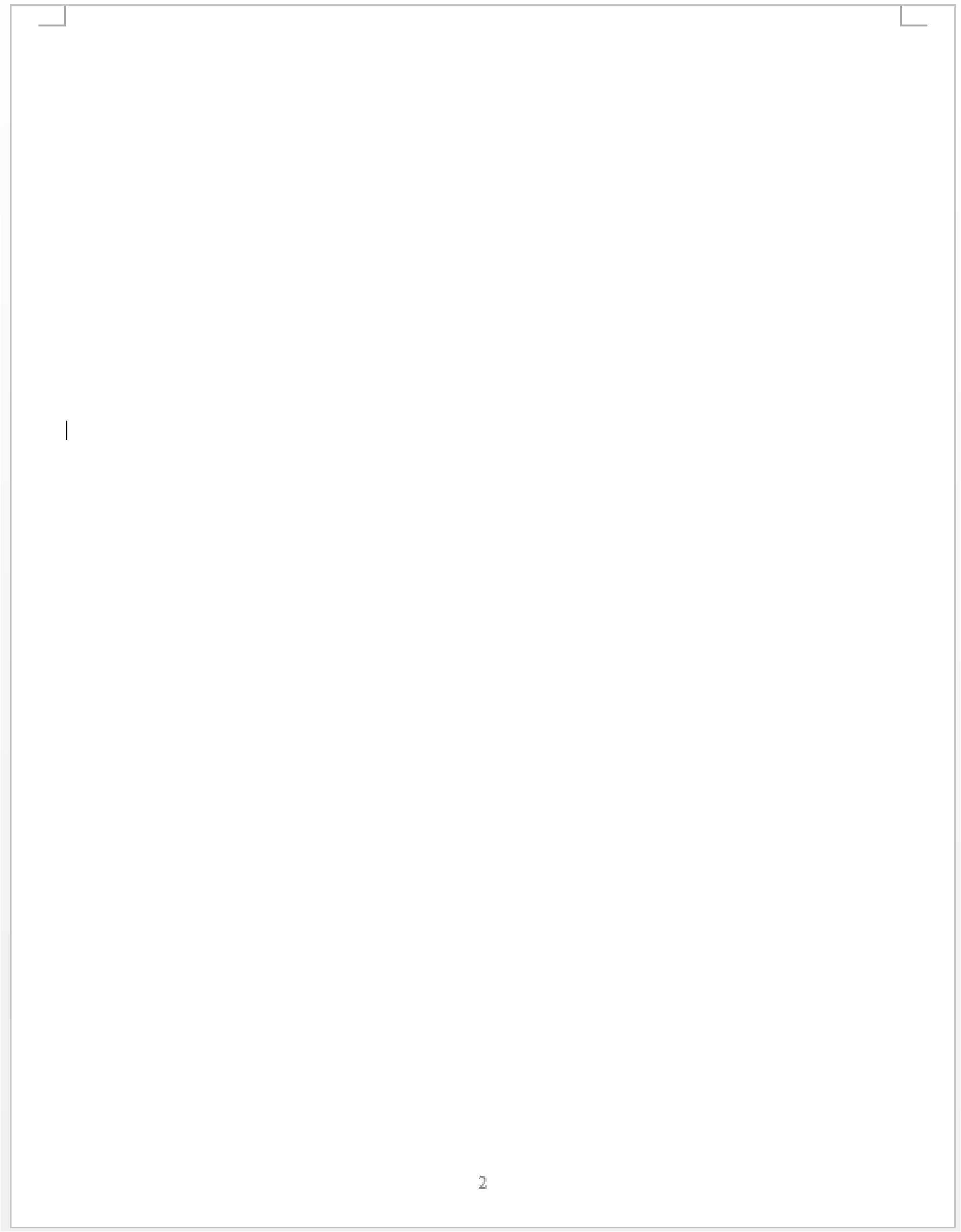
13 Year Questionnaire

156 Months

Please review the address labels and make any necessary corrections:

PLEASE DO NOT REMOVE THIS PAGE.

Revised *03/01/05*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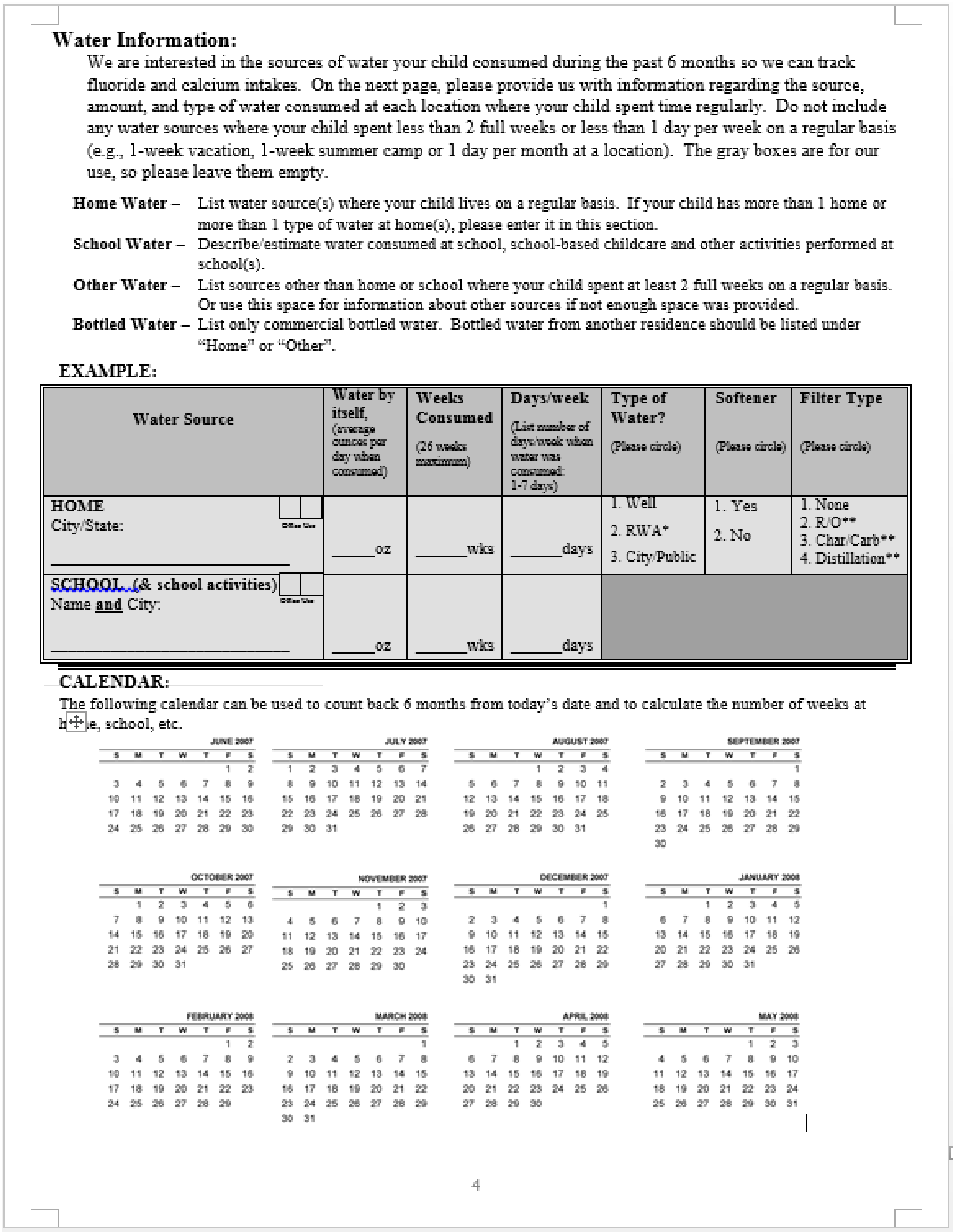

Water Information:

We are interested in the sources of water your child consumed during the past 6 months so we can track fluoride and calcium intakes. On the next page, please provide us with information regarding the source, amount, and type of water consumed at each location where your child spent time regularly. Do not include any water sources where your child spent less than 2 full weeks or less than 1 day per week on a regular basis (e.g., 1-week vacation, 1-week summer camp or 1 day per month at a location). The gray boxes are for our use, so please leave them empty.

Home Water –	List water source(s) where your child lives on a regular basis. If your child has more than 1 home or more than 1 type of water at home(s), please enter it in this section.
School Water –	Describe/estimate water consumed at school, school-based childcare and other activities performed at school(s).
Other Water –	List sources other than home or school where your child spent at least 2 full weeks on a regular basis. Or use this space for information about other sources if not enough space was provided.
Bottled Water –	List only commercial bottled water. Bottled water from another residence should be listed under "Home" or "Other".

EXAMPLE:

Water Source	**Water by itself,** (average ounces per day when consumed)	**Weeks Consumed** (26 weeks maximum)	**Days/week** (List number of days/week when water was consumed: 1-7 days)	**Type of Water?** (Please circle)	**Softener** (Please circle)	**Filter Type** (Please circle)
HOME ☐☐ Office Use City/State: ______________________________	_____oz	______wks	______days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
SCHOOL (& school activities) ☐☐ Office Use Name **and** City: ______________________________	_____oz	______wks	______days			

CALENDAR:

The following calendar can be used to count back 6 months from today's date and to calculate the number of weeks at home, school, etc.

JUNE 2007

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

JULY 2007

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

AUGUST 2007

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

SEPTEMBER 2007

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

OCTOBER 2007

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

NOVEMBER 2007

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

DECEMBER 2007

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

JANUARY 2008

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

FEBRUARY 2008

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

MARCH 2008

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

APRIL 2008

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

MAY 2008

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

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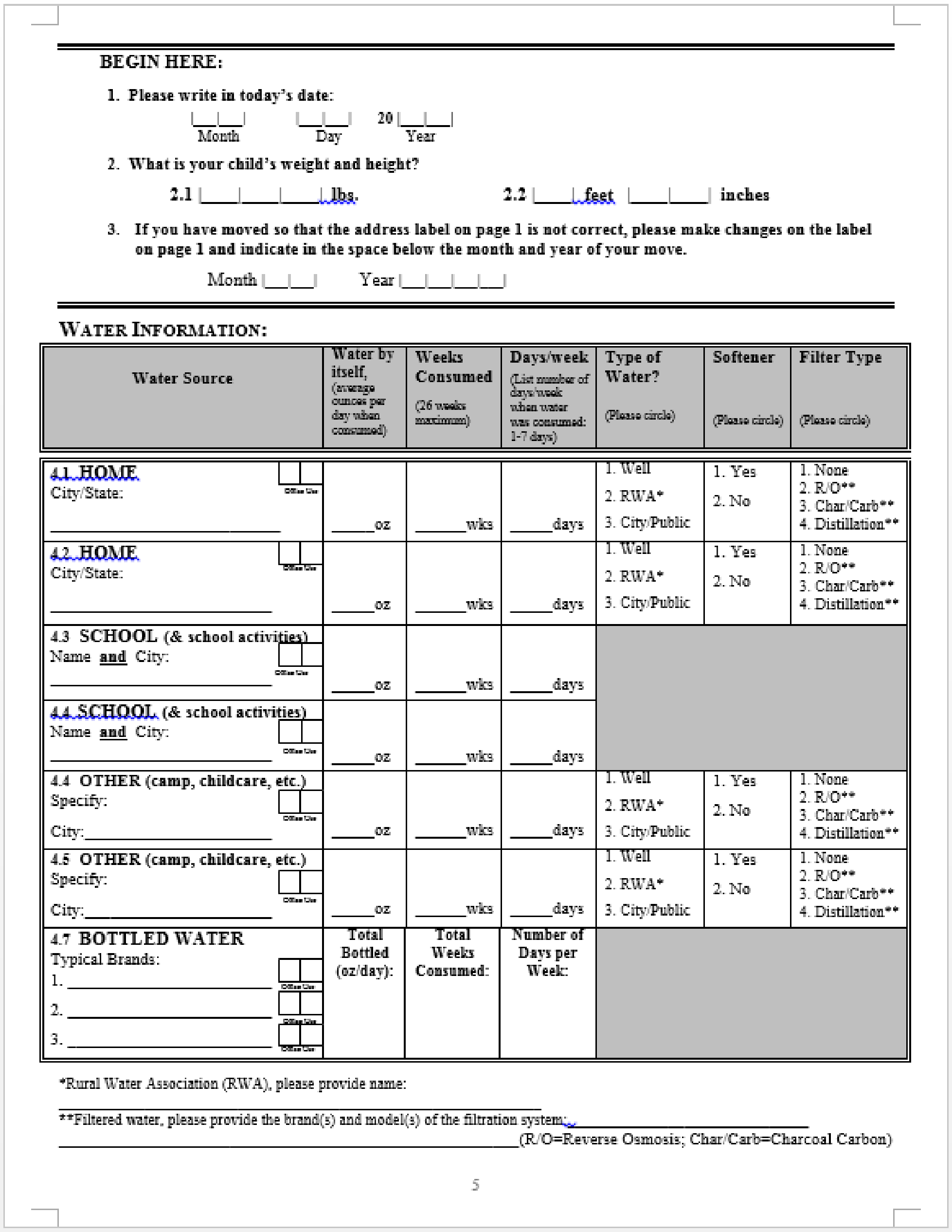


BEGIN HERE:

1. **Please write in today's date:**

|__|__| Month |__|__| Day   20 |__|__| Year

2. **What is your child's weight and height?**

2.1 |____|____|____| **lbs.**   **2.2** |____| **feet** |____|____| **inches**

3. **If you have moved so that the address label on page 1 is not correct, please make changes on the label on page 1 and indicate in the space below the month and year of your move.**

Month |__|__| Year |__|__|__|__|

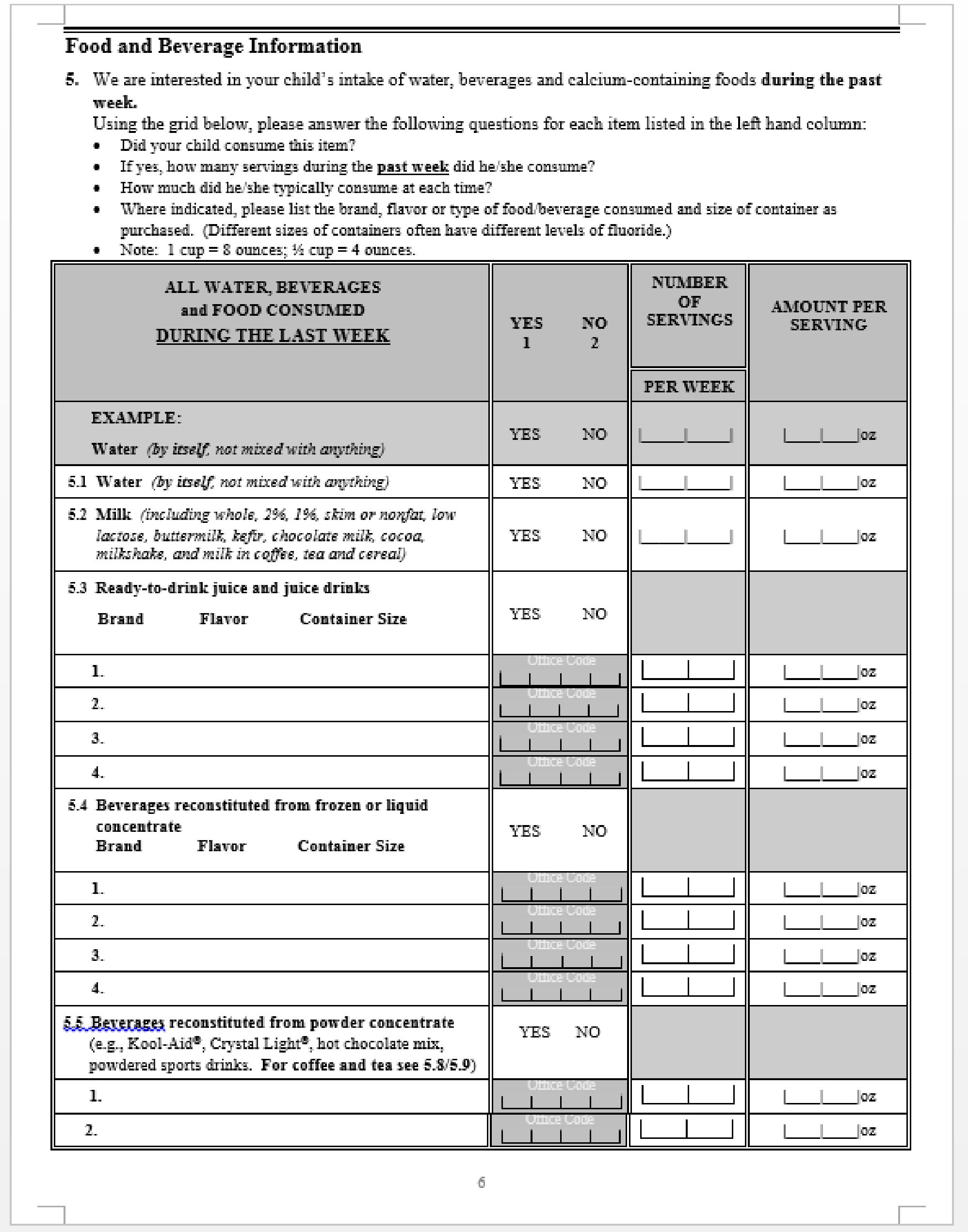
WATER INFORMATION:

Water Source	**Water by itself,** (average ounces per day when consumed)	**Weeks Consumed** (26 weeks maximum)	**Days/week** (List number of days/week when water was consumed: 1-7 days)	**Type of Water?** (Please circle)	**Softener** (Please circle)	**Filter Type** (Please circle)
4.1 HOME ☐☐ Office Use City/State: ____________________	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.2 HOME ☐☐ Office Use City/State: ____________________	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.3 **SCHOOL (& school activities)** Name **and** City: ☐☐ Office Use ____________________	_____oz	______wks	_____days			
4.4 SCHOOL (& school activities) Name **and** City: ☐☐ Office Use ____________________	_____oz	______wks	_____days			
4.4 **OTHER (camp, childcare, etc.)** Specify: ☐☐ Office Use City:____________________	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.5 **OTHER (camp, childcare, etc.)** Specify: ☐☐ Office Use City:____________________	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.7 **BOTTLED WATER** Typical Brands: 1. ____________________ ☐☐ Office Use 2. ____________________ ☐☐ Office Use 3. ____________________ ☐☐ Office Use	**Total Bottled (oz/day):**	**Total Weeks Consumed:**	**Number of Days per Week:**			

*Rural Water Association (RWA), please provide name:
____

**Filtered water, please provide the brand(s) and model(s) of the filtration system:____________________
____(R/O=Reverse Osmosis; Char/Carb=Charcoal Carbon)

5



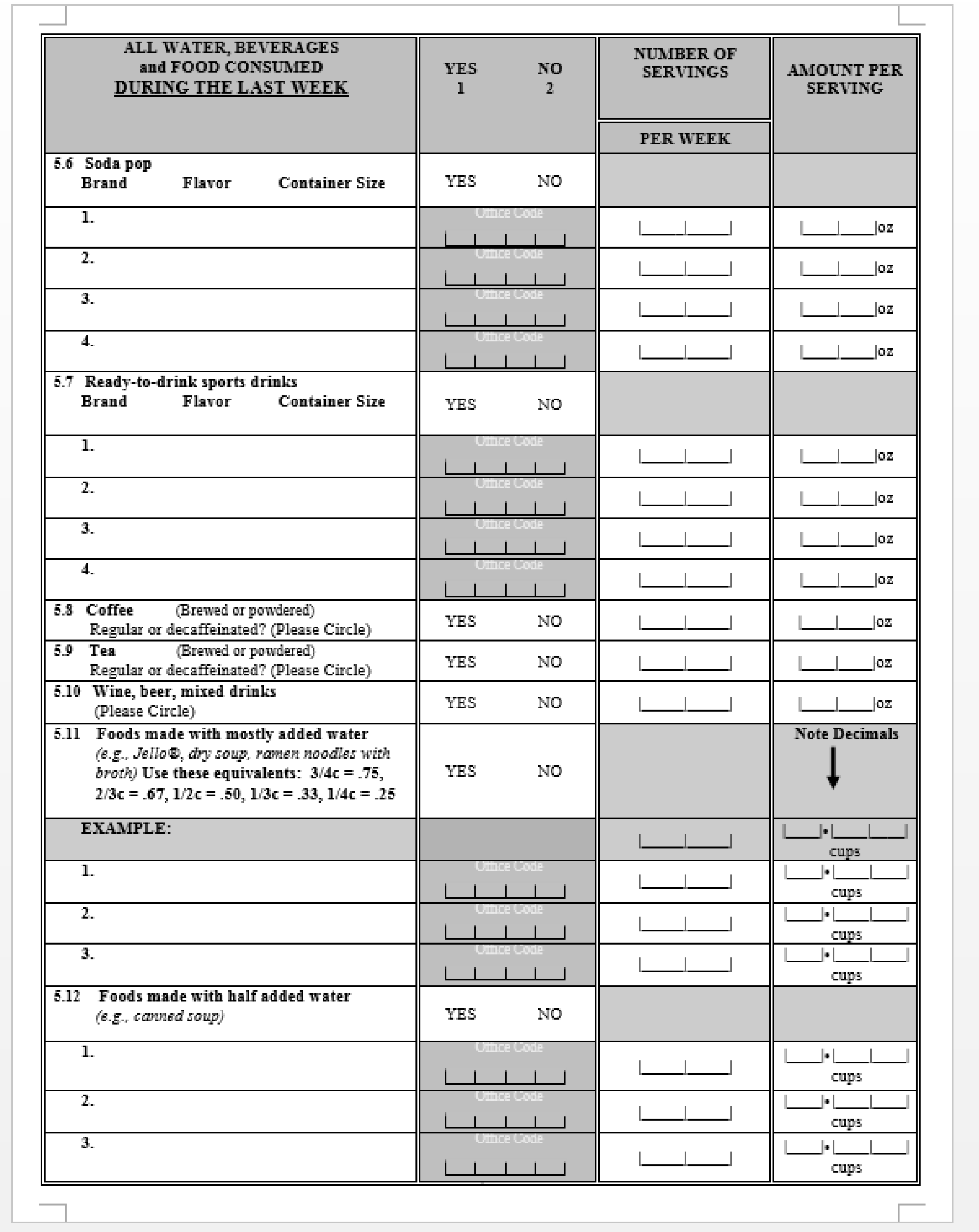
Food and Beverage Information

5. We are interested in your child's intake of water, beverages and calcium-containing foods **during the past week.**

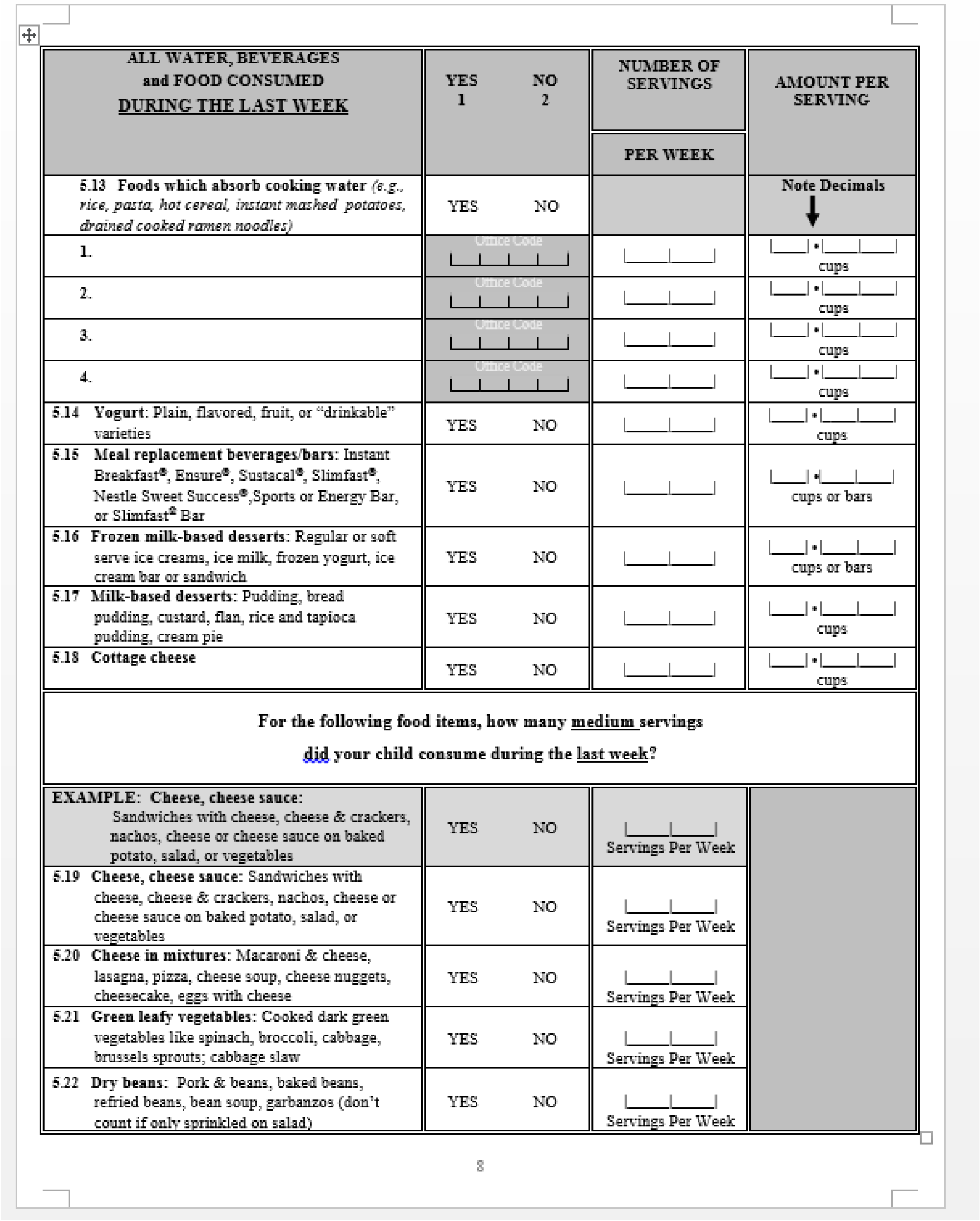
Using the grid below, please answer the following questions for each item listed in the left hand column:

- Did your child consume this item?
- If yes, how many servings during the **past week** did he/she consume?
- How much did he/she typically consume at each time?
- Where indicated, please list the brand, flavor or type of food/beverage consumed and size of container as purchased. (Different sizes of containers often have different levels of fluoride.)
- Note: 1 cup = 8 ounces; ½ cup = 4 ounces.

ALL WATER, BEVERAGES and FOOD CONSUMED DURING THE LAST WEEK	**YES 1** **NO 2**	**NUMBER OF SERVINGS**	**AMOUNT PER SERVING**
		PER WEEK	
EXAMPLE: **Water** *(by itself, not mixed with anything)*	YES NO		oz
5.1 **Water** *(by itself, not mixed with anything)*	YES NO		oz
5.2 **Milk** *(including whole, 2%, 1%, skim or nonfat, low lactose, buttermilk, kefir, chocolate milk, cocoa, milkshake, and milk in coffee, tea and cereal)*	YES NO		oz
5.3 **Ready-to-drink juice and juice drinks** **Brand** **Flavor** **Container Size**	YES NO		
1.	Office Code		oz
2.	Office Code		oz
3.	Office Code		oz
4.	Office Code		oz
5.4 **Beverages reconstituted from frozen or liquid concentrate** **Brand** **Flavor** **Container Size**	YES NO		
1.	Office Code		oz
2.	Office Code		oz
3.	Office Code		oz
4.	Office Code		oz
5.5 **Beverages reconstituted from powder concentrate** (e.g., Kool-Aid®, Crystal Light®, hot chocolate mix, powdered sports drinks. **For coffee and tea see 5.8/5.9**)	YES NO		
1.	Office Code		oz
2.	Office Code		oz



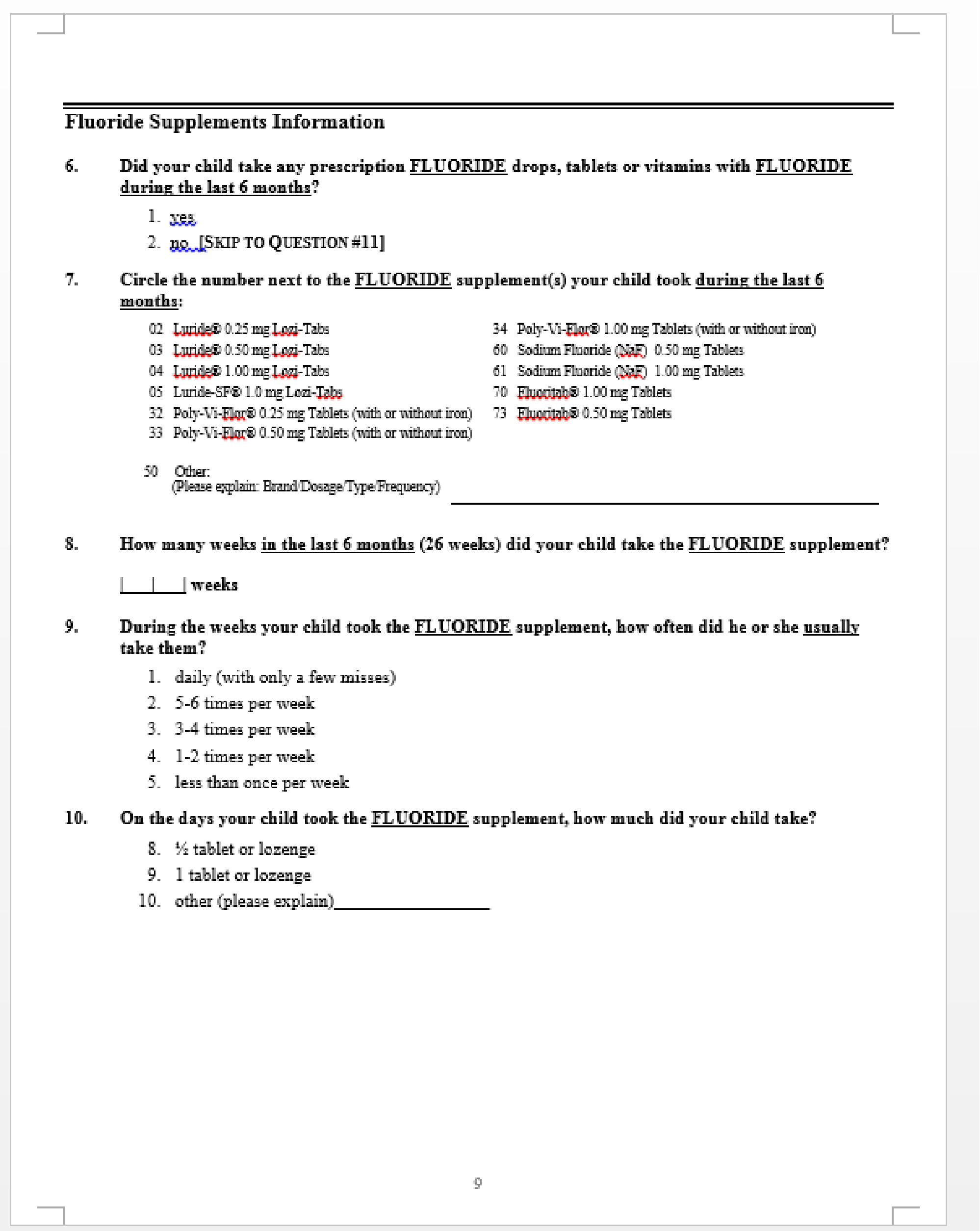
ALL WATER, BEVERAGES and FOOD CONSUMED **DURING THE LAST WEEK**	YES 1 NO 2	NUMBER OF SERVINGS PER WEEK	AMOUNT PER SERVING
5.6 Soda pop **Brand Flavor Container Size**	YES NO		
1.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
2.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
3.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
4.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
5.7 Ready-to-drink sports drinks **Brand Flavor Container Size**	YES NO		
1.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
2.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
3.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
4.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
5.8 Coffee (Brewed or powdered) Regular or decaffeinated? (Please Circle)	YES NO	|____|____|	|___|___|oz
5.9 Tea (Brewed or powdered) Regular or decaffeinated? (Please Circle)	YES NO	|____|____|	|___|___|oz
5.10 Wine, beer, mixed drinks (Please Circle)	YES NO	|____|____|	|___|___|oz
5.11 Foods made with mostly added water *(e.g., Jello®, dry soup, ramen noodles with broth)* **Use these equivalents: 3/4c = .75, 2/3c = .67, 1/2c = .50, 1/3c = .33, 1/4c = .25**	YES NO		**Note Decimals** ↓
EXAMPLE:		|____|____|	|___|•|___|___| cups
1.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
2.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
3.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
5.12 Foods made with half added water *(e.g., canned soup)*	YES NO		
1.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
2.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
3.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups



ALL WATER, BEVERAGES and FOOD CONSUMED <u>DURING THE LAST WEEK</u>	**YES 1**	**NO 2**	**NUMBER OF SERVINGS** **PER WEEK**	**AMOUNT PER SERVING**
5.13 **Foods which absorb cooking water** *(e.g., rice, pasta, hot cereal, instant mashed potatoes, drained cooked ramen noodles)*	YES	NO		**Note Decimals** ↓
1.	Office Code |__|__|__|__|		|___|___|	|__|•|__|__| cups
2.	Office Code |__|__|__|__|		|___|___|	|__|•|__|__| cups
3.	Office Code |__|__|__|__|		|___|___|	|__|•|__|__| cups
4.	Office Code |__|__|__|__|		|___|___|	|__|•|__|__| cups
5.14 **Yogurt**: Plain, flavored, fruit, or "drinkable" varieties	YES	NO	|___|___|	|__|•|__|__| cups
5.15 **Meal replacement beverages/bars**: Instant Breakfast®, Ensure®, Sustacal®, Slimfast®, Nestle Sweet Success®,Sports or Energy Bar, or Slimfast® Bar	YES	NO	|___|___|	|__|•|__|__| cups or bars
5.16 **Frozen milk-based desserts**: Regular or soft serve ice creams, ice milk, frozen yogurt, ice cream bar or sandwich	YES	NO	|___|___|	|__|•|__|__| cups or bars
5.17 **Milk-based desserts**: Pudding, bread pudding, custard, flan, rice and tapioca pudding, cream pie	YES	NO	|___|___|	|__|•|__|__| cups
5.18 **Cottage cheese**	YES	NO	|___|___|	|__|•|__|__| cups

For the following food items, how many <u>medium</u> servings did your child consume during the <u>last week</u>?

EXAMPLE: Cheese, cheese sauce: Sandwiches with cheese, cheese & crackers, nachos, cheese or cheese sauce on baked potato, salad, or vegetables	YES	NO	|___|___| Servings Per Week	
5.19 **Cheese, cheese sauce**: Sandwiches with cheese, cheese & crackers, nachos, cheese or cheese sauce on baked potato, salad, or vegetables	YES	NO	|___|___| Servings Per Week	
5.20 **Cheese in mixtures**: Macaroni & cheese, lasagna, pizza, cheese soup, cheese nuggets, cheesecake, eggs with cheese	YES	NO	|___|___| Servings Per Week	
5.21 **Green leafy vegetables**: Cooked dark green vegetables like spinach, broccoli, cabbage, brussels sprouts; cabbage slaw	YES	NO	|___|___| Servings Per Week	
5.22 **Dry beans**: Pork & beans, baked beans, refried beans, bean soup, garbanzos (don't count if only sprinkled on salad)	YES	NO	|___|___| Servings Per Week	



Fluoride Supplements Information

6. **Did your child take any prescription FLUORIDE drops, tablets or vitamins with FLUORIDE during the last 6 months?**

1. yes
2. no [SKIP TO QUESTION #11]

7. **Circle the number next to the FLUORIDE supplement(s) your child took during the last 6 months:**

02 Luride® 0.25 mg Lozi-Tabs
03 Luride® 0.50 mg Lozi-Tabs
04 Luride® 1.00 mg Lozi-Tabs
05 Luride-SF® 1.0 mg Lozi-Tabs
32 Poly-Vi-Flor® 0.25 mg Tablets (with or without iron)
33 Poly-Vi-Flor® 0.50 mg Tablets (with or without iron)
34 Poly-Vi-Flor® 1.00 mg Tablets (with or without iron)
60 Sodium Fluoride (NaF) 0.50 mg Tablets
61 Sodium Fluoride (NaF) 1.00 mg Tablets
70 Fluoritab® 1.00 mg Tablets
73 Fluoritab® 0.50 mg Tablets

50 Other:
(Please explain: Brand/Dosage/Type/Frequency) ________________________________

8. **How many weeks in the last 6 months (26 weeks) did your child take the FLUORIDE supplement?**

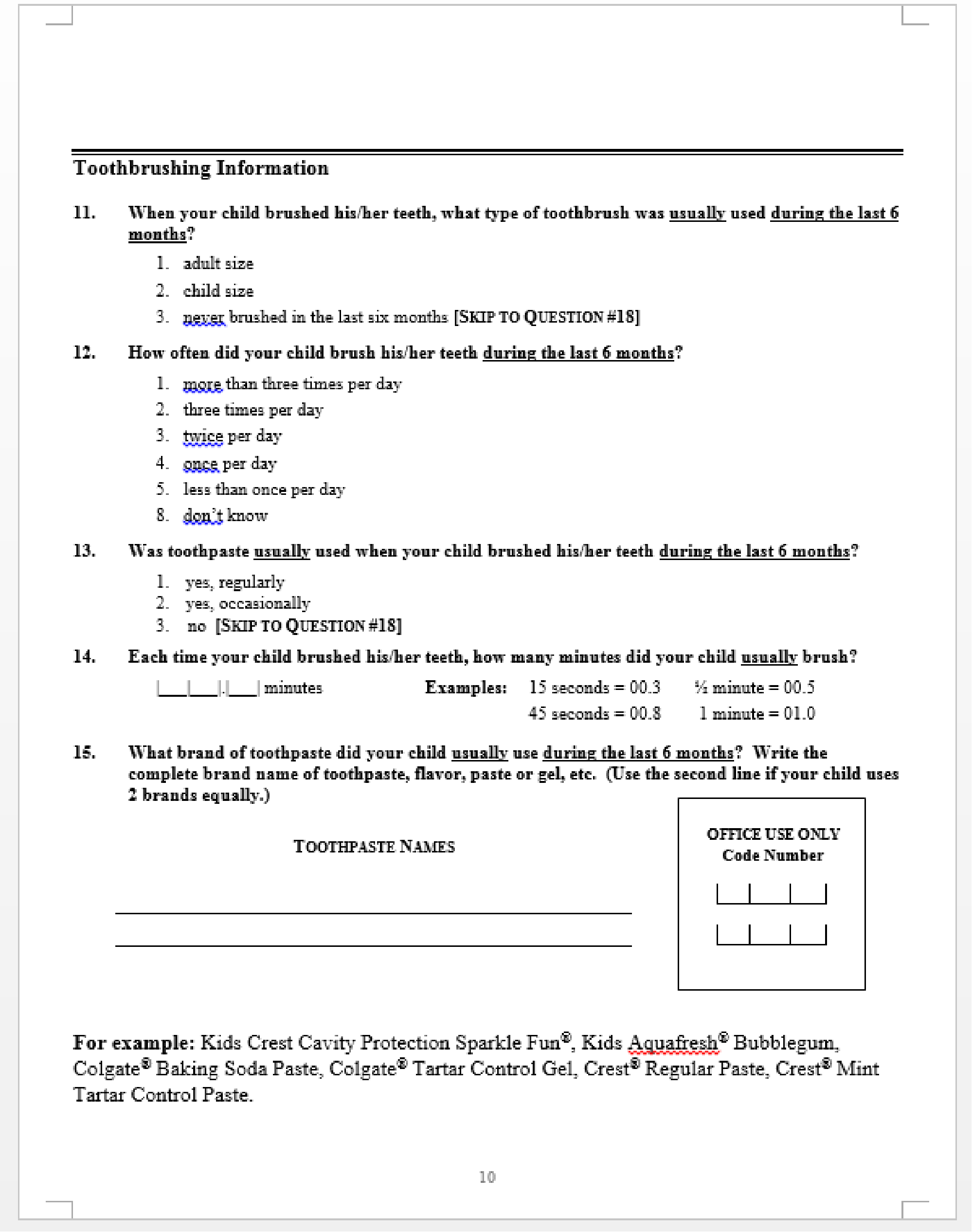
|___|___| **weeks**

9. **During the weeks your child took the FLUORIDE supplement, how often did he or she usually take them?**

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

10. **On the days your child took the FLUORIDE supplement, how much did your child take?**

8. ½ tablet or lozenge
9. 1 tablet or lozenge
10. other (please explain)_________________



Toothbrushing Information

11. When your child brushed his/her teeth, what type of toothbrush was usually used during the last 6 months?

1. adult size
2. child size
3. never brushed in the last six months [SKIP TO QUESTION #18]

12. How often did your child brush his/her teeth during the last 6 months?

1. more than three times per day
2. three times per day
3. twice per day
4. once per day
5. less than once per day
8. don't know

13. Was toothpaste usually used when your child brushed his/her teeth during the last 6 months?

1. yes, regularly
2. yes, occasionally
3. no [SKIP TO QUESTION #18]

14. Each time your child brushed his/her teeth, how many minutes did your child usually brush?

|___|___|.|___| minutes

Examples: 15 seconds = 00.3 ½ minute = 00.5
45 seconds = 00.8 1 minute = 01.0

15. What brand of toothpaste did your child usually use during the last 6 months? Write the complete brand name of toothpaste, flavor, paste or gel, etc. (Use the second line if your child uses 2 brands equally.)

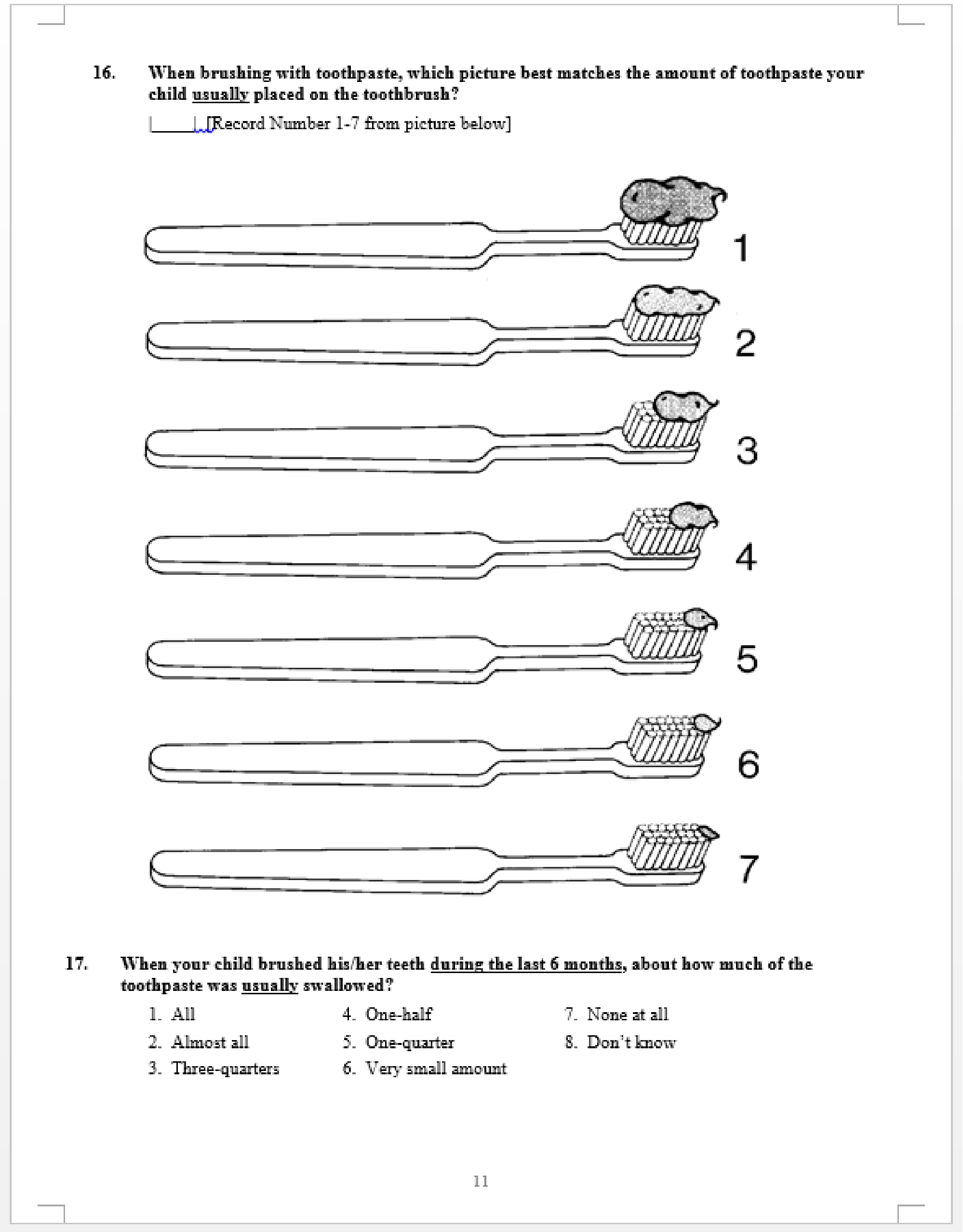
TOOTHPASTE NAMES

____

____

OFFICE USE ONLY
Code Number
|___|___|___|
|___|___|___|

For example: Kids Crest Cavity Protection Sparkle Fun®, Kids Aquafresh® Bubblegum, Colgate® Baking Soda Paste, Colgate® Tartar Control Gel, Crest® Regular Paste, Crest® Mint Tartar Control Paste.

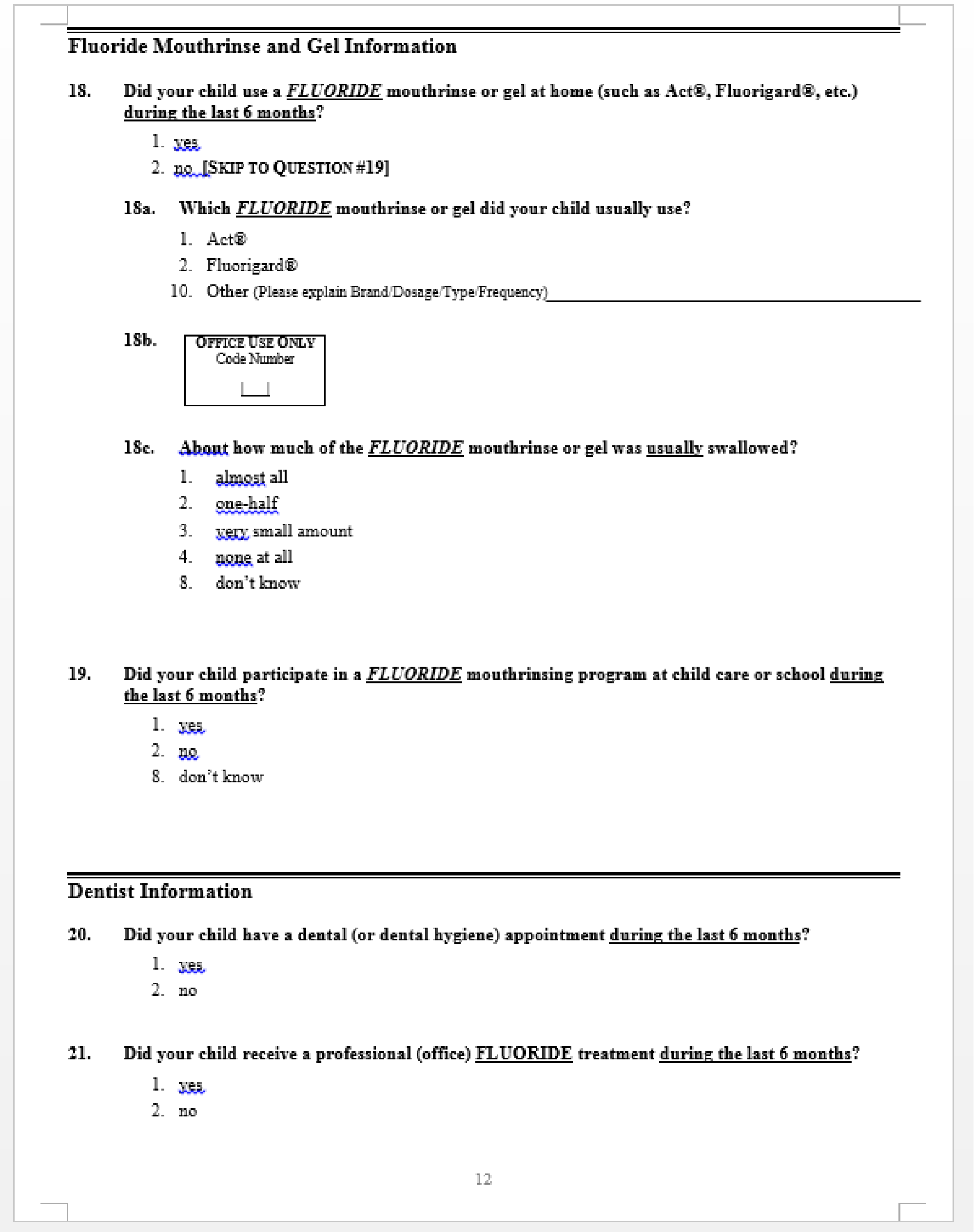


16. **When brushing with toothpaste, which picture best matches the amount of toothpaste your child <u>usually</u> placed on the toothbrush?**

|_____| [Record Number 1-7 from picture below]

17. **When your child brushed his/her teeth <u>during the last 6 months</u>, about how much of the toothpaste was <u>usually</u> swallowed?**

1. All
2. Almost all
3. Three-quarters
4. One-half
5. One-quarter
6. Very small amount
7. None at all
8. Don't know



Fluoride Mouthrinse and Gel Information

18. Did your child use a *FLUORIDE* mouthrinse or gel at home (such as Act®, Fluorigard®, etc.) during the last 6 months?

1. yes
2. no [SKIP TO QUESTION #19]

18a. Which *FLUORIDE* mouthrinse or gel did your child usually use?

1. Act®
2. Fluorigard®
10. Other (Please explain Brand/Dosage/Type/Frequency)______________________________

18b. OFFICE USE ONLY
Code Number
|__|

18c. About how much of the *FLUORIDE* mouthrinse or gel was usually swallowed?

1. almost all
2. one-half
3. very small amount
4. none at all
8. don't know

19. Did your child participate in a *FLUORIDE* mouthrinsing program at child care or school during the last 6 months?

1. yes
2. no
8. don't know

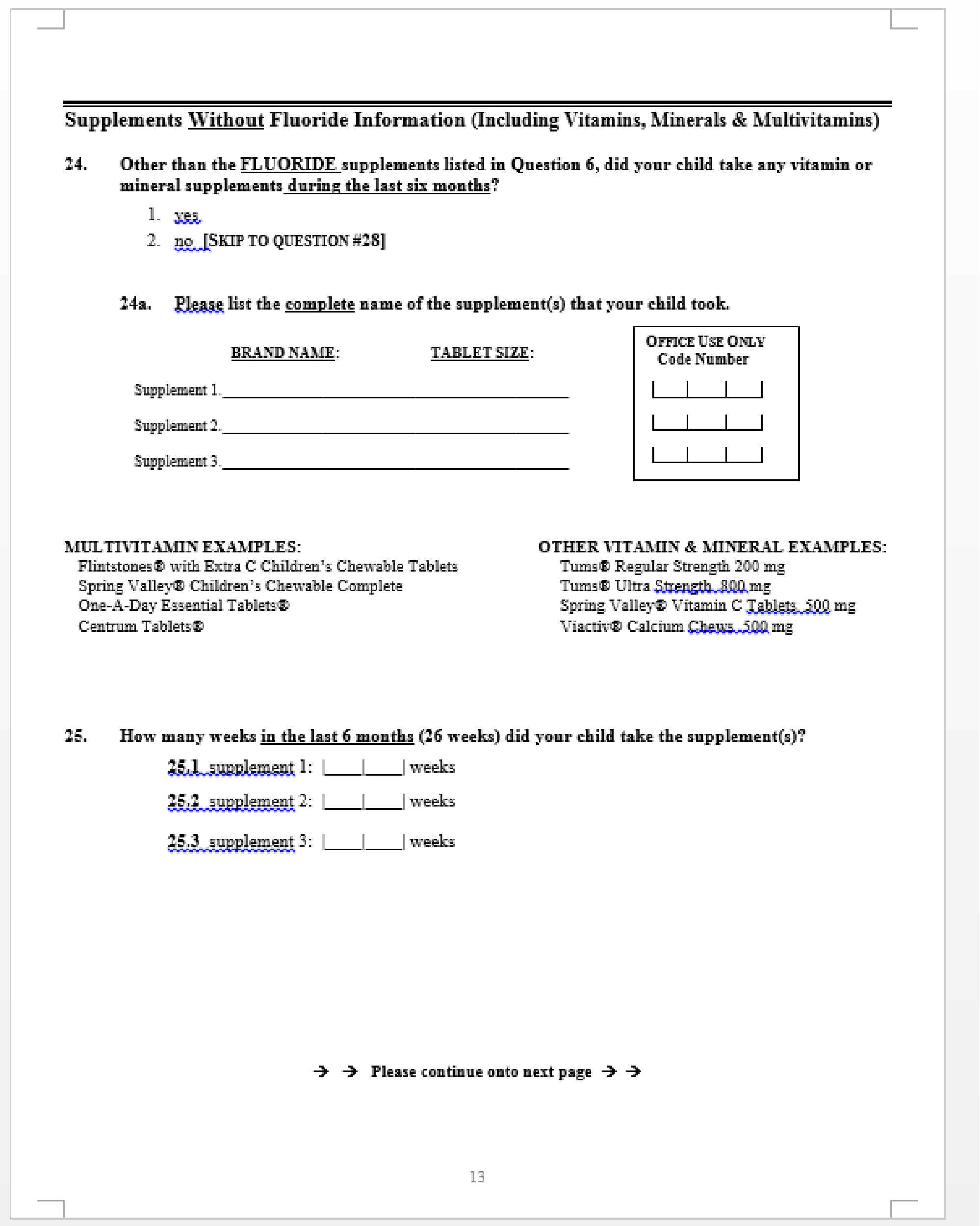
Dentist Information

20. Did your child have a dental (or dental hygiene) appointment during the last 6 months?

1. yes
2. no

21. Did your child receive a professional (office) FLUORIDE treatment during the last 6 months?

1. yes
2. no



Supplements Without Fluoride Information (Including Vitamins, Minerals & Multivitamins)

24. Other than the FLUORIDE supplements listed in Question 6, did your child take any vitamin or mineral supplements during the last six months?

1. yes
2. no [SKIP TO QUESTION #28]

24a. Please list the complete name of the supplement(s) that your child took.

	BRAND NAME:	TABLET SIZE:	OFFICE USE ONLY Code Number
Supplement 1.			|__|__|__|
Supplement 2.			|__|__|__|
Supplement 3.			|__|__|__|

MULTIVITAMIN EXAMPLES:

Flintstones® with Extra C Children's Chewable Tablets
Spring Valley® Children's Chewable Complete
One-A-Day Essential Tablets®
Centrum Tablets®

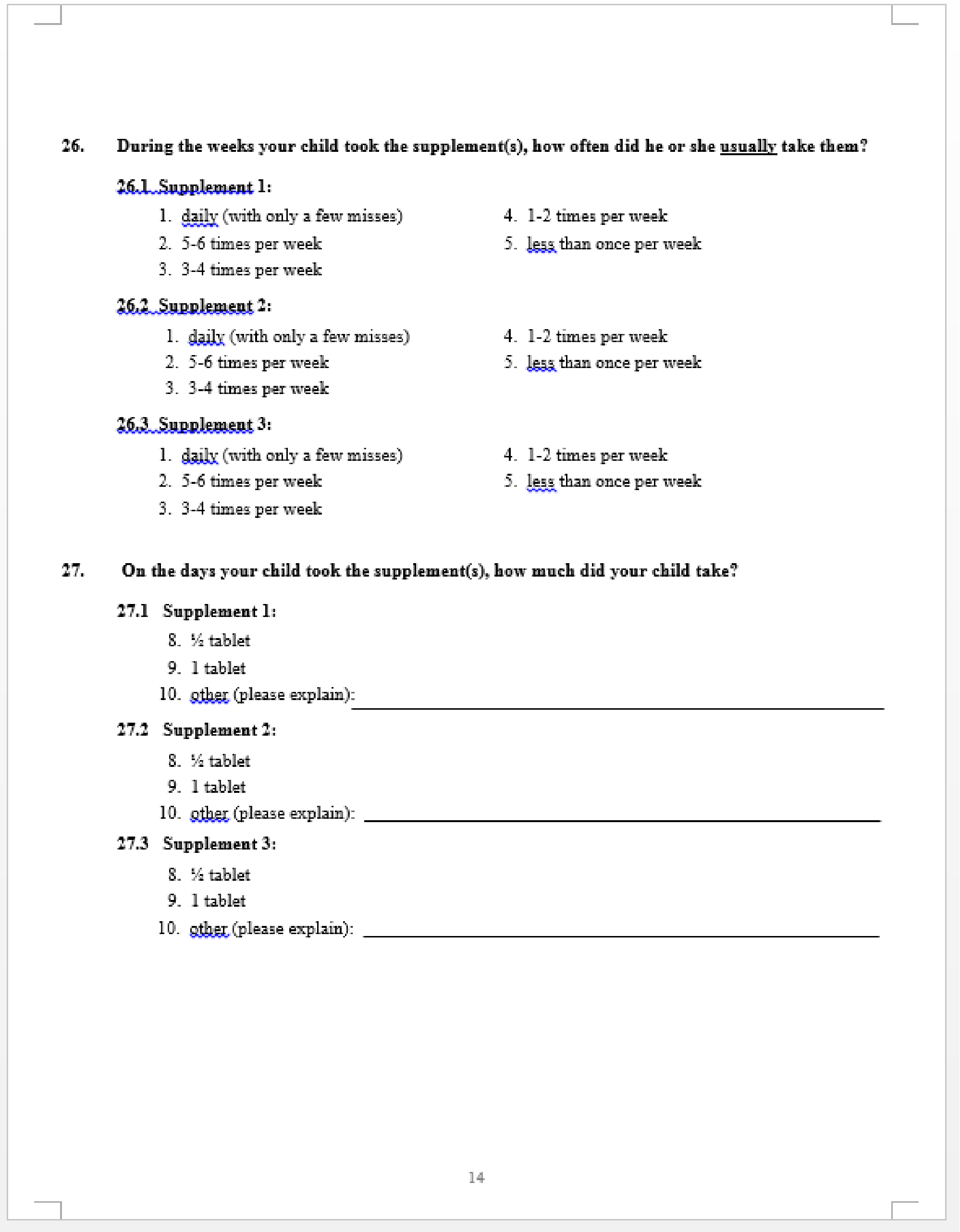
OTHER VITAMIN & MINERAL EXAMPLES:

Tums® Regular Strength 200 mg
Tums® Ultra Strength 800 mg
Spring Valley® Vitamin C Tablets 500 mg
Viactiv® Calcium Chews 500 mg

25. How many weeks in the last 6 months (26 weeks) did your child take the supplement(s)?

25.1 supplement 1: |____|____| weeks
25.2 supplement 2: |____|____| weeks
25.3 supplement 3: |____|____| weeks

→ → **Please continue onto next page** → →



26. During the weeks your child took the supplement(s), how often did he or she usually take them?

26.1 Supplement 1:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

26.2 Supplement 2:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

26.3 Supplement 3:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

27. On the days your child took the supplement(s), how much did your child take?

27.1 Supplement 1:

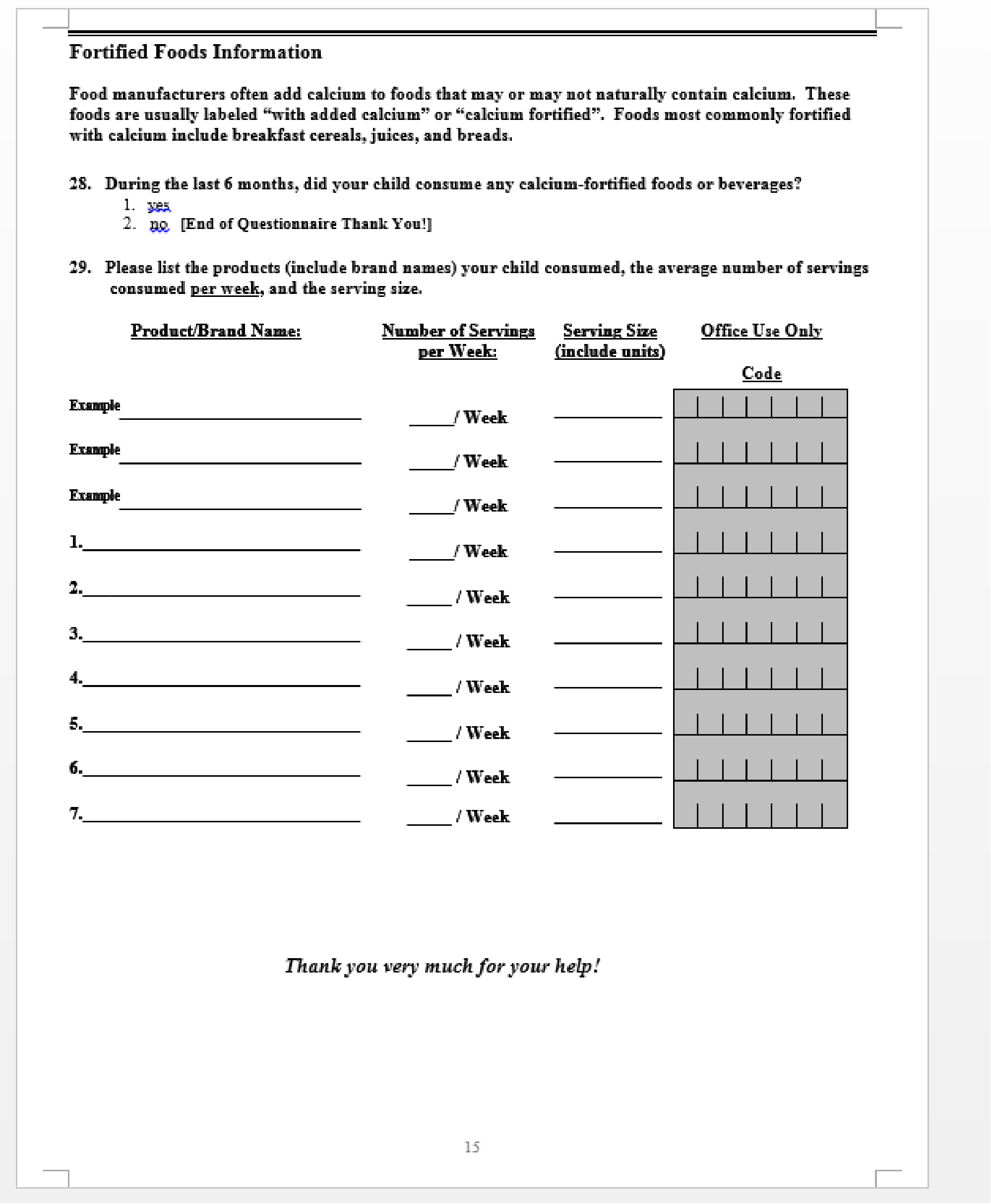
8. ½ tablet
9. 1 tablet
10. other (please explain): ____________________

27.2 Supplement 2:

8. ½ tablet
9. 1 tablet
10. other (please explain): ____________________

27.3 Supplement 3:

8. ½ tablet
9. 1 tablet
10. other (please explain): ____________________



Fortified Foods Information

Food manufacturers often add calcium to foods that may or may not naturally contain calcium. These foods are usually labeled "with added calcium" or "calcium fortified". Foods most commonly fortified with calcium include breakfast cereals, juices, and breads.

28. During the last 6 months, did your child consume any calcium-fortified foods or beverages?

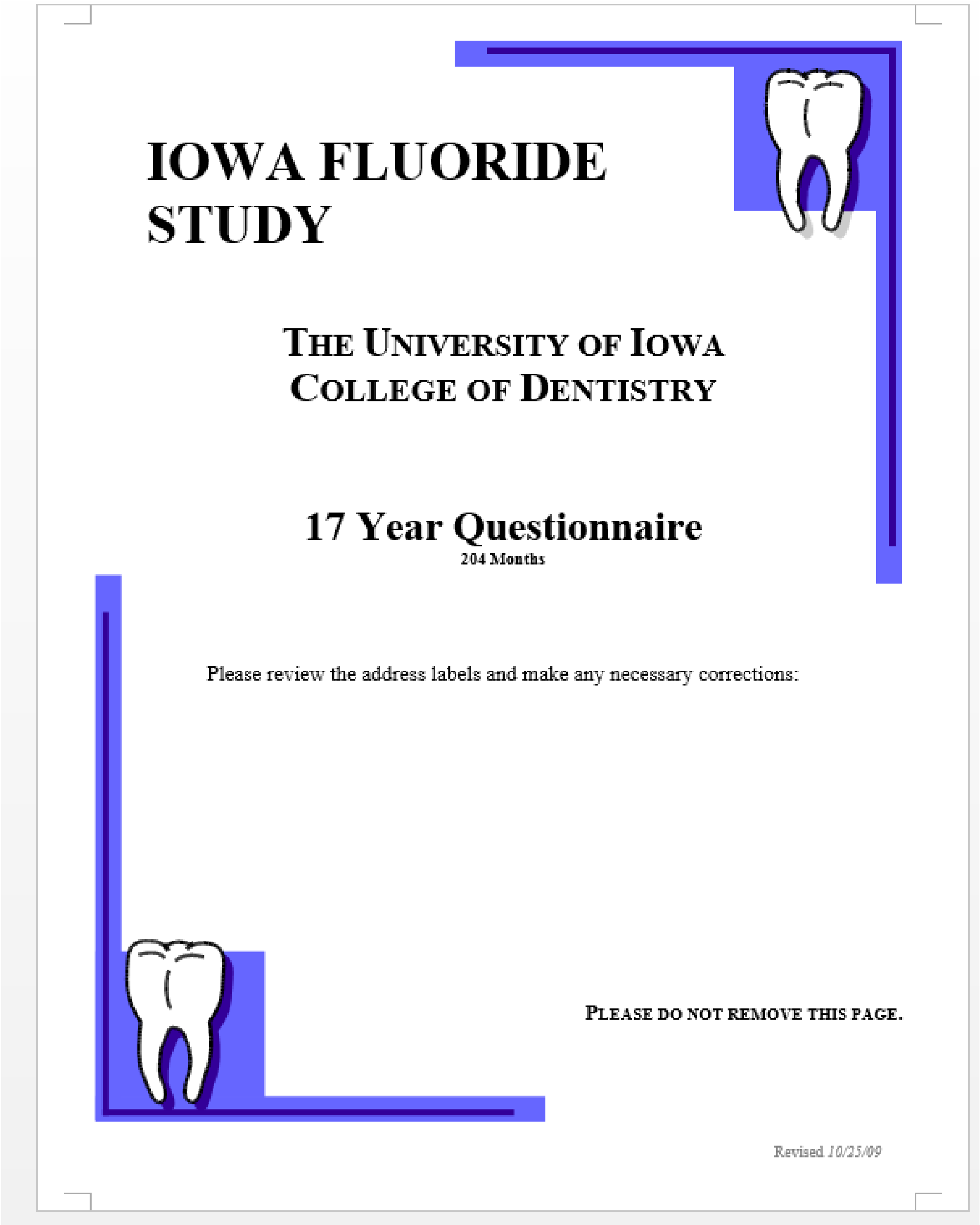
1. yes
2. no **[End of Questionnaire Thank You!]**

29. Please list the products (include brand names) your child consumed, the average number of servings consumed <u>per week</u>, and the serving size.

Product/Brand Name:	**Number of Servings per Week:**	**Serving Size (include units)**	**Office Use Only** **Code**
Example ____________________	_____/ Week	__________	
Example ____________________	_____/ Week	__________	
Example ____________________	_____/ Week	__________	
1. ____________________	_____/ Week	__________	
2. ____________________	_____ / Week	__________	
3. ____________________	_____ / Week	__________	
4. ____________________	_____ / Week	__________	
5. ____________________	_____ / Week	__________	
6. ____________________	_____ / Week	__________	
7. ____________________	_____ / Week	__________	

Thank you very much for your help!

APPENDIX F: IOWA FLUORIDE STUDY 17 YEAR QUESTIONNAIRE



IOWA FLUORIDE STUDY

The University of Iowa
College of Dentistry

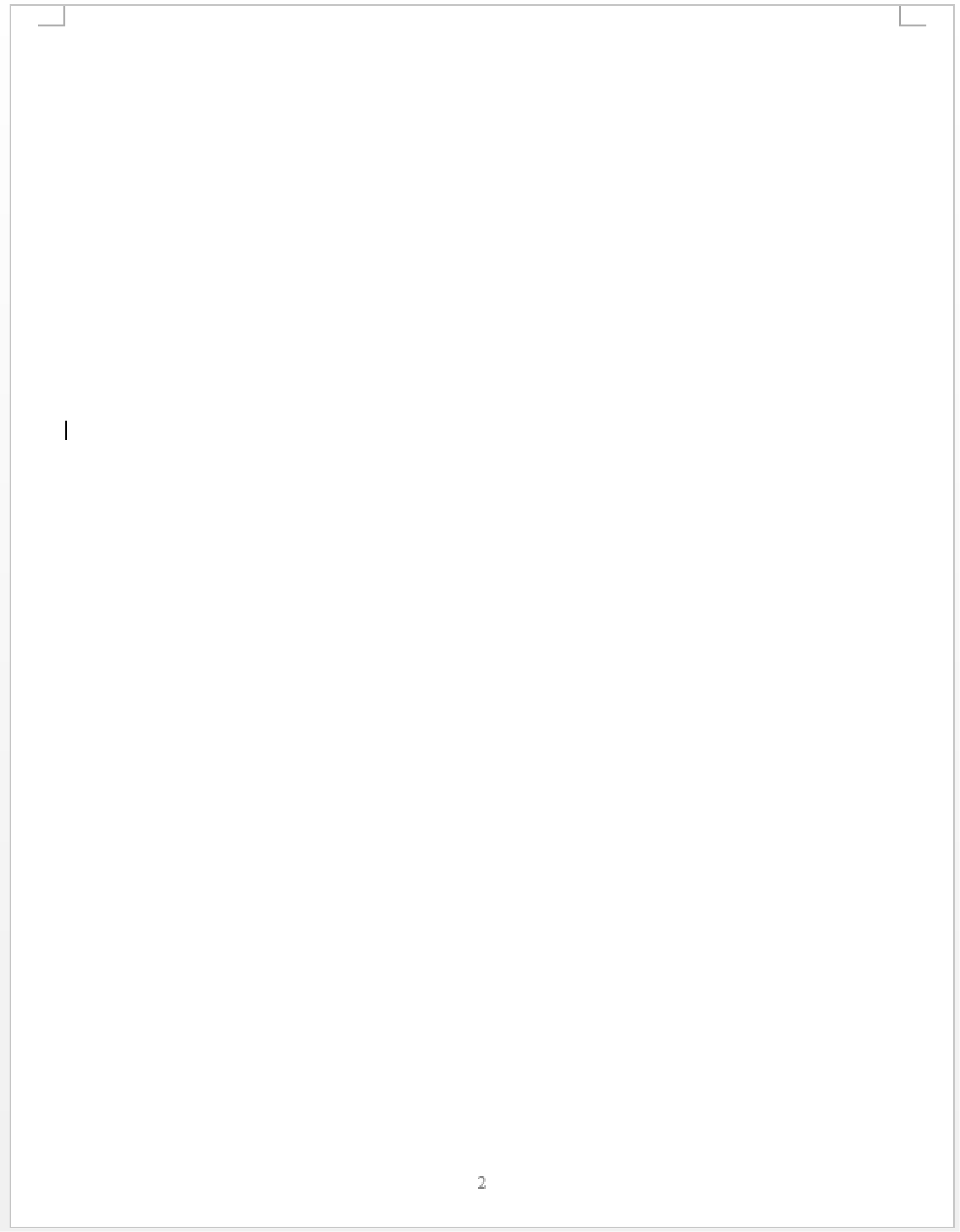
17 Year Questionnaire

204 Months

Please review the address labels and make any necessary corrections:

Please do not remove this page.

Revised *10/25/09*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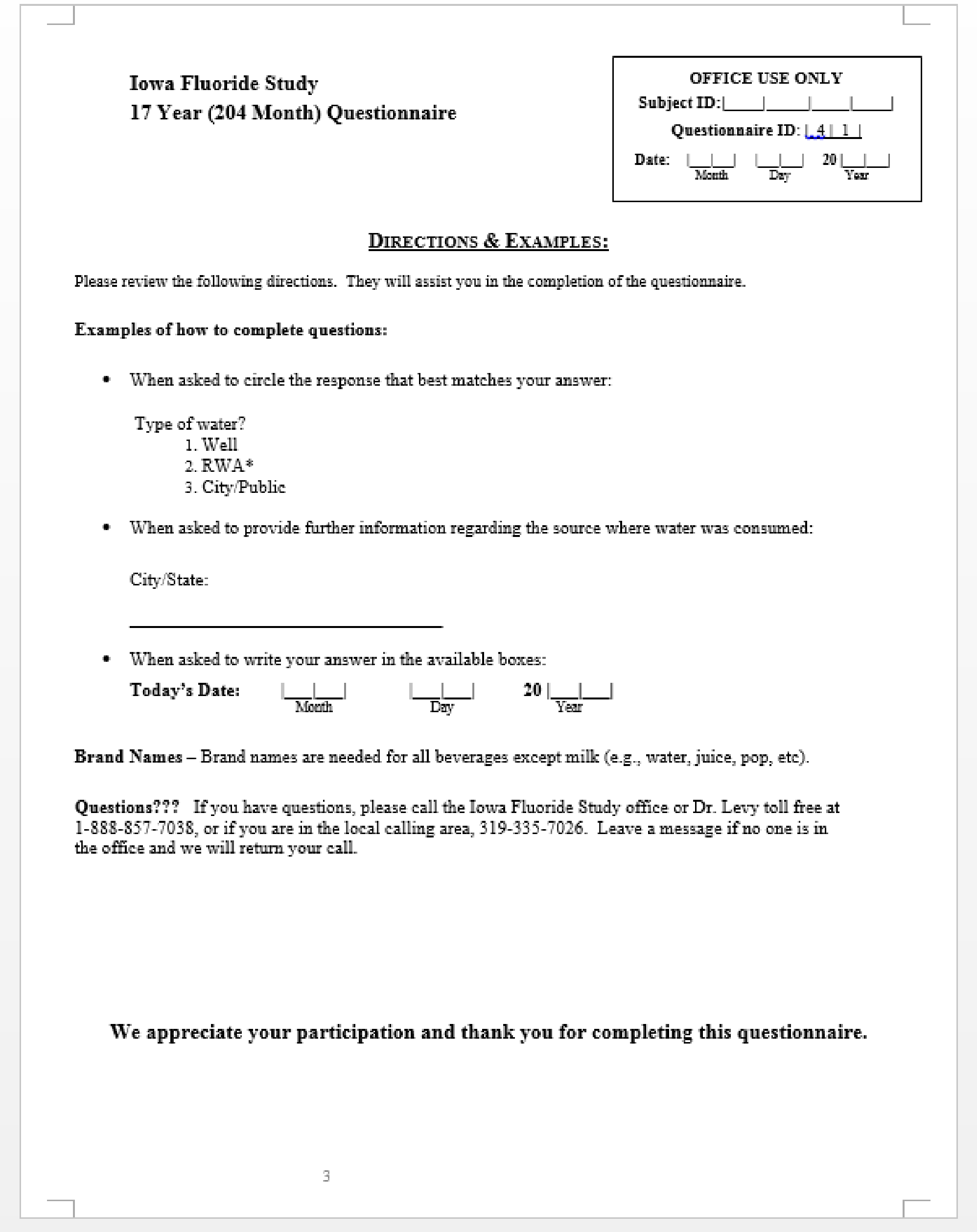


Iowa Fluoride Study
17 Year (204 Month) Questionnaire

OFFICE USE ONLY
Subject ID:|_____|_____|_____|_____|
Questionnaire ID: |_4_|_1_|
Date: |__|__| Month |__|__| Day **20** |__|__| Year

Directions & Examples:

Please review the following directions. They will assist you in the completion of the questionnaire.

Examples of how to complete questions:

- When asked to circle the response that best matches your answer:

  Type of water?
  1. Well
  2. RWA*
  3. City/Public

- When asked to provide further information regarding the source where water was consumed:

  City/State:

  ____

- When asked to write your answer in the available boxes:

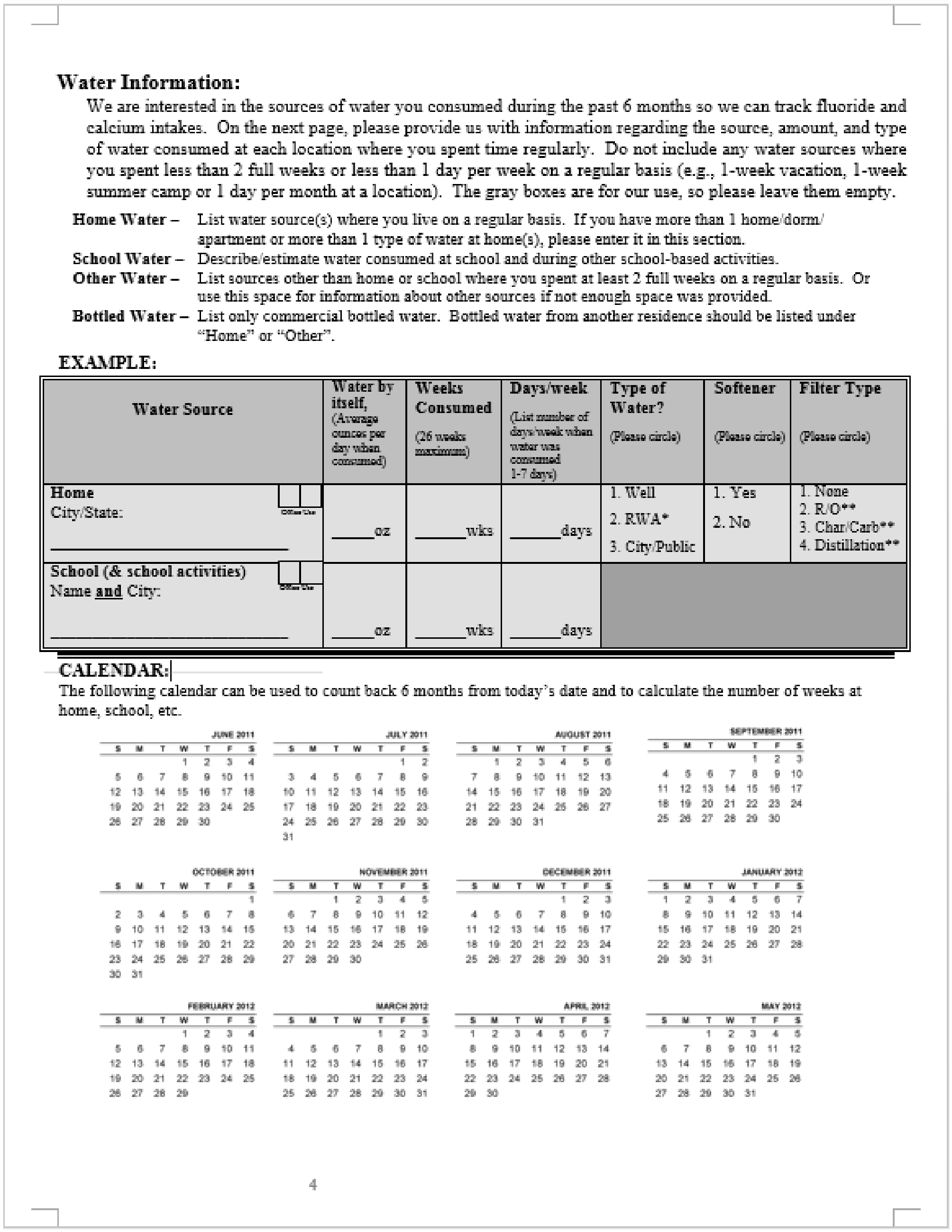
  Today's Date: |___|___| Month |___|___| Day **20** |___|___| Year

Brand Names – Brand names are needed for all beverages except milk (e.g., water, juice, pop, etc).

Questions??? If you have questions, please call the Iowa Fluoride Study office or Dr. Levy toll free at 1-888-857-7038, or if you are in the local calling area, 319-335-7026. Leave a message if no one is in the office and we will return your call.

We appreciate your participation and thank you for completing this questionnaire.

3



Water Information:

We are interested in the sources of water you consumed during the past 6 months so we can track fluoride and calcium intakes. On the next page, please provide us with information regarding the source, amount, and type of water consumed at each location where you spent time regularly. Do not include any water sources where you spent less than 2 full weeks or less than 1 day per week on a regular basis (e.g., 1-week vacation, 1-week summer camp or 1 day per month at a location). The gray boxes are for our use, so please leave them empty.

Home Water –	List water source(s) where you live on a regular basis. If you have more than 1 home/dorm/apartment or more than 1 type of water at home(s), please enter it in this section.
School Water –	Describe/estimate water consumed at school and during other school-based activities.
Other Water –	List sources other than home or school where you spent at least 2 full weeks on a regular basis. Or use this space for information about other sources if not enough space was provided.
Bottled Water –	List only commercial bottled water. Bottled water from another residence should be listed under "Home" or "Other".

EXAMPLE:

Water Source	**Water by itself,** (Average ounces per day when consumed)	**Weeks Consumed** (26 weeks maximum)	**Days/week** (List number of days/week when water was consumed 1-7 days)	**Type of Water?** (Please circle)	**Softener** (Please circle)	**Filter Type** (Please circle)
Home ☐☐ Office Use City/State: ______________________________	_____oz	______wks	______days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
School (& school activities) ☐☐ Office Use Name **and** City: ______________________________	_____oz	______wks	______days			

CALENDAR:

The following calendar can be used to count back 6 months from today's date and to calculate the number of weeks at home, school, etc.

JUNE 2011

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

JULY 2011

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

AUGUST 2011

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

SEPTEMBER 2011

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

OCTOBER 2011

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

NOVEMBER 2011

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

DECEMBER 2011

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

JANUARY 2012

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

FEBRUARY 2012

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29			

MARCH 2012

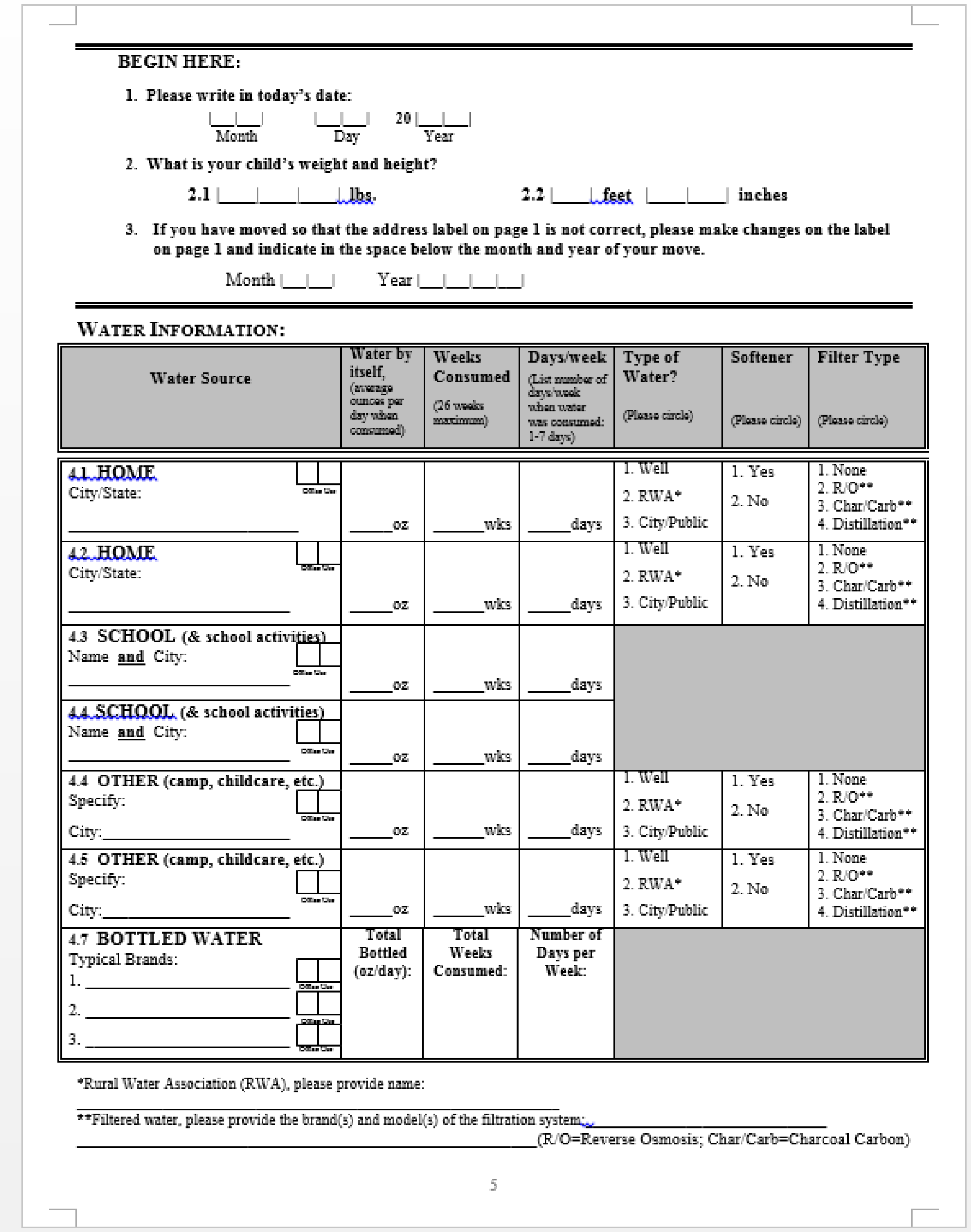
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

APRIL 2012

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

MAY 2012

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		



BEGIN HERE:

1. **Please write in today's date:**

|__|__| Month |__|__| Day **20** |__|__| Year

2. **What is your child's weight and height?**

2.1 |____|____|____| **lbs.** **2.2** |____| **feet** |____|____| **inches**

3. **If you have moved so that the address label on page 1 is not correct, please make changes on the label on page 1 and indicate in the space below the month and year of your move.**

Month |__|__| Year |__|__|__|__|

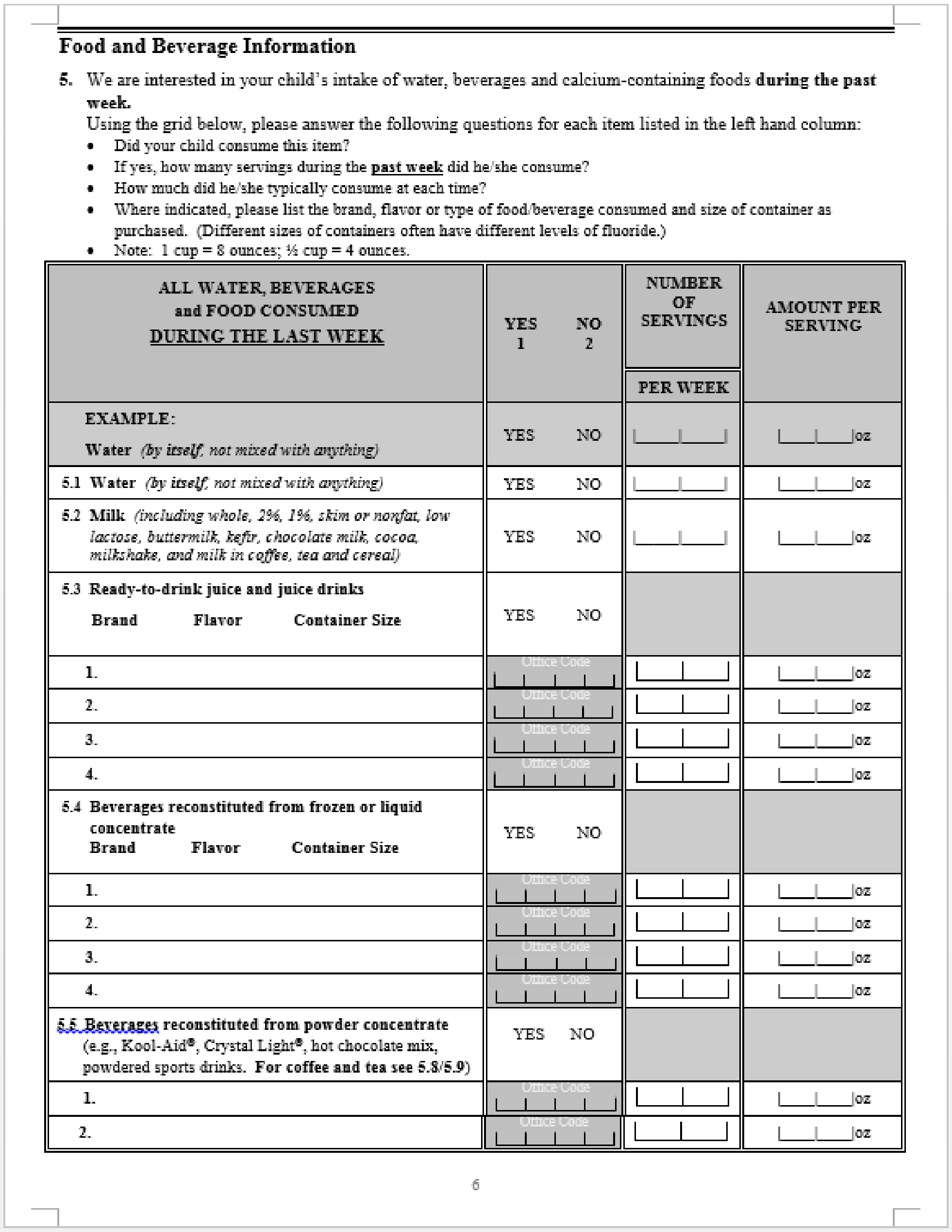
WATER INFORMATION:

Water Source	**Water by itself,** (average ounces per day when consumed)	**Weeks Consumed** (26 weeks maximum)	**Days/week** (List number of days/week when water was consumed: 1-7 days)	**Type of Water?** (Please circle)	**Softener** (Please circle)	**Filter Type** (Please circle)
4.1 HOME City/State: ____________________ ☐☐ Office Use	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.2 HOME City/State: ____________________ ☐☐ Office Use	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.3 **SCHOOL** **(& school activities)** Name **and** City: ____________________ ☐☐ Office Use	_____oz	______wks	_____days			
4.4 SCHOOL **(& school activities)** Name **and** City: ____________________ ☐☐ Office Use	_____oz	______wks	_____days			
4.4 OTHER (camp, childcare, etc.) Specify: City:__________________ ☐☐ Office Use	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.5 OTHER (camp, childcare, etc.) Specify: City:__________________ ☐☐ Office Use	_____oz	______wks	_____days	1. Well 2. RWA* 3. City/Public	1. Yes 2. No	1. None 2. R/O** 3. Char/Carb** 4. Distillation**
4.7 **BOTTLED WATER** Typical Brands: 1. __________________ ☐☐ Office Use 2. __________________ ☐☐ Office Use 3. __________________ ☐☐ Office Use	**Total Bottled (oz/day):**	**Total Weeks Consumed:**	**Number of Days per Week:**			

*Rural Water Association (RWA), please provide name: ______________________________

**Filtered water, please provide the brand(s) and model(s) of the filtration system: ____(R/O=Reverse Osmosis; Char/Carb=Charcoal Carbon)

5



Food and Beverage Information

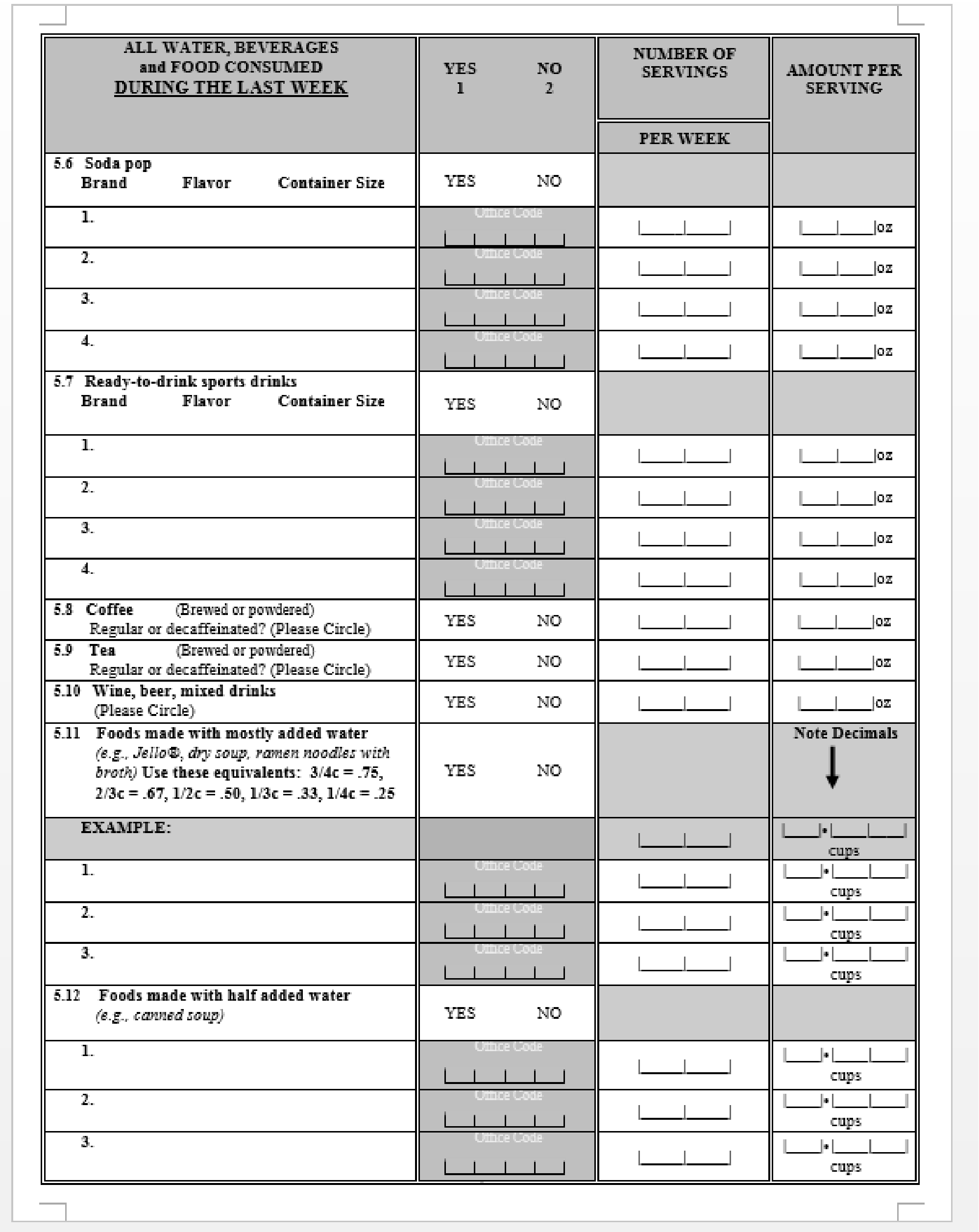
5. We are interested in your child's intake of water, beverages and calcium-containing foods **during the past week.**

Using the grid below, please answer the following questions for each item listed in the left hand column:

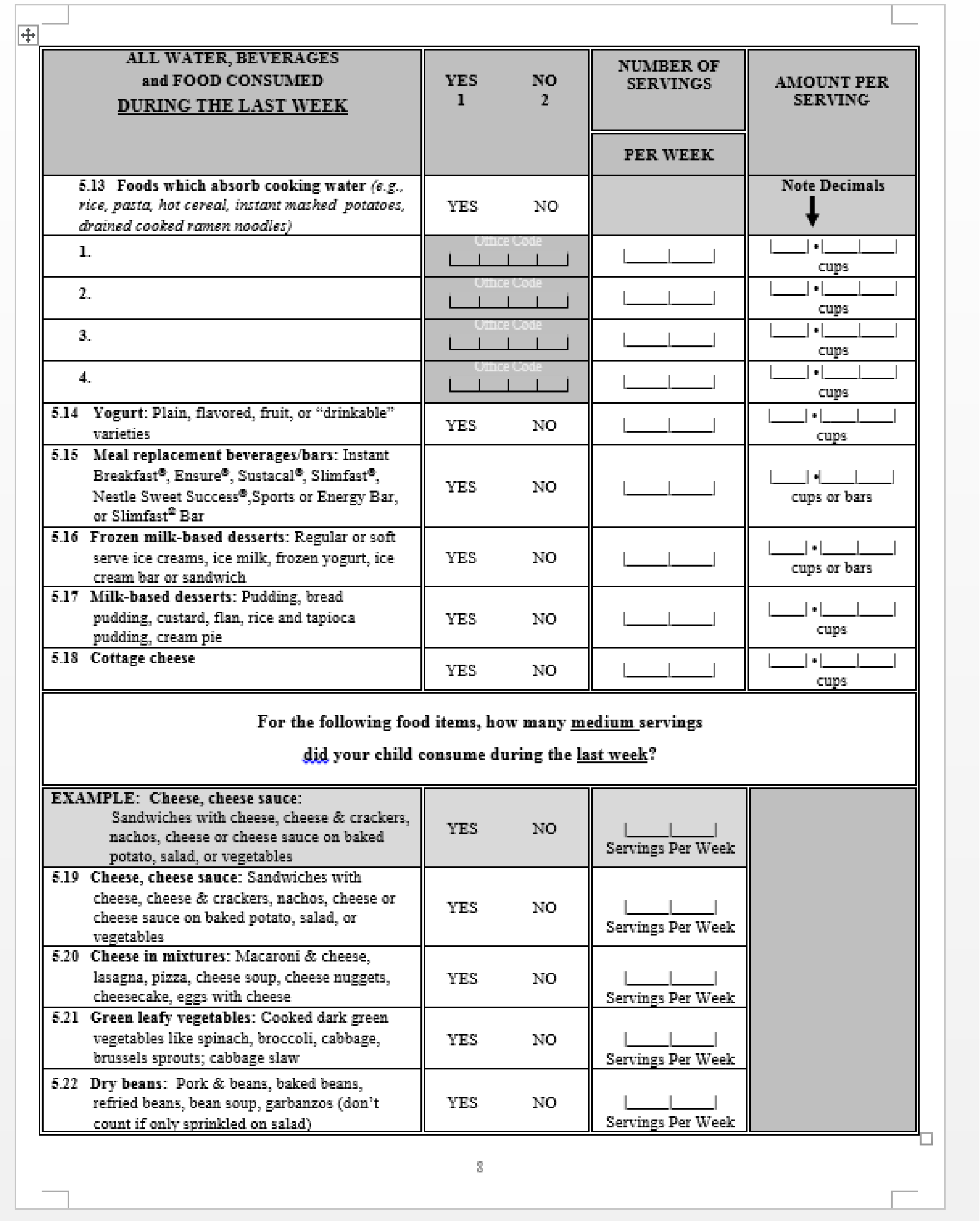
- Did your child consume this item?
- If yes, how many servings during the **past week** did he/she consume?
- How much did he/she typically consume at each time?
- Where indicated, please list the brand, flavor or type of food/beverage consumed and size of container as purchased. (Different sizes of containers often have different levels of fluoride.)
- Note: 1 cup = 8 ounces; ½ cup = 4 ounces.

ALL WATER, BEVERAGES and FOOD CONSUMED DURING THE LAST WEEK	**YES 1**	**NO 2**	**NUMBER OF SERVINGS**	**AMOUNT PER SERVING**
			PER WEEK	
EXAMPLE: **Water** *(by itself, not mixed with anything)*	YES	NO		oz
5.1 **Water** *(by itself, not mixed with anything)*	YES	NO		oz
5.2 **Milk** *(including whole, 2%, 1%, skim or nonfat, low lactose, buttermilk, kefir, chocolate milk, cocoa, milkshake, and milk in coffee, tea and cereal)*	YES	NO		oz
5.3 Ready-to-drink juice and juice drinks **Brand** **Flavor** **Container Size**	YES	NO		
1.	Office Code			oz
2.	Office Code			oz
3.	Office Code			oz
4.	Office Code			oz
5.4 Beverages reconstituted from frozen or liquid concentrate **Brand** **Flavor** **Container Size**	YES	NO		
1.	Office Code			oz
2.	Office Code			oz
3.	Office Code			oz
4.	Office Code			oz
5.5 Beverages reconstituted from powder concentrate (e.g., Kool-Aid®, Crystal Light®, hot chocolate mix, powdered sports drinks. **For coffee and tea see 5.8/5.9**)	YES	NO		
1.	Office Code			oz
2.	Office Code			oz

6



ALL WATER, BEVERAGES and FOOD CONSUMED **DURING THE LAST WEEK**	YES 1 NO 2	NUMBER OF SERVINGS PER WEEK	AMOUNT PER SERVING
5.6 Soda pop **Brand Flavor Container Size**	YES NO		
1.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
2.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
3.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
4.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
5.7 Ready-to-drink sports drinks **Brand Flavor Container Size**	YES NO		
1.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
2.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
3.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
4.	Office Code |__|__|__|__|	|____|____|	|___|___|oz
5.8 Coffee (Brewed or powdered) Regular or decaffeinated? (Please Circle)	YES NO	|____|____|	|___|___|oz
5.9 Tea (Brewed or powdered) Regular or decaffeinated? (Please Circle)	YES NO	|____|____|	|___|___|oz
5.10 Wine, beer, mixed drinks (Please Circle)	YES NO	|____|____|	|___|___|oz
5.11 Foods made with mostly added water *(e.g., Jello®, dry soup, ramen noodles with broth)* **Use these equivalents: 3/4c = .75, 2/3c = .67, 1/2c = .50, 1/3c = .33, 1/4c = .25**	YES NO		**Note Decimals** ↓
EXAMPLE:		|____|____|	|___|•|___|___| cups
1.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
2.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
3.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
5.12 Foods made with half added water *(e.g., canned soup)*	YES NO		
1.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
2.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups
3.	Office Code |__|__|__|__|	|____|____|	|___|•|___|___| cups



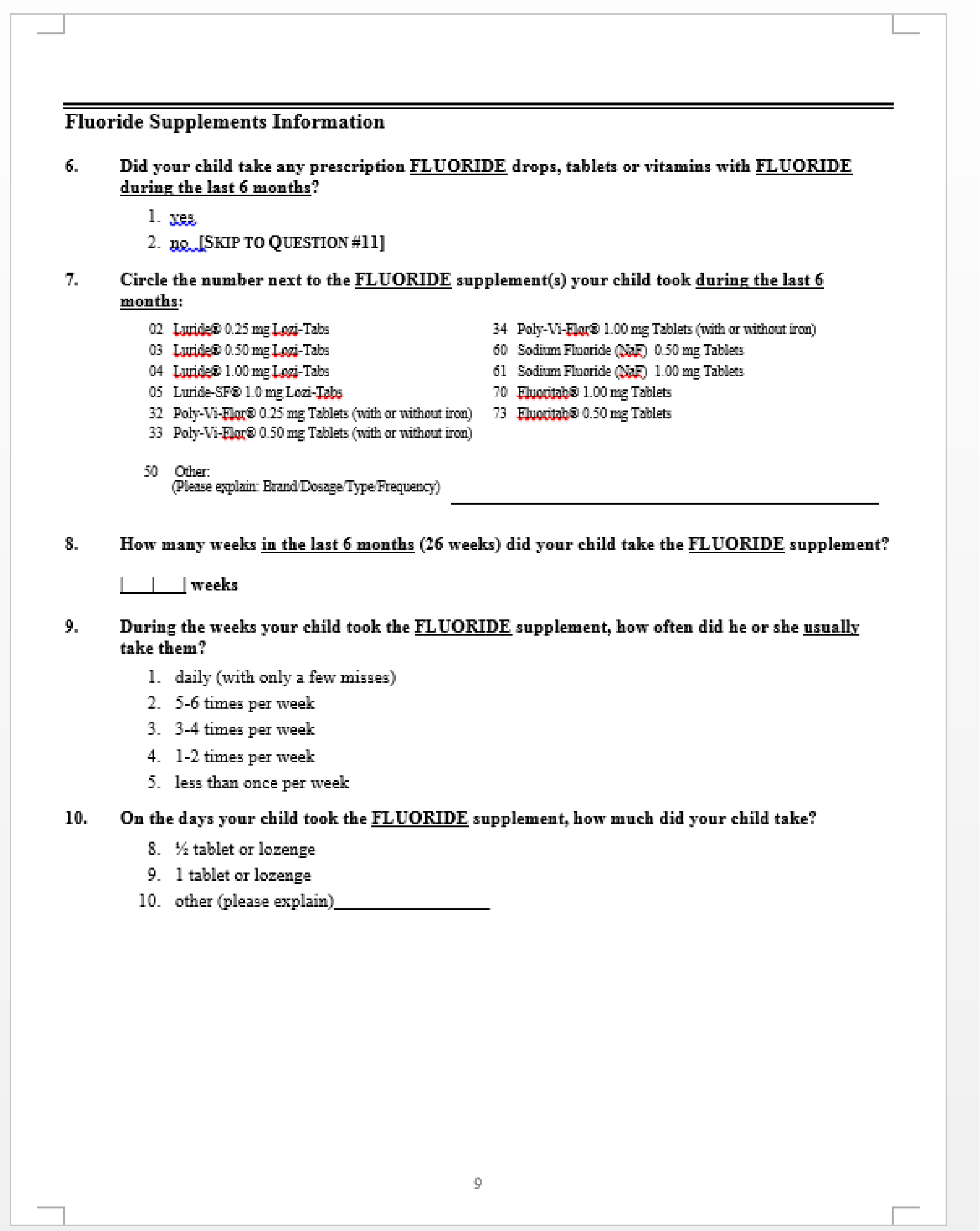
ALL WATER, BEVERAGES and FOOD CONSUMED <u>DURING THE LAST WEEK</u>	**YES 1**	**NO 2**	**NUMBER OF SERVINGS PER WEEK**	**AMOUNT PER SERVING**
5.13 Foods which absorb cooking water *(e.g., rice, pasta, hot cereal, instant masked potatoes, drained cooked ramen noodles)*	YES	NO		**Note Decimals** ↓
1.	Office Code |__|__|__|__|		|____|____|	|____|•|____|____| cups
2.	Office Code |__|__|__|__|		|____|____|	|____|•|____|____| cups
3.	Office Code |__|__|__|__|		|____|____|	|____|•|____|____| cups
4.	Office Code |__|__|__|__|		|____|____|	|____|•|____|____| cups
5.14 **Yogurt**: Plain, flavored, fruit, or "drinkable" varieties	YES	NO	|____|____|	|____|•|____|____| cups
5.15 **Meal replacement beverages/bars**: Instant Breakfast®, Ensure®, Sustacal®, Slimfast®, Nestle Sweet Success®,Sports or Energy Bar, or Slimfast® Bar	YES	NO	|____|____|	|____|•|____|____| cups or bars
5.16 **Frozen milk-based desserts**: Regular or soft serve ice creams, ice milk, frozen yogurt, ice cream bar or sandwich	YES	NO	|____|____|	|____|•|____|____| cups or bars
5.17 **Milk-based desserts**: Pudding, bread pudding, custard, flan, rice and tapioca pudding, cream pie	YES	NO	|____|____|	|____|•|____|____| cups
5.18 **Cottage cheese**	YES	NO	|____|____|	|____|•|____|____| cups

For the following food items, how many <u>medium</u> servings

<u>did</u> your child consume during the <u>last week</u>?

EXAMPLE: Cheese, cheese sauce: Sandwiches with cheese, cheese & crackers, nachos, cheese or cheese sauce on baked potato, salad, or vegetables	YES	NO	|____|____| Servings Per Week	
5.19 **Cheese, cheese sauce**: Sandwiches with cheese, cheese & crackers, nachos, cheese or cheese sauce on baked potato, salad, or vegetables	YES	NO	|____|____| Servings Per Week	
5.20 **Cheese in mixtures**: Macaroni & cheese, lasagna, pizza, cheese soup, cheese nuggets, cheesecake, eggs with cheese	YES	NO	|____|____| Servings Per Week	
5.21 **Green leafy vegetables**: Cooked dark green vegetables like spinach, broccoli, cabbage, brussels sprouts; cabbage slaw	YES	NO	|____|____| Servings Per Week	
5.22 **Dry beans**: Pork & beans, baked beans, refried beans, bean soup, garbanzos (don't count if only sprinkled on salad)	YES	NO	|____|____| Servings Per Week	

8



Fluoride Supplements Information

6. Did your child take any prescription FLUORIDE drops, tablets or vitamins with FLUORIDE during the last 6 months?

1. yes
2. no [SKIP TO QUESTION #11]

7. Circle the number next to the FLUORIDE supplement(s) your child took during the last 6 months:

02 Luride® 0.25 mg Lozi-Tabs
03 Luride® 0.50 mg Lozi-Tabs
04 Luride® 1.00 mg Lozi-Tabs
05 Luride-SF® 1.0 mg Lozi-Tabs
32 Poly-Vi-Flor® 0.25 mg Tablets (with or without iron)
33 Poly-Vi-Flor® 0.50 mg Tablets (with or without iron)
34 Poly-Vi-Flor® 1.00 mg Tablets (with or without iron)
60 Sodium Fluoride (NaF) 0.50 mg Tablets
61 Sodium Fluoride (NaF) 1.00 mg Tablets
70 Fluoritab® 1.00 mg Tablets
73 Fluoritab® 0.50 mg Tablets

50 Other:
(Please explain: Brand/Dosage/Type/Frequency) ______________________________

8. How many weeks in the last 6 months (26 weeks) did your child take the FLUORIDE supplement?

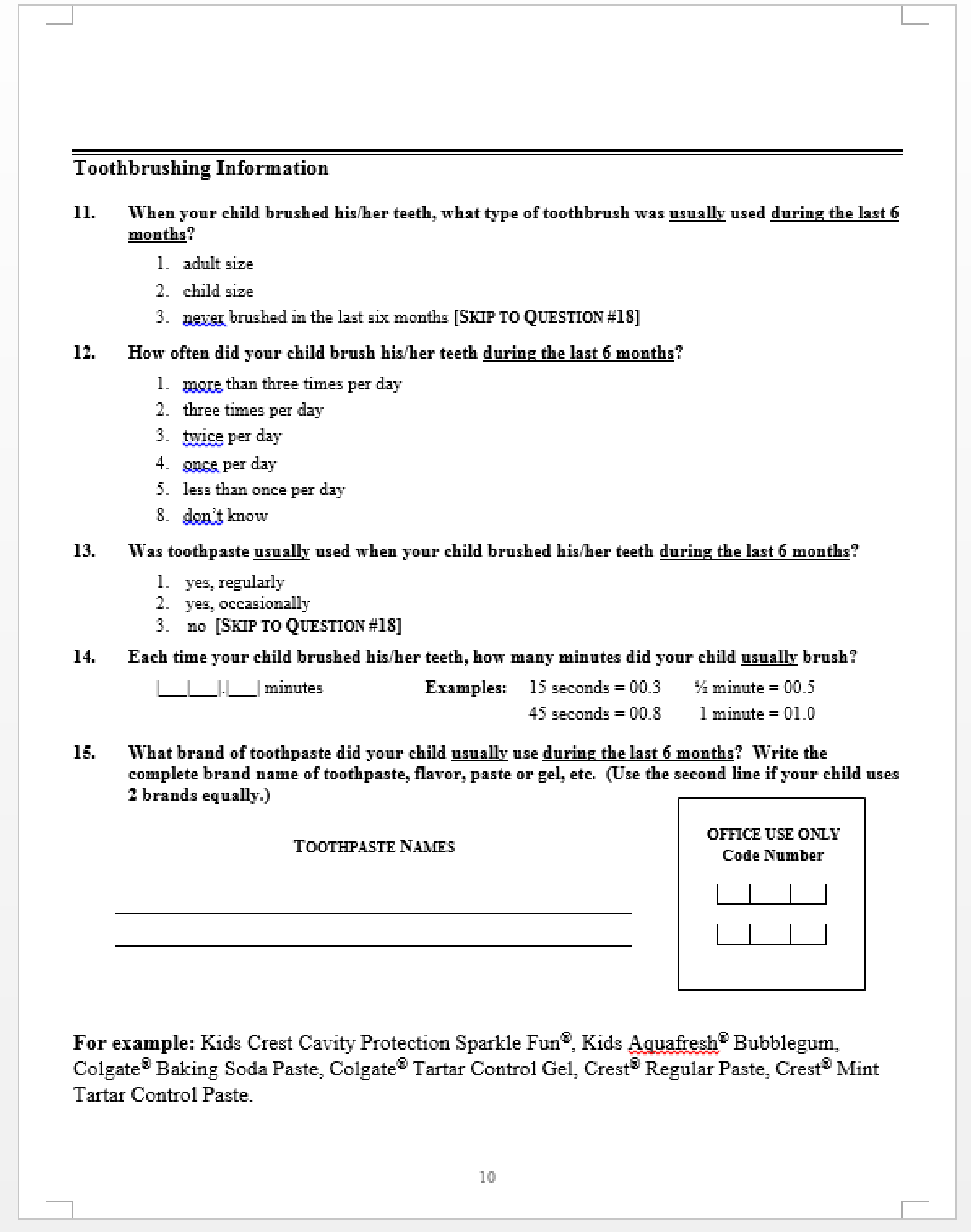
|___|___| **weeks**

9. During the weeks your child took the FLUORIDE supplement, how often did he or she usually take them?

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

10. On the days your child took the FLUORIDE supplement, how much did your child take?

8. ½ tablet or lozenge
9. 1 tablet or lozenge
10. other (please explain)_________________



Toothbrushing Information

11. **When your child brushed his/her teeth, what type of toothbrush was <u>usually</u> used <u>during the last 6 months</u>?**

1. adult size
2. child size
3. never brushed in the last six months [SKIP TO QUESTION #18]

12. **How often did your child brush his/her teeth <u>during the last 6 months</u>?**

1. more than three times per day
2. three times per day
3. twice per day
4. once per day
5. less than once per day
8. don't know

13. **Was toothpaste <u>usually</u> used when your child brushed his/her teeth <u>during the last 6 months</u>?**

1. yes, regularly
2. yes, occasionally
3. no [SKIP TO QUESTION #18]

14. **Each time your child brushed his/her teeth, how many minutes did your child <u>usually</u> brush?**

|___|___|.|___| minutes

Examples:
15 seconds = 00.3
½ minute = 00.5
45 seconds = 00.8
1 minute = 01.0

15. **What brand of toothpaste did your child <u>usually</u> use <u>during the last 6 months</u>? Write the complete brand name of toothpaste, flavor, paste or gel, etc. (Use the second line if your child uses 2 brands equally.)**

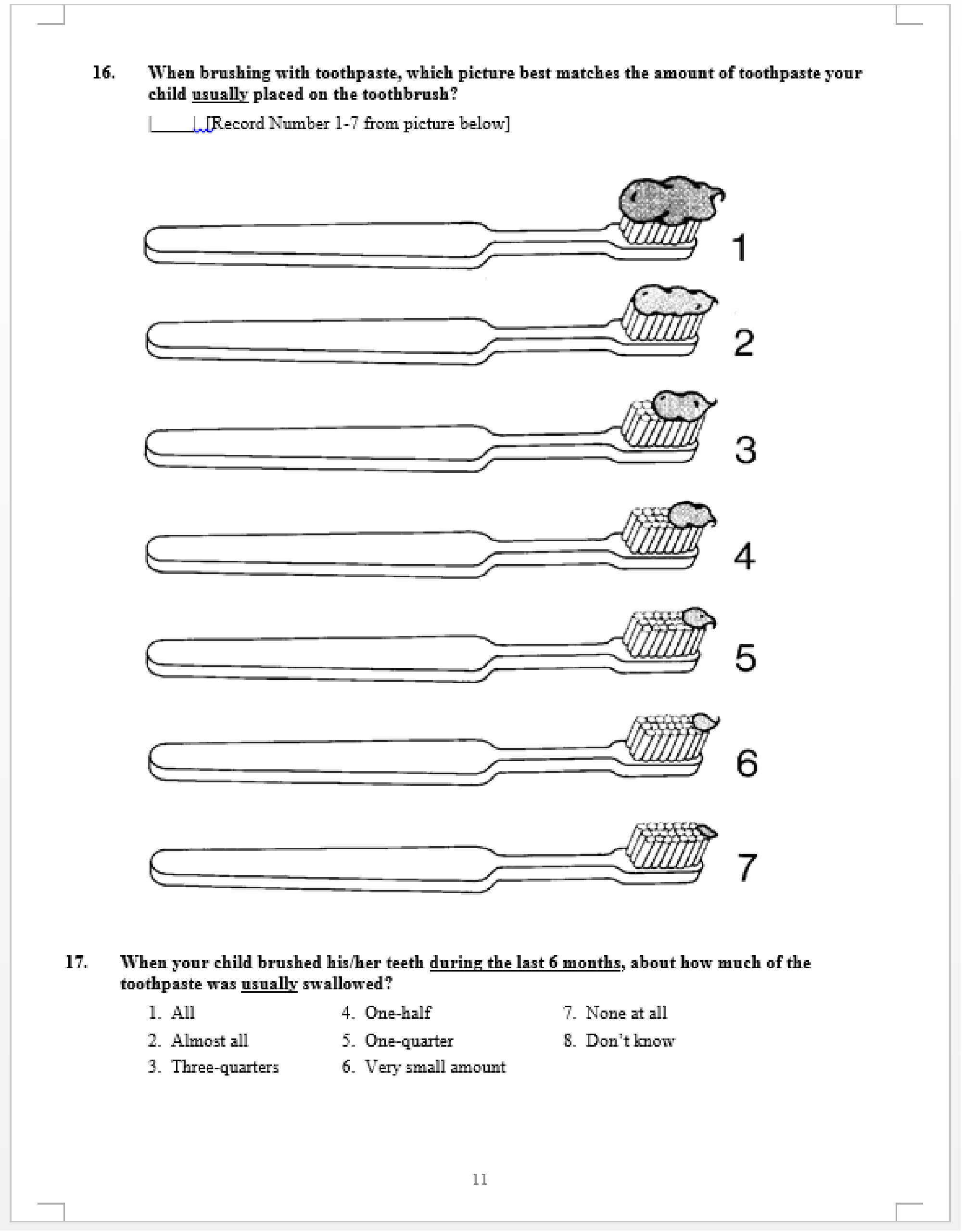
TOOTHPASTE NAMES

____

____

OFFICE USE ONLY
Code Number
|___|___|___|
|___|___|___|

For example: Kids Crest Cavity Protection Sparkle Fun®, Kids Aquafresh® Bubblegum, Colgate® Baking Soda Paste, Colgate® Tartar Control Gel, Crest® Regular Paste, Crest® Mint Tartar Control Paste.



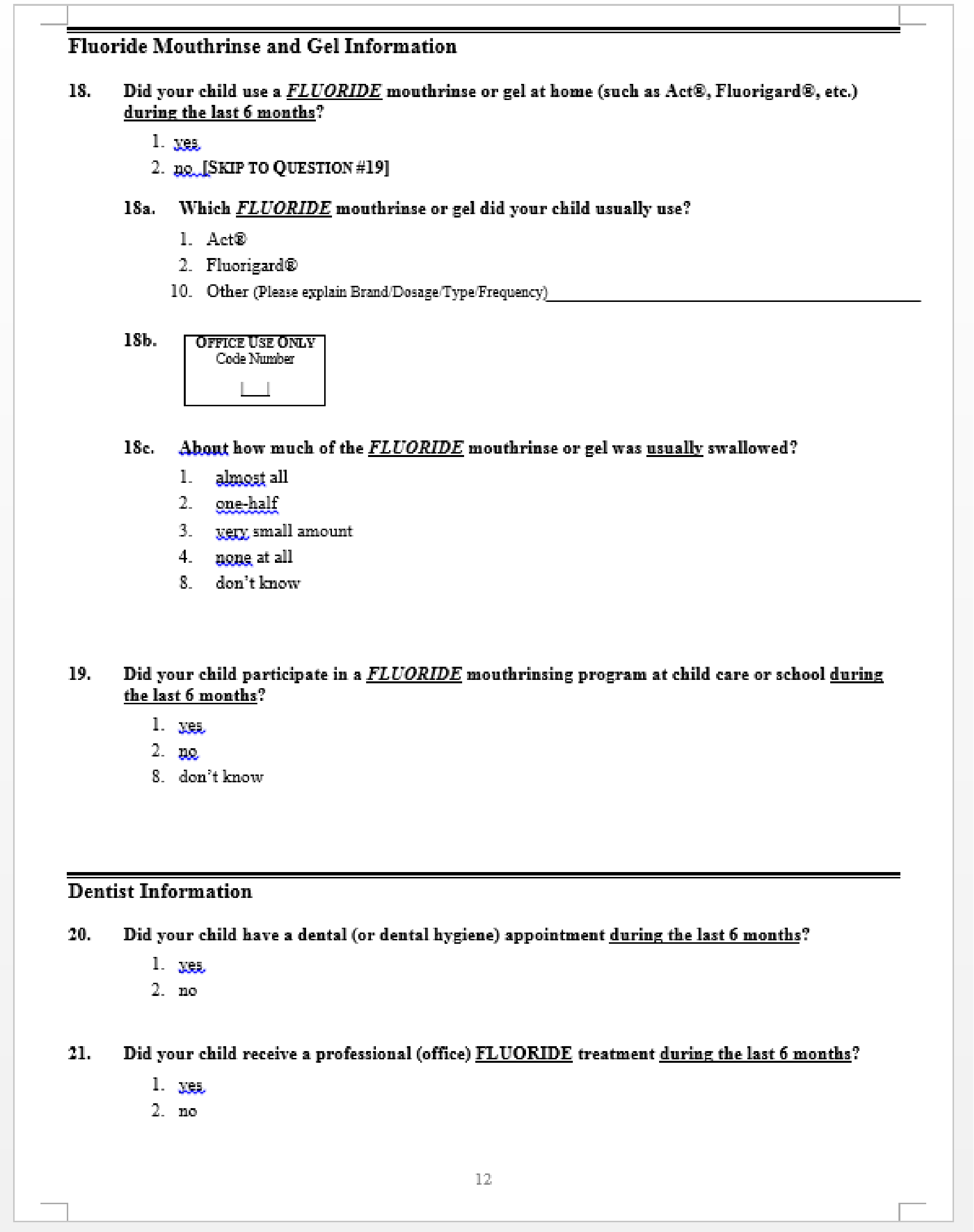
16. When brushing with toothpaste, which picture best matches the amount of toothpaste your child usually placed on the toothbrush?

|_____| [Record Number 1-7 from picture below]

17. When your child brushed his/her teeth during the last 6 months, about how much of the toothpaste was usually swallowed?

1. All
2. Almost all
3. Three-quarters
4. One-half
5. One-quarter
6. Very small amount
7. None at all
8. Don't know

11



Fluoride Mouthrinse and Gel Information

18. **Did your child use a *FLUORIDE* mouthrinse or gel at home (such as Act®, Fluorigard®, etc.) during the last 6 months?**

1. yes
2. no [SKIP TO QUESTION #19]

18a. **Which *FLUORIDE* mouthrinse or gel did your child usually use?**

1. Act®
2. Fluorigard®
10. Other (Please explain Brand/Dosage/Type/Frequency)________________________________

18b. OFFICE USE ONLY
Code Number
|__|

18c. **About how much of the *FLUORIDE* mouthrinse or gel was usually swallowed?**

1. almost all
2. one-half
3. very small amount
4. none at all
8. don't know

19. **Did your child participate in a *FLUORIDE* mouthrinsing program at child care or school during the last 6 months?**

1. yes
2. no
8. don't know

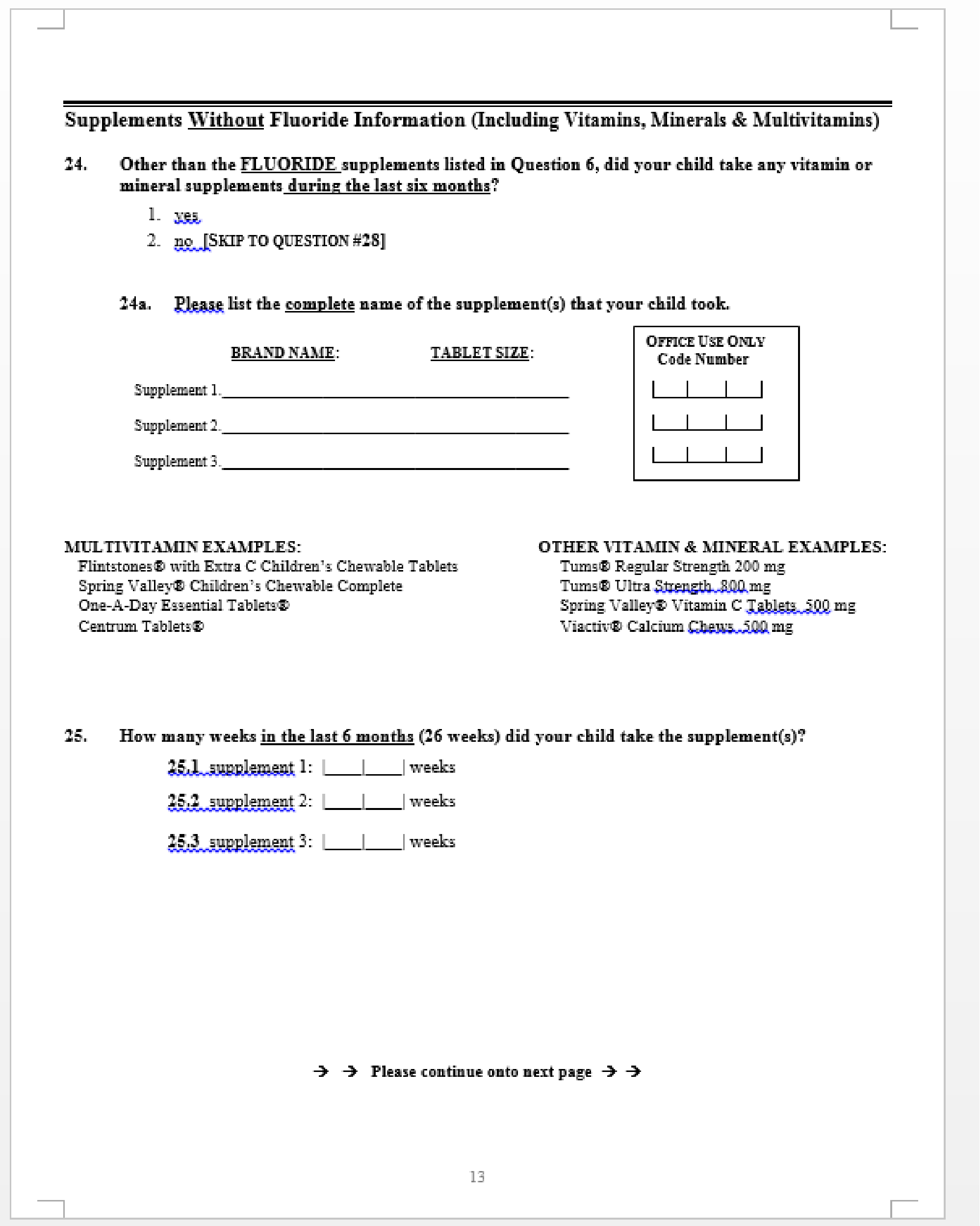
Dentist Information

20. **Did your child have a dental (or dental hygiene) appointment during the last 6 months?**

1. yes
2. no

21. **Did your child receive a professional (office) FLUORIDE treatment during the last 6 months?**

1. yes
2. no



Supplements **Without** Fluoride Information (Including Vitamins, Minerals & Multivitamins)

24. Other than the FLUORIDE supplements listed in Question 6, did your child take any vitamin or mineral supplements during the last six months?

1. yes
2. no [SKIP TO QUESTION #28]

24a. Please list the complete name of the supplement(s) that your child took.

BRAND NAME: **TABLET SIZE**:

Supplement 1.____

Supplement 2.____

Supplement 3.____

OFFICE USE ONLY
Code Number
__	__	__
__	__	__
__	__	__

MULTIVITAMIN EXAMPLES:
- Flintstones® with Extra C Children's Chewable Tablets
- Spring Valley® Children's Chewable Complete
- One-A-Day Essential Tablets®
- Centrum Tablets®

OTHER VITAMIN & MINERAL EXAMPLES:
- Tums® Regular Strength 200 mg
- Tums® Ultra Strength 800 mg
- Spring Valley® Vitamin C Tablets 500 mg
- Viactiv® Calcium Chews 500 mg

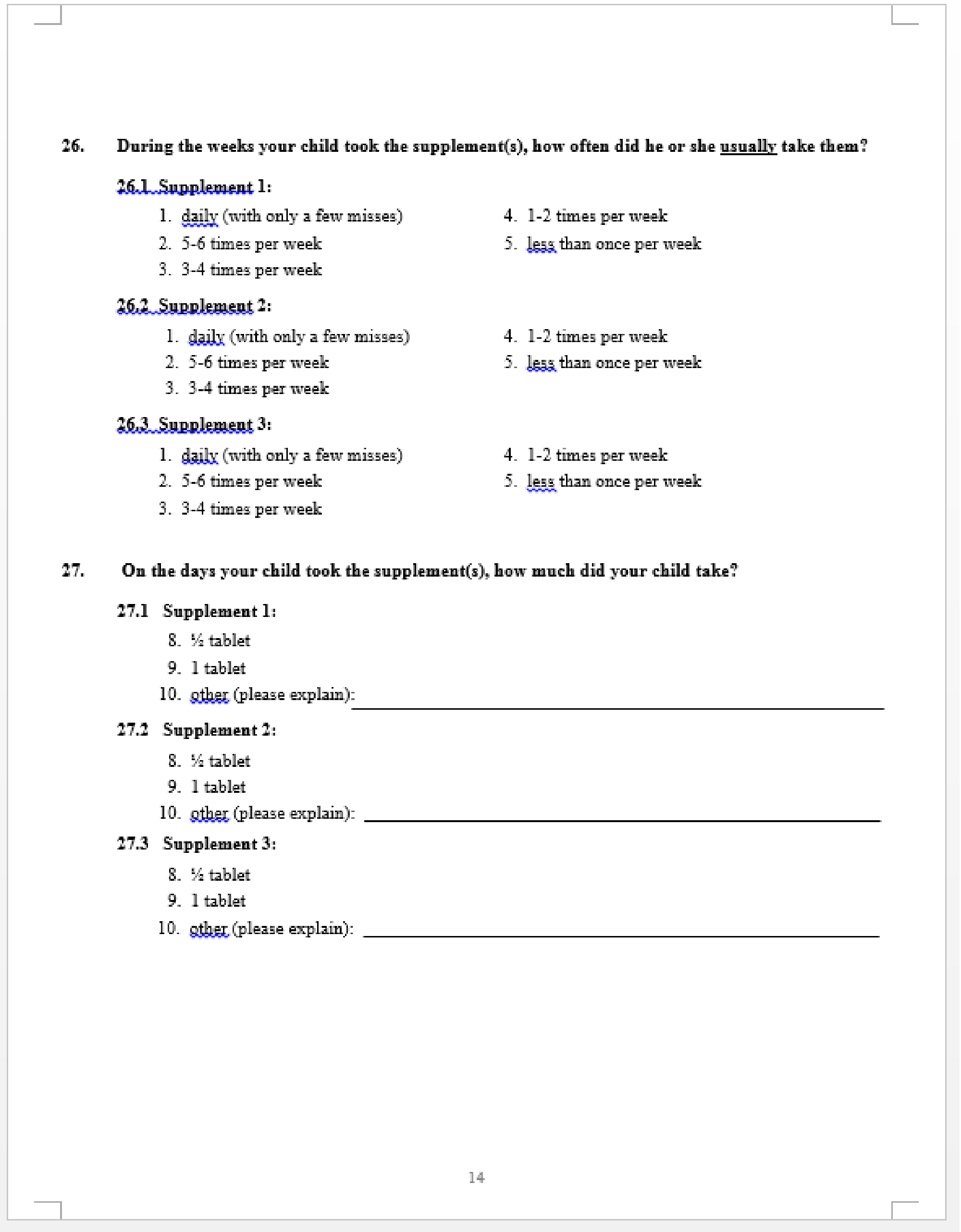
25. How many weeks in the last 6 months (26 weeks) did your child take the supplement(s)?

25.1 supplement 1: |____|____| weeks

25.2 supplement 2: |____|____| weeks

25.3 supplement 3: |____|____| weeks

→ → **Please continue onto next page** → →



26. During the weeks your child took the supplement(s), how often did he or she usually take them?

26.1 Supplement 1:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

26.2 Supplement 2:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

26.3 Supplement 3:

1. daily (with only a few misses)
2. 5-6 times per week
3. 3-4 times per week
4. 1-2 times per week
5. less than once per week

27. On the days your child took the supplement(s), how much did your child take?

27.1 Supplement 1:

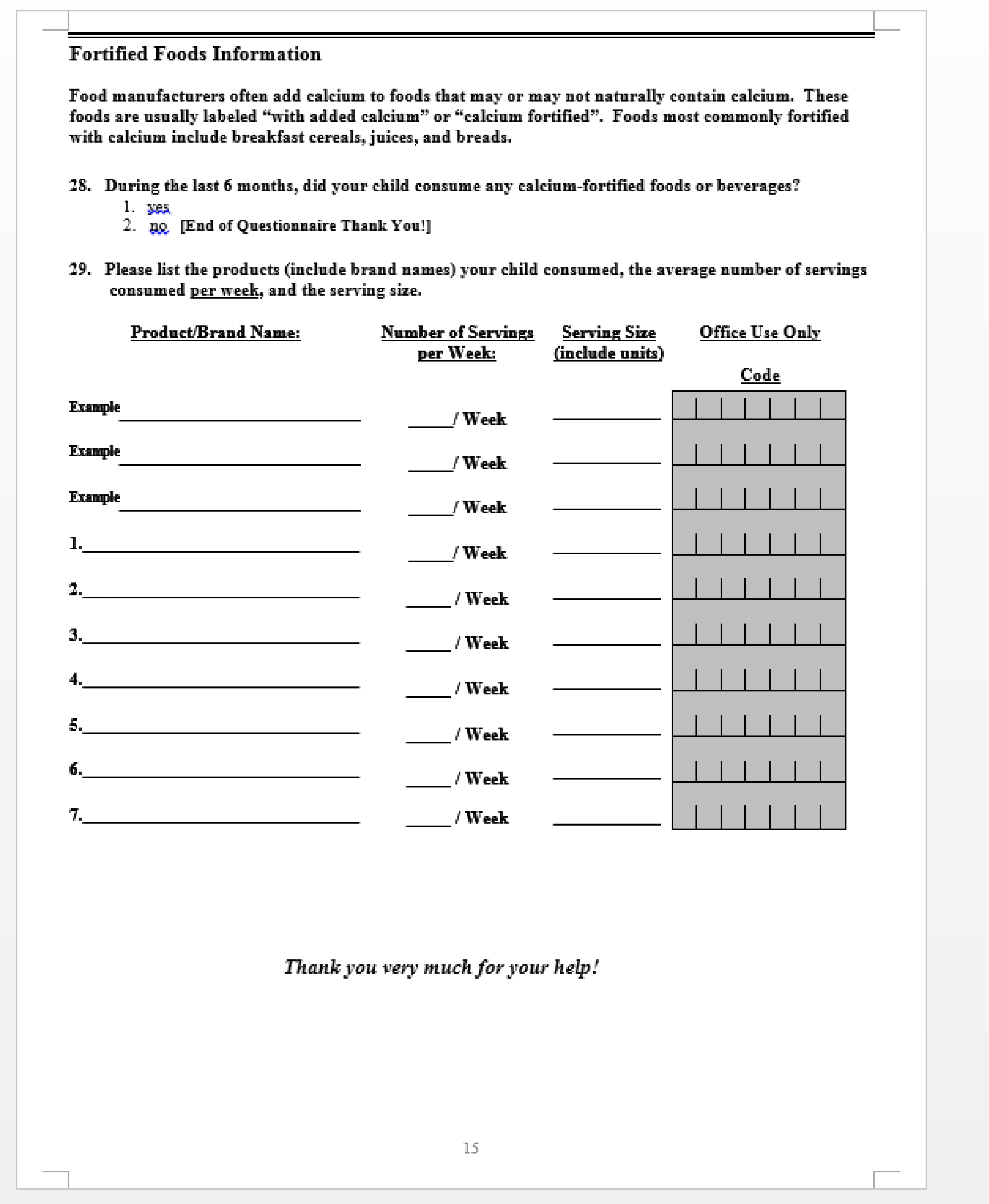
8. ½ tablet
9. 1 tablet
10. other (please explain): ______________________________

27.2 Supplement 2:

8. ½ tablet
9. 1 tablet
10. other (please explain): ______________________________

27.3 Supplement 3:

8. ½ tablet
9. 1 tablet
10. other (please explain): ______________________________



Fortified Foods Information

Food manufacturers often add calcium to foods that may or may not naturally contain calcium. These foods are usually labeled "with added calcium" or "calcium fortified". Foods most commonly fortified with calcium include breakfast cereals, juices, and breads.

28. During the last 6 months, did your child consume any calcium-fortified foods or beverages?

1. yes
2. no **[End of Questionnaire Thank You!]**

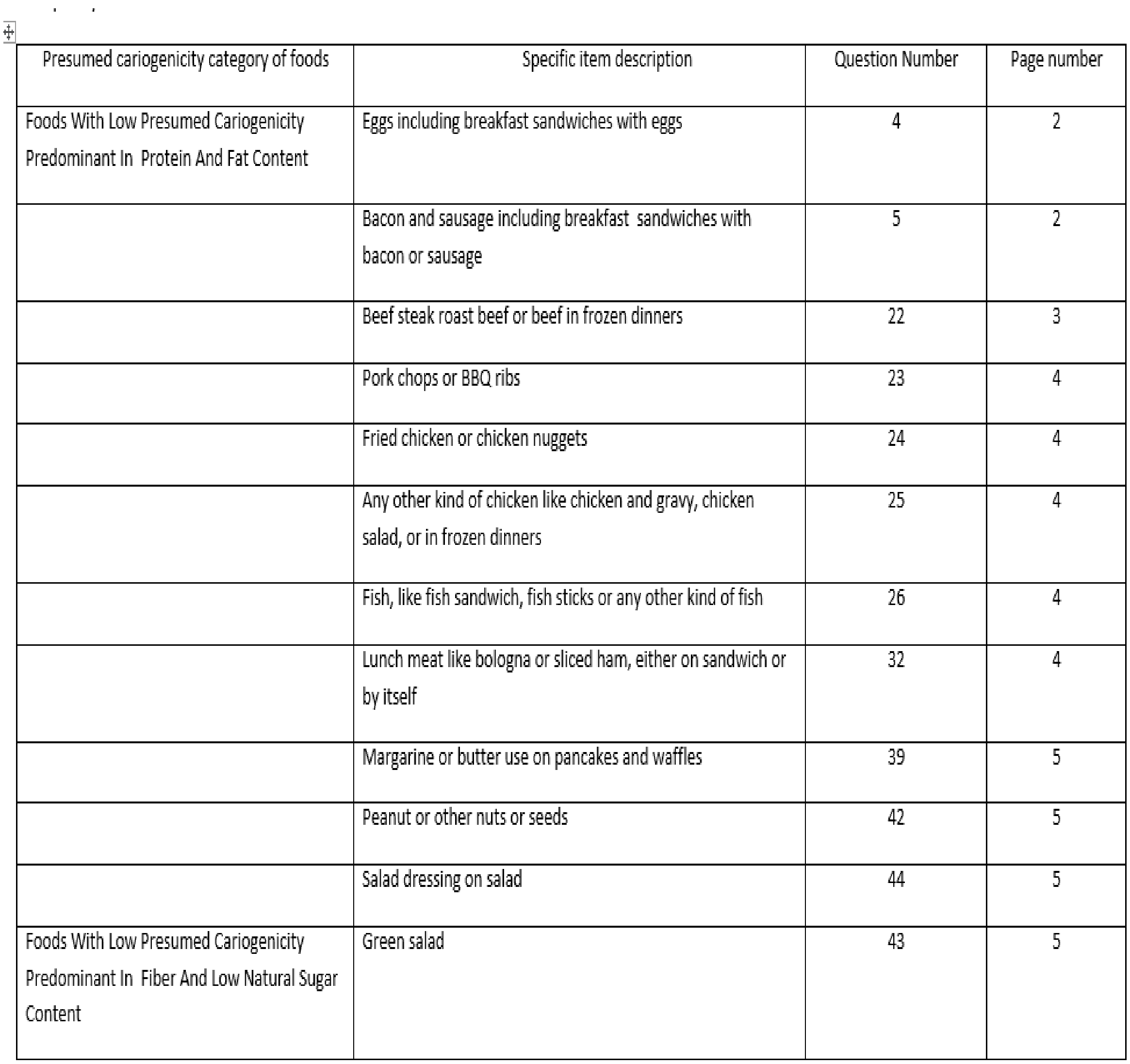
29. Please list the products (include brand names) your child consumed, the average number of servings consumed per week, and the serving size.

Product/Brand Name:	**Number of Servings per Week:**	**Serving Size (include units)**	**Office Use Only** **Code**
Example ______	_____/ Week	______	
Example ______	_____/ Week	______	
Example ______	_____/ Week	______	
1. ______	_____/ Week	______	
2. ______	_____ / Week	______	
3. ______	_____ / Week	______	
4. ______	_____ / Week	______	
5. ______	_____ / Week	______	
6. ______	_____ / Week	______	
7. ______	_____ / Week	______	

Thank you very much for your help!

APPENDIX G: INDEX: SOLID FOODS CATEGORIES BASED ON PRESUMED CARIOGENICITY

The presumed cariogenicity category of foods along with specific item description, question and page number of the item



Presumed cariogenicity category of foods	Specific item description	Question Number	Page number
Foods With Low Presumed Cariogenicity Predominant In Protein And Fat Content	Eggs including breakfast sandwiches with eggs	4	2
	Bacon and sausage including breakfast sandwiches with bacon or sausage	5	2
	Beef steak roast beef or beef in frozen dinners	22	3
	Pork chops or BBQ ribs	23	4
	Fried chicken or chicken nuggets	24	4
	Any other kind of chicken like chicken and gravy, chicken salad, or in frozen dinners	25	4
	Fish, like fish sandwich, fish sticks or any other kind of fish	26	4
	Lunch meat like bologna or sliced ham, either on sandwich or by itself	32	4
	Margarine or butter use on pancakes and waffles	39	5
	Peanut or other nuts or seeds	42	5
	Salad dressing on salad	44	5
Foods With Low Presumed Cariogenicity Predominant In Fiber And Low Natural Sugar Content	Green salad	43	5

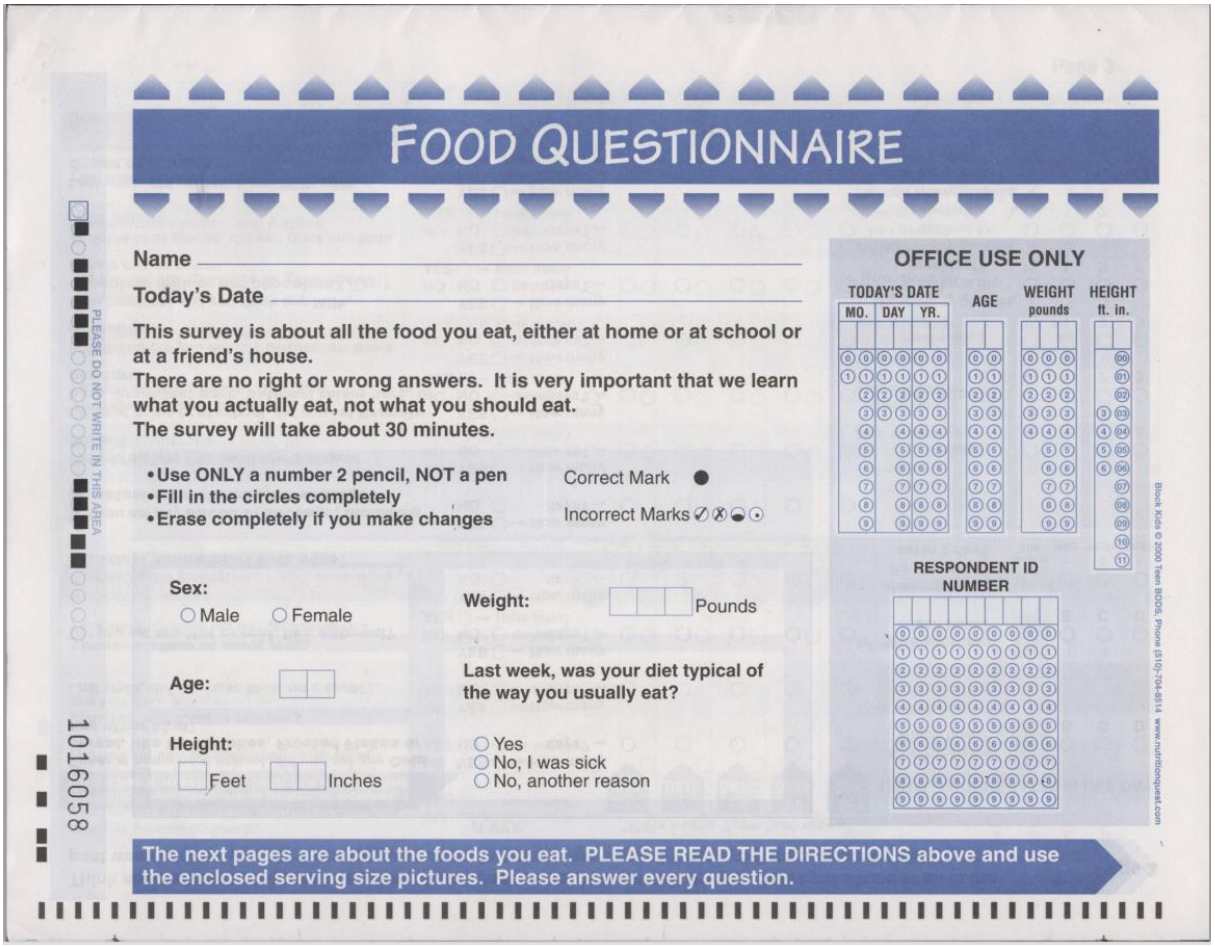
Presumed cariogenicity category of foods	Specific item description	Question Number	Page number
Foods With Low Presumed Cariogenicity Predominant In Protein And Fat Content	Eggs including breakfast sandwiches with eggs	4	2
	Bacon and sausage including breakfast sandwiches with bacon or sausage	5	2
	Beef steak roast beef or beef in frozen dinners	22	3
	Pork chops or BBQ ribs	23	4
	Fried chicken or chicken nuggets	24	4
	Any other kind of chicken like chicken and gravy, chicken salad, or in frozen dinners	25	4
	Fish, like fish sandwich, fish sticks or any other kind of fish	26	4
	Lunch meat like bologna or sliced ham, either on sandwich or by itself	32	4
	Margarine or butter use on pancakes and waffles	39	5
	Peanut or other nuts or seeds	42	5
	Salad dressing on salad	44	5
Foods With Low Presumed Cariogenicity Predominant In Fiber And Low Natural Sugar Content	Green salad	43	5

	Green beans, string beans	44	5
	Baked beans, chili beans, or any kind of beans	46	5
	Corn or corn on the cob	47	5
	Tomatoes (excluding tomato sauce)	48	6
	Greens including spinach, mustard greens or collards	49	6
	Broccoli	50	6
	Coleslaw or cabbage	51	6
	Carrots either raw or cooked	52	6
	Other vegetables like peas, squash or peppers	56	6
Foods With Moderate Presumed Cariogenicity Predominant In Natural Sugars Content	Bananas	13	3
	Apples or pears	14	3
	Oranges or tangerines	15	3
	Canned fruit like applesauce, fruit cocktail	17	3
	Other fruit, like grapes, fresh peaches or melon	18	3
Foods With Moderate Presumed Cariogenicity Predominant In Starch And Protein Content.	Hamburgers, cheeseburgers or meat loaf	19	3
	Tacos or burritos with meat or chicken	20	3
	Sandwiches with beef, like hot pockets, or meat ball subs	21	3
	Beef and noodles, pot pie, Hamburger Helper, stew	27	4
	Other soup like Chicken noodle or a cup a soup (not vegetable,	35	4

	veg beef, or tomato soup)		
	Hot dogs or corn dogs	31	4
	Peanut butter sandwich	41	5
	Nachos with cheese	62	7
	Sliced cheese, Cheese Whiz or grilled cheese sandwiches	40	5
	Macaroni and Cheese	29	4
	Refried beans or bean Burritos	33	4
	Vegetable soup, vegetable beef soup or tomato soup excluding other soup like chicken noodles and cup a cup soup.	34	4
	Pizza and pizza pockets	30	4
Foods With Moderate Presumed Cariogenicity Based On Starch Content	Hamburger buns or hotdog buns, or bagels either alone or as a sandwich	36	5
	Bread or toast including sandwiches	37	5
	Tortillas	38	5
	French fries, fried potatoes or Tater Tots	54	6
	Any other kind of potatoes like Baked , boiled or mashed potatoes	55	6
	Rice	57	6
	Gravy on mashed potatoes or on rice	58	6
	Spaghetti, ravioli or lasagna with tomato sauce	28	4
Foods With High Presumed Cariogenicity	Cold cereal, like corn flakes, frosted flakes, or any other kind	1	2

Predominant In Both Sugar And Starch	of flakes		
	Hot cereal like oatmeal	3	2
	Granola Bars, breakfast bars, oatmeal raisin bars, or pop tarts	7	2
	Cinnamon buns or muffins	8	2
	Pancakes, Waffles or French toast (including sugar syrup)	6	2
	Potato chips, corn chips or popcorn	60	7
	Crackers, Snack crackers like goldfish	61	7
	Sweet potato or sweet potato pie	53	6
	Ice-cream, ice-cream bars, or frozen yogurt	63	6
	Cookies	64	7
	Doughnuts	65	7
	Cake, Cup-Cakes, Tasty cake, Ho-Ho's, Twinkies, etc.	66	7
	Pie or turnovers	67	7
Foods With High Presumed Cariogenicity Predominant In Sugar Content	Pudding	68	7
	Chocolate candy, like candy bars, Hugs, M&Ms	69	7
	Other candy like Gummy bears, Starburst, Skittles	70	7
	Ketchup, salsa or barbeque sauce	59	6
	Raisins, fruit roll ups or dried fruit	16	3

APPENDIX H: BLOCK KIDS FOOD FREQUENCY QUESTIONNAIRE



Page 3

FOOD QUESTIONNAIRE

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1016058

Name ______________________________

Today's Date __________________________

This survey is about all the food you eat, either at home or at school or at a friend's house.
There are no right or wrong answers. It is very important that we learn what you actually eat, not what you should eat.
The survey will take about 30 minutes.

- **Use ONLY a number 2 pencil, NOT a pen**
- **Fill in the circles completely**
- **Erase completely if you make changes**

Correct Mark ●

Incorrect Marks ⊘ ⊗ ◒ ⊙

Sex:
○ Male ○ Female

Age: ☐☐

Height:
☐ Feet ☐☐ Inches

Weight: ☐☐☐ Pounds

Last week, was your diet typical of the way you usually eat?
○ Yes
○ No, I was sick
○ No, another reason

OFFICE USE ONLY

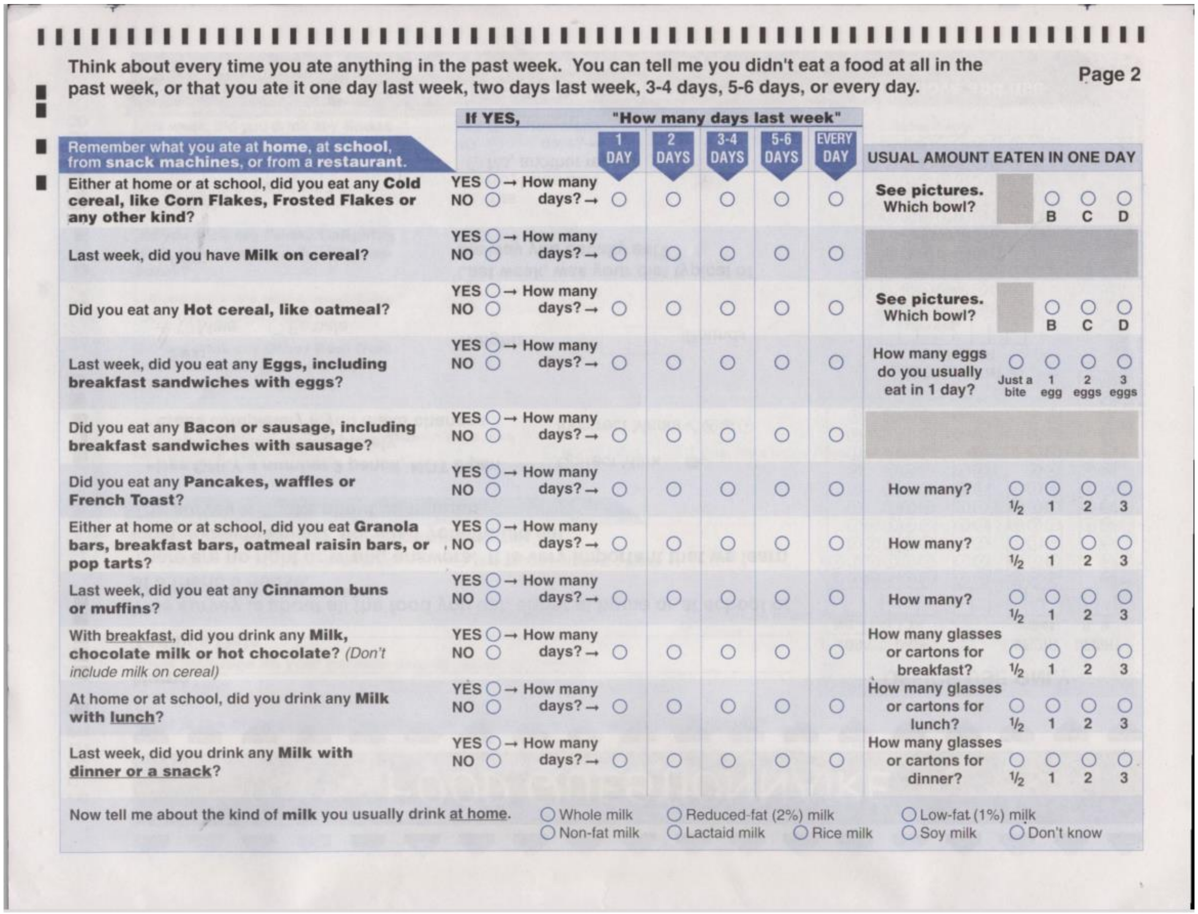
TODAY'S DATE MO.		DAY		YR.		AGE		WEIGHT pounds			HEIGHT ft.	in.
0	0	0	0	0	0	0	0	0	0	0		00
1	1	1	1	1	1	1	1	1	1	1		01
	2	2	2	2	2	2	2	2	2	2		02
	3	3	3	3	3	3	3	3	3	3	3	03
	4		4	4	4	4	4	4	4	4	4	04
	5		5	5	5	5	5		5	5	5	05
	6		6	6	6	6	6		6	6	6	06
	7		7	7	7	7	7		7	7		07
	8		8	8	8	8	8		8	8		08
	9		9	9	9	9	9		9	9		09
												10
												11

RESPONDENT ID NUMBER

0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9

Block Kids © 2000 Teen BODS, Phone (510)-704-8514 www.nutritionquest.com

The next pages are about the foods you eat. PLEASE READ THE DIRECTIONS above and use the enclosed serving size pictures. Please answer every question.

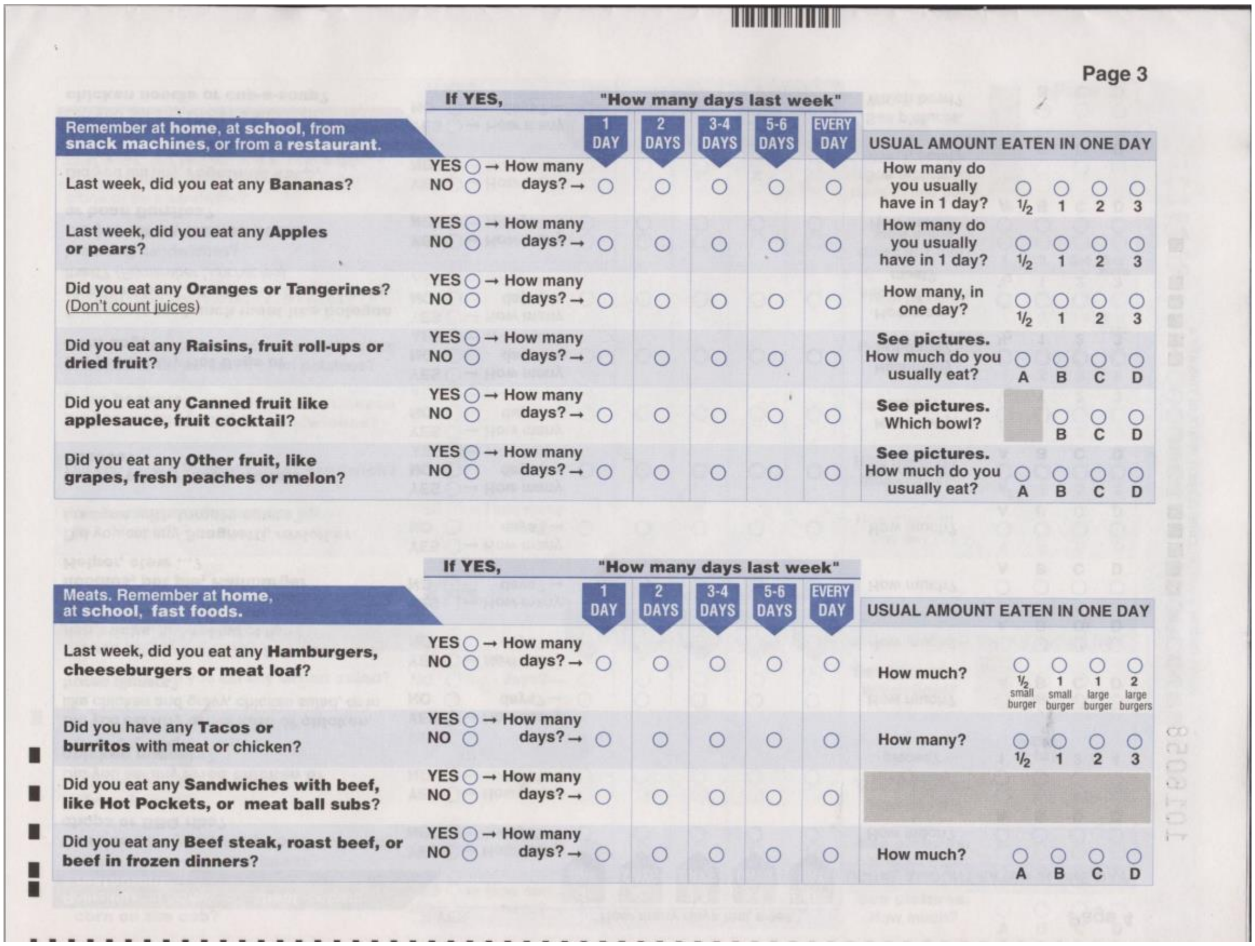


Think about every time you ate anything in the past week. You can tell me you didn't eat a food at all in the past week, or that you ate it one day last week, two days last week, 3-4 days, 5-6 days, or every day.

Page 2

	If YES,	**"How many days last week"**									
Remember what you ate at **home**, at **school**, from **snack machines**, or from a **restaurant**.		1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY	**USUAL AMOUNT EATEN IN ONE DAY**				
Either at home or at school, did you eat any **Cold cereal, like Corn Flakes, Frosted Flakes or any other kind**?	YES ○ → How many days? → NO ○	○	○	○	○	○	**See pictures.** Which bowl?		○ B	○ C	○ D
Last week, did you have **Milk on cereal**?	YES ○ → How many days? → NO ○	○	○	○	○	○					
Did you eat any **Hot cereal, like oatmeal**?	YES ○ → How many days? → NO ○	○	○	○	○	○	**See pictures.** Which bowl?		○ B	○ C	○ D
Last week, did you eat any **Eggs, including breakfast sandwiches with eggs**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many eggs do you usually eat in 1 day?	○ Just a bite	○ 1 egg	○ 2 eggs	○ 3 eggs
Did you eat any **Bacon or sausage, including breakfast sandwiches with sausage**?	YES ○ → How many days? → NO ○	○	○	○	○	○					
Did you eat any **Pancakes, waffles or French Toast**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many?	○ ½	○ 1	○ 2	○ 3
Either at home or at school, did you eat **Granola bars, breakfast bars, oatmeal raisin bars, or pop tarts**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many?	○ ½	○ 1	○ 2	○ 3
Last week, did you eat any **Cinnamon buns or muffins**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many?	○ ½	○ 1	○ 2	○ 3
With breakfast, did you drink any **Milk, chocolate milk or hot chocolate**? *(Don't include milk on cereal)*	YES ○ → How many days? → NO ○	○	○	○	○	○	How many glasses or cartons for breakfast?	○ ½	○ 1	○ 2	○ 3
At home or at school, did you drink any **Milk with lunch**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many glasses or cartons for lunch?	○ ½	○ 1	○ 2	○ 3
Last week, did you drink any **Milk with dinner or a snack**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many glasses or cartons for dinner?	○ ½	○ 1	○ 2	○ 3

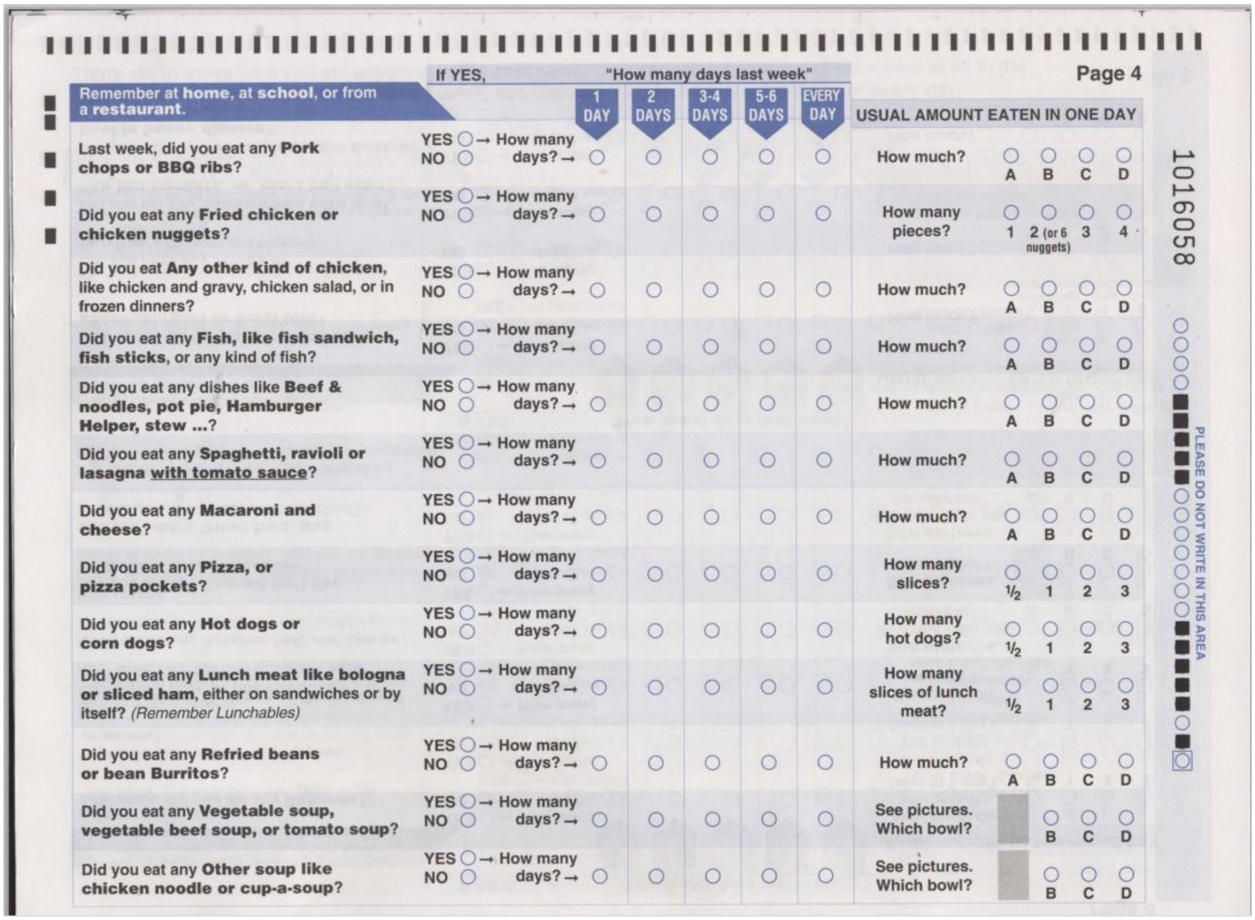
Now tell me about the kind of **milk** you usually drink at home.
○ Whole milk ○ Reduced-fat (2%) milk ○ Low-fat (1%) milk
○ Non-fat milk ○ Lactaid milk ○ Rice milk ○ Soy milk ○ Don't know



Page 3

Remember at home, at school, from snack machines, or from a restaurant.	**If YES,**	**"How many days last week"**					**USUAL AMOUNT EATEN IN ONE DAY**				
		1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY					
Last week, did you eat any **Bananas**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	How many do you usually have in 1 day?	○ ½	○ 1	○ 2	○ 3
Last week, did you eat any **Apples or pears**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	How many do you usually have in 1 day?	○ ½	○ 1	○ 2	○ 3
Did you eat any **Oranges or Tangerines**? (Don't count juices)	YES ○ → How many NO ○ days? →	○	○	○	○	○	How many, in one day?	○ ½	○ 1	○ 2	○ 3
Did you eat any **Raisins, fruit roll-ups or dried fruit**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much do you usually eat?	○ A	○ B	○ C	○ D
Did you eat any **Canned fruit like applesauce, fruit cocktail**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** Which bowl?		○ B	○ C	○ D
Did you eat any **Other fruit, like grapes, fresh peaches or melon**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much do you usually eat?	○ A	○ B	○ C	○ D

Meats. Remember at home, at school, fast foods.	**If YES,**	**"How many days last week"**					**USUAL AMOUNT EATEN IN ONE DAY**				
		1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY					
Last week, did you eat any **Hamburgers, cheeseburgers or meat loaf**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	How much?	○ ½ small burger	○ 1 small burger	○ 1 large burger	○ 2 large burgers
Did you have any **Tacos or burritos** with meat or chicken?	YES ○ → How many NO ○ days? →	○	○	○	○	○	How many?	○ ½	○ 1	○ 2	○ 3
Did you eat any **Sandwiches with beef, like Hot Pockets, or meat ball subs**?	YES ○ → How many NO ○ days? →	○	○	○	○	○					
Did you eat any **Beef steak, roast beef, or beef in frozen dinners**?	YES ○ → How many NO ○ days? →	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D



Page 4

Remember at **home**, at **school**, or from a **restaurant**.	If YES,	"How many days last week"					USUAL AMOUNT EATEN IN ONE DAY				
		1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY					
Last week, did you eat any **Pork chops or BBQ ribs**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any **Fried chicken or chicken nuggets**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How many pieces?	○ 1	○ 2 (or 6 nuggets)	○ 3	○ 4
Did you eat **Any other kind of chicken,** like chicken and gravy, chicken salad, or in frozen dinners?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any **Fish, like fish sandwich, fish sticks**, or any kind of fish?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any dishes like **Beef & noodles, pot pie, Hamburger Helper, stew ...**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any **Spaghetti, ravioli or lasagna** with tomato sauce?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any **Macaroni and cheese**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any **Pizza, or pizza pockets**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How many slices?	○ ½	○ 1	○ 2	○ 3
Did you eat any **Hot dogs or corn dogs**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How many hot dogs?	○ ½	○ 1	○ 2	○ 3
Did you eat any **Lunch meat like bologna or sliced ham**, either on sandwiches or by itself? *(Remember Lunchables)*	YES ○→ How many NO ○ days?→	○	○	○	○	○	How many slices of lunch meat?	○ ½	○ 1	○ 2	○ 3
Did you eat any **Refried beans or bean Burritos**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you eat any **Vegetable soup, vegetable beef soup, or tomato soup**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	See pictures. Which bowl?	▨	○ B	○ C	○ D
Did you eat any **Other soup like chicken noodle or cup-a-soup**?	YES ○→ How many NO ○ days?→	○	○	○	○	○	See pictures. Which bowl?	▨	○ B	○ C	○ D

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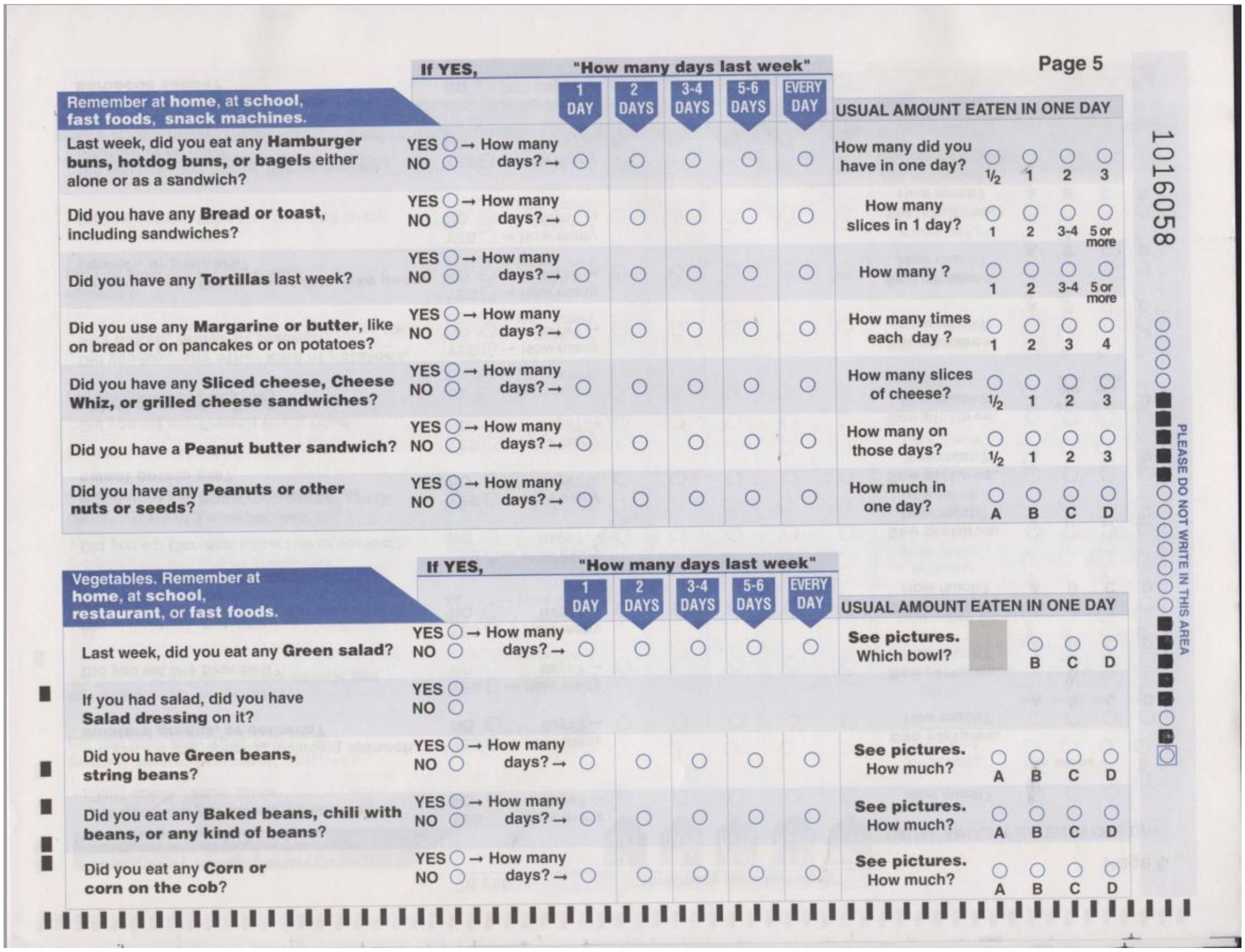

Page 5

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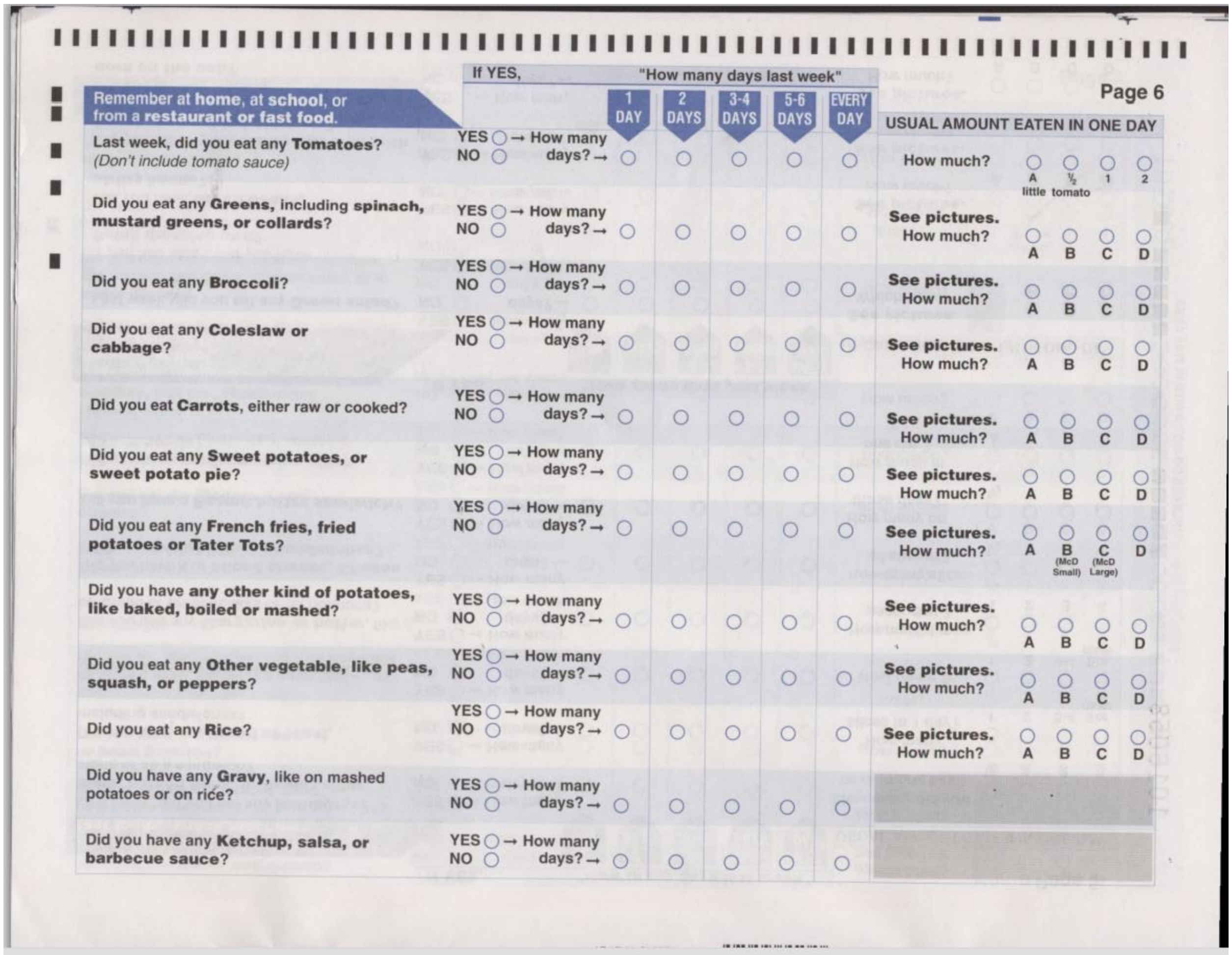
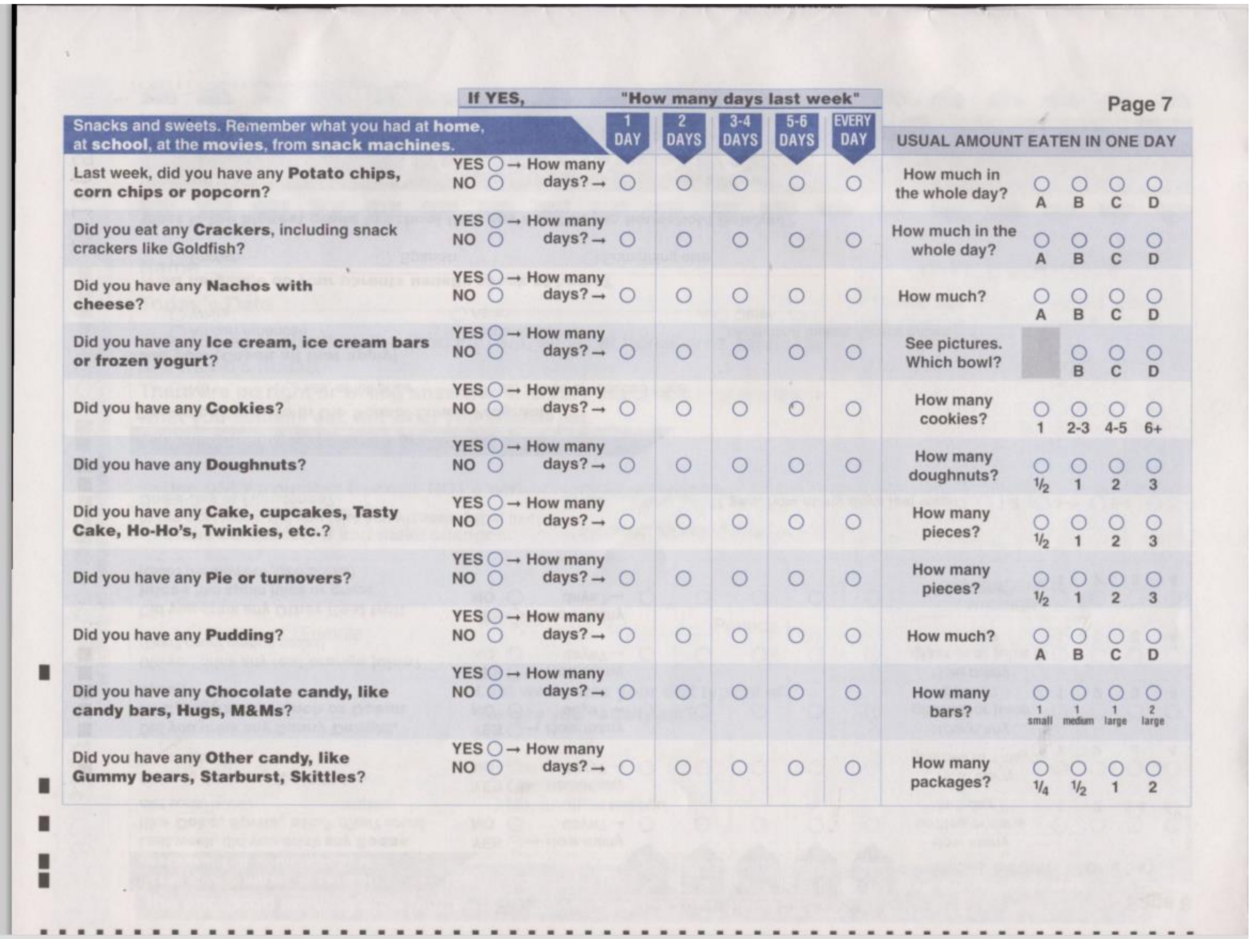
Remember at **home**, at **school**, **fast foods**, **snack machines**.	**If YES,**	"How many days last week" 1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY	USUAL AMOUNT EATEN IN ONE DAY				
Last week, did you eat any **Hamburger buns, hotdog buns, or bagels** either alone or as a sandwich?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many did you have in one day?	○ ½	○ 1	○ 2	○ 3
Did you have any **Bread or toast**, including sandwiches?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many slices in 1 day?	○ 1	○ 2	○ 3-4	○ 5 or more
Did you have any **Tortillas** last week?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many ?	○ 1	○ 2	○ 3-4	○ 5 or more
Did you use any **Margarine or butter**, like on bread or on pancakes or on potatoes?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many times each day ?	○ 1	○ 2	○ 3	○ 4
Did you have any **Sliced cheese, Cheese Whiz, or grilled cheese sandwiches?**	YES ○ → How many days? → NO ○	○	○	○	○	○	How many slices of cheese?	○ ½	○ 1	○ 2	○ 3
Did you have a **Peanut butter sandwich?**	YES ○ → How many days? → NO ○	○	○	○	○	○	How many on those days?	○ ½	○ 1	○ 2	○ 3
Did you have any **Peanuts or other nuts or seeds?**	YES ○ → How many days? → NO ○	○	○	○	○	○	How much in one day?	○ A	○ B	○ C	○ D

Vegetables. Remember at **home**, at **school**, **restaurant**, or **fast foods**.	**If YES,**	"How many days last week" 1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY	USUAL AMOUNT EATEN IN ONE DAY				
Last week, did you eat any **Green salad?**	YES ○ → How many days? → NO ○	○	○	○	○	○	**See pictures.** Which bowl?	▨	○ B	○ C	○ D
If you had salad, did you have **Salad dressing** on it?	YES ○ NO ○										
Did you have **Green beans, string beans?**	YES ○ → How many days? → NO ○	○	○	○	○	○	**See pictures.** How much?	○ A	○ B	○ C	○ D
Did you eat any **Baked beans, chili with beans, or any kind of beans?**	YES ○ → How many days? → NO ○	○	○	○	○	○	**See pictures.** How much?	○ A	○ B	○ C	○ D
Did you eat any **Corn or corn on the cob?**	YES ○ → How many days? → NO ○	○	○	○	○	○	**See pictures.** How much?	○ A	○ B	○ C	○ D



Page 6

Remember at **home**, at **school**, or from a **restaurant or fast food.**	If YES,	"How many days last week" 1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY	USUAL AMOUNT EATEN IN ONE DAY
Last week, did you eat any **Tomatoes?** *(Don't include tomato sauce)*	YES ○ → How many NO ○ days? →	○	○	○	○	○	How much? ○ A little ○ ½ tomato ○ 1 ○ 2
Did you eat any **Greens, including spinach, mustard greens, or collards?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat any **Broccoli?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat any **Coleslaw or cabbage?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat **Carrots**, either raw or cooked?	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat any **Sweet potatoes, or sweet potato pie?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat any **French fries, fried potatoes or Tater Tots?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B (McD Small) ○ C (McD Large) ○ D
Did you have **any other kind of potatoes, like baked, boiled or mashed?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat any **Other vegetable, like peas, squash, or peppers?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you eat any **Rice?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	**See pictures.** How much? ○ A ○ B ○ C ○ D
Did you have any **Gravy**, like on mashed potatoes or on rice?	YES ○ → How many NO ○ days? →	○	○	○	○	○	
Did you have any **Ketchup, salsa, or barbecue sauce?**	YES ○ → How many NO ○ days? →	○	○	○	○	○	



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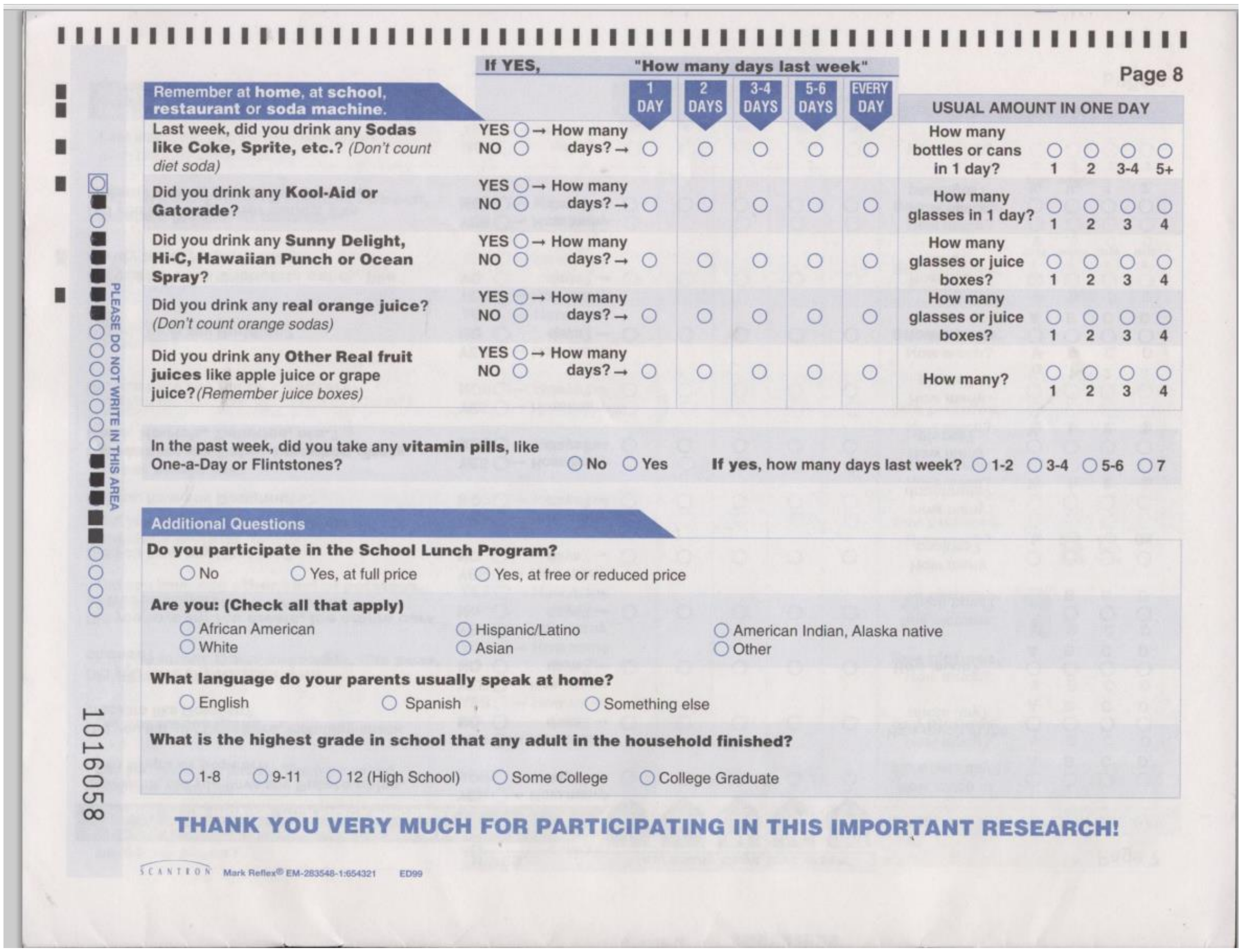
	If YES,	"How many days last week"									
Snacks and sweets. Remember what you had at **home**, at **school**, at the **movies**, from **snack machines**.		1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY	USUAL AMOUNT EATEN IN ONE DAY				
Last week, did you have any **Potato chips, corn chips or popcorn**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How much in the whole day?	○ A	○ B	○ C	○ D
Did you eat any **Crackers**, including snack crackers like Goldfish?	YES ○ → How many days? → NO ○	○	○	○	○	○	How much in the whole day?	○ A	○ B	○ C	○ D
Did you have any **Nachos with cheese**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you have any **Ice cream, ice cream bars or frozen yogurt**?	YES ○ → How many days? → NO ○	○	○	○	○	○	See pictures. Which bowl?	▨	○ B	○ C	○ D
Did you have any **Cookies**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many cookies?	○ 1	○ 2-3	○ 4-5	○ 6+
Did you have any **Doughnuts**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many doughnuts?	○ ½	○ 1	○ 2	○ 3
Did you have any **Cake, cupcakes, Tasty Cake, Ho-Ho's, Twinkies, etc.**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many pieces?	○ ½	○ 1	○ 2	○ 3
Did you have any **Pie or turnovers**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many pieces?	○ ½	○ 1	○ 2	○ 3
Did you have any **Pudding**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How much?	○ A	○ B	○ C	○ D
Did you have any **Chocolate candy, like candy bars, Hugs, M&Ms**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many bars?	○ 1 small	○ 1 medium	○ 1 large	○ 2 large
Did you have any **Other candy, like Gummy bears, Starburst, Skittles**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many packages?	○ ¼	○ ½	○ 1	○ 2



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PLEASE DO NOT WRITE IN THIS AREA

1016058

	If YES,	"How many days last week"						
Remember at **home**, at **school**, **restaurant** or **soda machine**.		1 DAY	2 DAYS	3-4 DAYS	5-6 DAYS	EVERY DAY	USUAL AMOUNT IN ONE DAY	
Last week, did you drink any **Sodas like Coke, Sprite, etc.**? *(Don't count diet soda)*	YES ○ → How many days? → NO ○	○	○	○	○	○	How many bottles or cans in 1 day?	○ 1 ○ 2 ○ 3-4 ○ 5+
Did you drink any **Kool-Aid or Gatorade**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many glasses in 1 day?	○ 1 ○ 2 ○ 3 ○ 4
Did you drink any **Sunny Delight, Hi-C, Hawaiian Punch or Ocean Spray**?	YES ○ → How many days? → NO ○	○	○	○	○	○	How many glasses or juice boxes?	○ 1 ○ 2 ○ 3 ○ 4
Did you drink any **real orange juice**? *(Don't count orange sodas)*	YES ○ → How many days? → NO ○	○	○	○	○	○	How many glasses or juice boxes?	○ 1 ○ 2 ○ 3 ○ 4
Did you drink any **Other Real fruit juices** like apple juice or grape juice? *(Remember juice boxes)*	YES ○ → How many days? → NO ○	○	○	○	○	○	How many?	○ 1 ○ 2 ○ 3 ○ 4

In the past week, did you take any **vitamin pills**, like One-a-Day or Flintstones? ○ No ○ Yes **If yes,** how many days last week? ○ 1-2 ○ 3-4 ○ 5-6 ○ 7

Additional Questions

Do you participate in the School Lunch Program?

○ No ○ Yes, at full price ○ Yes, at free or reduced price

Are you: (Check all that apply)

○ African American ○ Hispanic/Latino ○ American Indian, Alaska native
○ White ○ Asian ○ Other

What language do your parents usually speak at home?

○ English ○ Spanish ○ Something else

What is the highest grade in school that any adult in the household finished?

○ 1-8 ○ 9-11 ○ 12 (High School) ○ Some College ○ College Graduate

THANK YOU VERY MUCH FOR PARTICIPATING IN THIS IMPORTANT RESEARCH!

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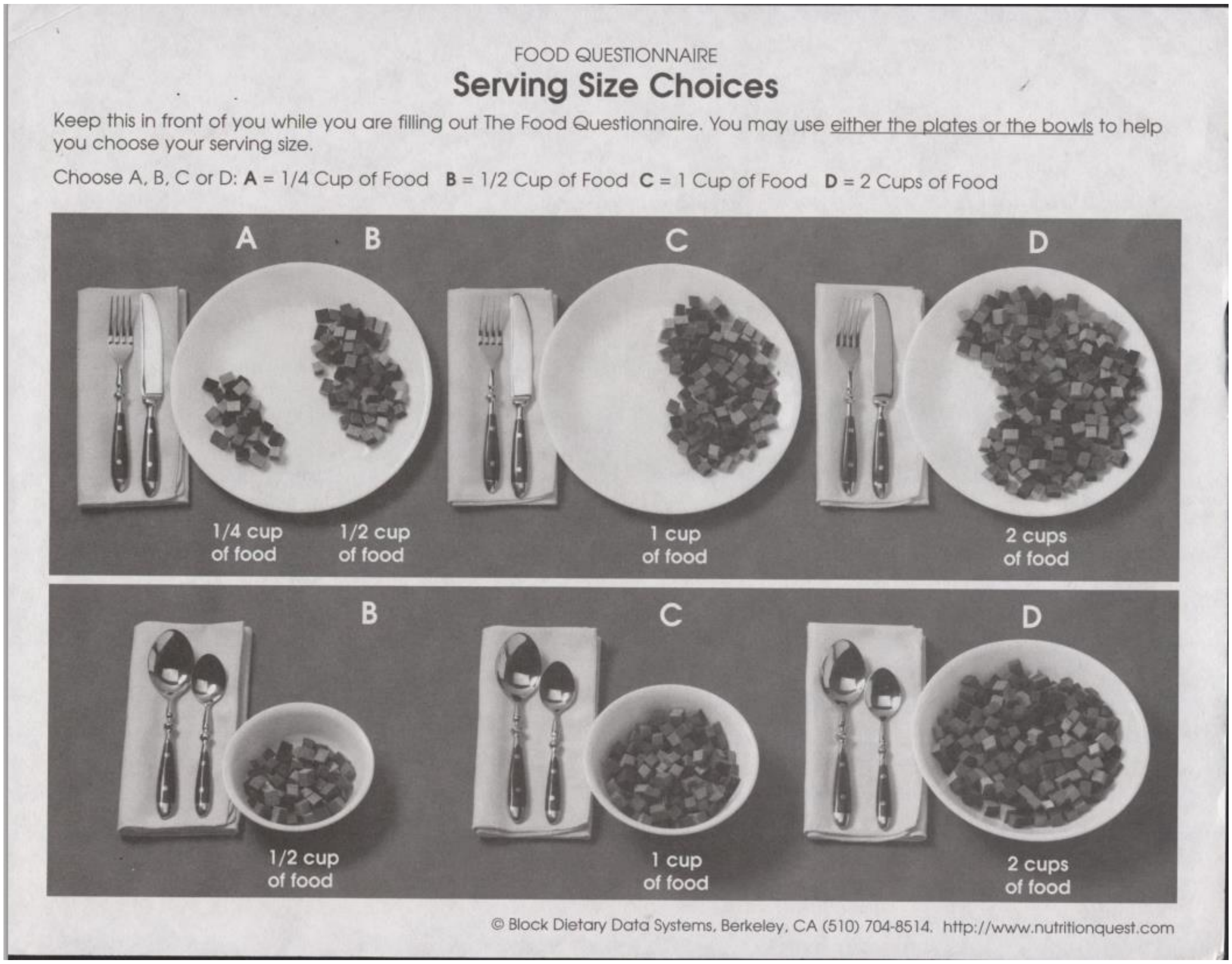


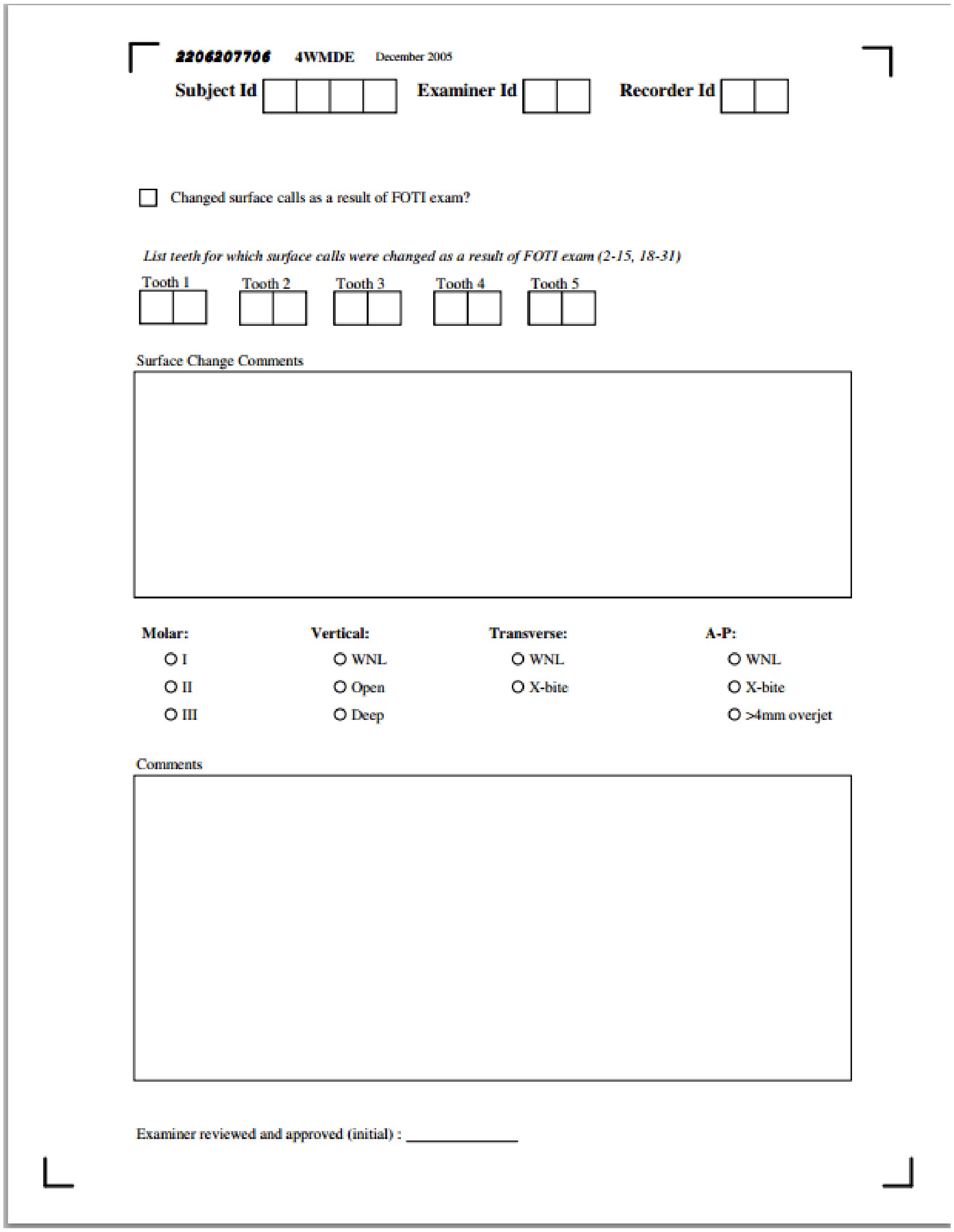
FOOD QUESTIONNAIRE

Serving Size Choices

Keep this in front of you while you are filling out The Food Questionnaire. You may use either the plates or the bowls to help you choose your serving size.

Choose A, B, C or D: **A** = 1/4 Cup of Food **B** = 1/2 Cup of Food **C** = 1 Cup of Food **D** = 2 Cups of Food

APPENDIX I: IFS PERMANENT DENTITION EXAM FORM



2206207706 4WMDE December 2005

Subject Id ☐☐☐☐ **Examiner Id** ☐☐ **Recorder Id** ☐☐

☐ Changed surface calls as a result of FOTI exam?

List teeth for which surface calls were changed as a result of FOTI exam (2-15, 18-31)

Tooth 1 ☐☐ Tooth 2 ☐☐ Tooth 3 ☐☐ Tooth 4 ☐☐ Tooth 5 ☐☐

Surface Change Comments

Molar:	**Vertical:**	**Transverse:**	**A-P:**
○ I	○ WNL	○ WNL	○ WNL
○ II	○ Open	○ X-bite	○ X-bite
○ III	○ Deep		○ >4mm overjet

Comments

Examiner reviewed and approved (initial) : ______________

APPENDIX J: MEASURE OF ASSOCIATION

Odds Ratio

The odds ratio is the preferred measure of association in logistic regression. Modeling the log (odds of having cavitated caries)

$$log\left(\frac{P}{1-P}\right) = \beta_0 + \ \beta_1 x_1 + \ \beta_2 x_2 + \cdots \beta_p x_p$$

Where, P is the probability of disease. Let's say the interest is to estimate the odds (and in turn the odds ratio) of exposed and non-exposed having disease. Let $x_1 = 1\ if\ exposed$ and $x_1 = 0\ if\ non - exposed.$

$$log\left(OR_{Exposed\ vs.\ Non-exposed}\right) = log\left(\frac{\frac{P}{1-P}|x_1 = 1}{\frac{P}{1-P}|x_1 = 0}\right)$$
$$= log\left(\frac{P}{1-P}|x_1 = 1\right) - log\left(\frac{P}{1-P}|x_1 = 0\right)$$
$$= \left(\beta_0 + \ \beta_1 * 1 + \ \beta_2 x_2 + \cdots \beta_p x_p\right)$$
$$-\left(\beta_0 + \ \beta_1 * 0 + \ \beta_2 x_2 + \cdots \beta_p x_p\right)$$
$$= \beta_1$$

Exponentiating both sides,

$$OR_{Exposed\ vs.\ Non-exposed} = exp(\beta_1)$$

So, this is the OR of the exposed group having disease versus the non-exposed group having disease.

For example,

The odds ratio is the preferred measure of association for comparing the odds of having cavitated caries incidence among females vs. the odds of having cavitated caries among males. Thus, modeling the log of having cavitated caries incidence

$$log\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p$$

Where, P is the probability of having cavitated caries incidence. Let's say the interest is to estimate the odds (and in turn the odds ratio) of males and females having cavitated caries. Let $x_1 = 1\ if\ female$ and $x_1 = 0\ if\ male$.

$$\begin{aligned}
log(OR_{Females\ vs.Males}) &= log\left(\frac{\frac{P}{1-P}|x_1 = 1}{\frac{P}{1-P}|x_1 = 0}\right) \\
&= log\left(\frac{P}{1-P}|x_1 = 1\right) - log\left(\frac{P}{1-P}|x_1 = 0\right) \\
&= \left(\beta_0 + \beta_1 * 1 + \beta_2 x_2 + \cdots \beta_p x_p\right) - \left(\beta_0 + \beta_1 * 0 + \beta_2 x_2 + \cdots \beta_p x_p\right) \\
&= \beta_1
\end{aligned}$$

Exponentiating both sides,

$$OR_{Females\ vs.Males} = exp(\beta_1)$$

So this is the OR for females having cavitated caries versus males having cavitated caries.

Incidence rate ratio

The incidence rate ratio is the preferred measure to assess the strength of association between incidence rate of net cavitated caries increment count and independent variables in the negative binomial regression model. In calculating the incidence rate ratio, the main focus is to calculate the incidence rate of disease among the exposed vs. the incidence rate of disease among the non-exposed. This can be done by using the beta estimates derived from the negative binomial regression using the log link function which follows a rule similar to the estimation of the odds ratio from beta estimates in logistic regression. This is so because the logistic regression considers the Bernoulli distribution, while for the count data, the negative binomial distribution is considered. Both the distributions comply with different assumptions and link functions, hence the different measures of association.

In negative binomial regression, the mean or the rate parameter $\lambda(x)$ of the response variable is modeled, assuming that it has a negative binomial distribution. The rate parameter is a function of x because it depends on the value of x. In the analysis, this rate parameter $\lambda(x)$ is equivalent to the incidence rate of cavitated caries. So the model is

$$log(\lambda(x)) = \tilde{\beta}_0 + \tilde{\beta}_1 x_1 + \tilde{\beta}_2 x_2 + \cdots \tilde{\beta}_p x_p$$

Then,

$$\begin{aligned} &log(IRR_{Exposed\ vs.\ Unexpsoed}) = log\left(\frac{\lambda(x_1 = 1)}{\lambda(x_1 = 0)}\right) \\ &= log(\lambda(x_1 = 1)) - log(\lambda(x_1 = 0)) \\ &= (\tilde{\beta}_0 + \tilde{\beta}_1 x_1 + \tilde{\beta}_2 x_2 + \cdots \tilde{\beta}_p x_p) - (\tilde{\beta}_0 + \tilde{\beta}_1 x_1 + \tilde{\beta}_2 x_2 + \cdots \tilde{\beta}_p x_p x_p) \\ &= \tilde{\beta}_1 \end{aligned}$$

Exponentiating both sides,

$$(IRR_{Exposed\ vs.Unexpsoed}) = exp(\tilde{\beta}_1)$$

So this is the incidence rate ratio of counts of cavitated caries in exposed versus disease in non-exposed.

Example:

Suppose the independent variable under consideration is sex which was dichotomized into two categories such as male $(\mathrm{x}_1 = 0)$ and female$(\mathrm{x}_1 = 1)$. In the given case, the rate parameter would again be the incidence rate of having cavitated caries increment counts among females versus the incidence rate of having cavitated caries counts among males, which would be expressed as $\frac{\lambda(\mathrm{x}_1=1)}{\lambda(\mathrm{x}_1=0)}$. This ratio would represent the log of the incidence rate ratio.

Log $(\mathrm{IRR}\ _{\text{Females vs.males}})$ = log [Incidence rate of having cavitated caries among females/ incidence rate of having cavitated caries among males.]

Suppose that the value of $\tilde{\beta}_1$ = 0.81

$(\mathrm{IRR}_{\text{Females vs.males}})$ = exp (0.81)

Thus, the IRR= 2.25

$(\mathrm{IRR}_{\text{Females vs.males}})$ = (2.25)

This can be interpreted as the incidence rate for females is 2.25 times the incidence rate for males when all other variables in the model are held constant.

APPENDIX K: BIVARIATE APPROACHES

For binary outcome data:

The SAS (9.3) procedure used in the given analyses for logistic regression models for dichotomous outcomes was GENMOD, which is a procedure for Generalized Linear Models. In addition, the DESCENDING command was used for binomial models for binary outcome data. This modeled the probability that net cavitated caries incidence was equal to ‘1’ and not ‘0’. The CLASS command was used when variables were dichotomous and categorical. The AGGREGATE option was used to calculate pearson chi-square statistics and deviations. Odds ratios were used for determining odds of disease vs. no disease using logistic regression analyses. The algorithms used for the logistic regression model were the Newton Raphson and the Alternating Logistic Regression algorithms. Using these algorithms enhances the maximum likelihood function L (y, μ, ϕ) for the regression parameters. It is assumed, that the data have a binomial distribution for the dependent variable of caries incidence (dichotomous outcome) (The GENMOD procedure, SAS knowledge Base retrieved from http://support.sas.com/documentation/cdl/en/statug/63962/HTML/default/viewer.htm#statug_genmod_sect037.htm)

In order to get the best fit for the model, on the rth iteration, the algorithm updates the parameter vector β_r with

$$\beta_{r+1} = \beta_r - H^{-1} s$$

Both s and H are evaluated at the current likelihood of parameter vector s = $\left[s_j\right] = \left[\frac{\partial L}{\partial \beta_j}\right]$ is the gradient (first derivative) vector of the log-likelihood function

H = $\left[h_{ij}\right] = \left[\frac{\partial^2 L}{\partial \beta_i \partial \beta_j}\right]$ Hessian (second derivative matrix)

For count outcome data:

The algorithms for negative binomial modeling were the Newton–Raphson algorithm and the Estimation Maximization Algorithm. The Generalized Linear Model approach was preferred in this case, as the modelling technique brings in more flexibility, especially for count data that are not normally distributed. It is also observed generally that the log link can be used with the binomial, Poisson and negative binomial distributions. As summarized earlier, the negative binomial model was considered as an appropriate distribution; other possible distributions that were considered for the analysis of count data were the zero inflated negative binomial and zero inflated Poisson. Furthermore, the link function considered in the given analysis is the log link function. By considering the log link function, the aim was to maximize and test the association between the dependent and independent variables using an exponential function. This has been explained mathematically in the equation (McCullagh and Nelder, 1998):

$$\text{Log } \mu_{i\,=}\, \eta_{i\,=}\, \beta^T x_i \qquad \text{(where i = 1, 2, …..n)}$$

The log link function also enables to determine the relative risk ratios. It should be understood that relative risk ratios are ratios between incidence of disease in the exposed vs. incidence of disease in the non-exposed. The incidence rate ratio is a preferred method to determine the rate of net cavitated caries incidence on a surface level among a population with a specific exposure and a population without the same exposure. Hence, in order to determine and observe the surface level rate of net cavitated caries increment among the IFS subjects with exposure to factors vs. those without exposure to factors, the incidence rate ratio has been used. Using the log link function, this can be derived by the proc GENMOD (SAS 9.3) procedures, a common procedure used for log linear models. The log of the interval variable was created to use “interval” as an offset variable. The CLASS command was used for categorical independent variables.

APPENDIX L: INTERACTION IN MULTIVARIABLE MODELLING

The logistic regression and negative binomial regression models are types of generalized linear models. A generalized linear model consists of components such as a random component a linear predictor. A mean function of the linear predictor is used to transform the response variable on a linear scale. A mean function of the linear predictor can be shown by the following equation:

$$g_{(\mu i)} = \eta_i = \alpha + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik}$$

For negative binomial and logistic regression models, the link functions are log and logit, respectively. When the log link function is used, the equation $g_{(ui)}$ can be given as $\log_e \mu_i$, whereas for the logit link function it is $\log_e \mu_i / 1 - \mu_i$.

It should be understood that, when the equation includes the coefficients for the main effects and interaction effects of the variables, along with the random error, it can be given as follows:

$$g_{(\mu i)} = \mu + \alpha_i + \beta_j + \gamma_{ij}$$

Interaction in Logistic Regression Modelling

In order to describe the interaction effect of A (e.g., sex) with B (e.g., presence of surface zones with sealants), the combined base effect of all independent variables in the model is first computed, excluding the variables sex and presence of surface zones with sealants and the interaction. The combined base effect is comprised of variables that are not part of the interaction term and does not include the main effects of the variables in the interaction term.

This can be done by considering the intercept, and the median values of the remaining independent variables multiplied by their respective regression coefficients. Suppose, the median value for a given variable C (e.g., daily brushing frequency (AUC) is 1.78 and the regression coefficient value is -0.7139. Then, the variable daily brushing frequency (AUC) would contribute a part to the combined base effect that can be calculated by using the regression coefficient multiplied by its median value, i.e., -0.7139*1.78= -1.2707. Suppose that the sum of the products of median values and regression coefficients of all covariates is 0.267.

If suppose, the interaction between sex and presence of sealants is considered, then the summation product of the combined base effect would exclude the main effects of presence of sealants and sex and the interaction effect of sex with presence of sealants. If, for instance, the final base value so derived is 0.267. Then, say for consideration of the two-way interaction effect of sex with presence of sealants, a two-by-two table (Table L-1) showing logit values for males with sealants, males without sealants, females with sealants and females without sealants can be created as follows.

Table L-1 Logit values for males with and without sealants and females with and without sealants

Sex	Presence of Sealants	
	No	Yes
Male	Value of the combined base effect =a (Combined base effect is the only consideration here as no sealants and males are both reference categories)	Total value of the combined base effect + regression coefficient for main effect of presence of sealants) =b
Female	Total value of the combined base effect + the estimate for main effect of being female=c	Total value of the combined base effect + the estimate for main effect of presence of sealants + the estimate for main effect of being female + the interaction term of female with presence of surface zones with sealants =d

In the next step, exponentiate the values obtained in each cell. Then, each of the cells would contain the respective values, i.e., exp (a), exp (b), exp(c) and exp(d) (Table L-2).

Table L-2 Exponentiated logit values for males with and without sealants and females with and without sealants

Sex	Presence of Sealants	
	No	Yes
Male	Exp(a)	Exp(b)
Female	Exp(c)	Exp(d)

Since logistic regression uses a logit link, each exponentiated value of a logit for a given cell is equal to the ratio of probability of the event in that cell to 1- probability of the event in that cell (P/1-P). This is because

L = In (P/1-P).

then,

Exp (L) = P/1-P.

By solving the algebra, the value of the probability of the event is as follows:

P= exp (L)/ (1+ Exp L)

Then, deriving probabilities for each logit value, i.e., a, b, c and d, the probabilities are as shown in Table L-3.

Table L-3 Probability of event net cavitated caries incidence among males with and without sealants and females with and without sealants

Sex	Presence of Sealants	
	No	Yes
Male	Probability of caries incidence among males without sealants = P_a	Probability of caries incidence among males with sealants = P_b
Female	Probability of caries incidence among females without sealants = P_c	Probability of caries incidence among females with sealants =P_d

Assuming that the probabilities of events considered in this interaction effect are

$P_a = 0.57$

$P_b = 0.59$

$P_c = 0.47$

$P_d = 0.81$

Measure of Association for Interaction

Although not typically presented, here is additional information about the interaction effects odds ratios. In order to derive the measure of association for the overall effect of variables B (presence of sealants) with A (sex), including the interaction effect (A+B), consider the net effect in each cell, and derive the logit, for which, first derive the value for the combined base effect. The combined base effect is comprised of variables that are statistically significant in the final model without the variables included in the interaction term and interaction term itself. The value of the combined base effect would be the sum of the products of the medians of the independent variable and their respective beta estimate for each covariate added to the intercept of the model. The combined base effect from other covariates would exclude the main effects of variables B (presence of sealants) and A (sex) and the interaction effect of sex with sealants (A + B). Once the combined base effect is derived, the net effect of each cell can be calculated as shown in Table L-4.

Table L-4 Net interaction effect for males with and without sealants and females with and without sealants

Sex	Presence of Sealants	
	No	Yes
Male	Numerical value of the combined base effect (Combined base effect is the only consideration made, as no sealants and males are both reference categories and the regression coefficient values will be zero) = a	Numerical value of the combined base effect + regression coefficient for main effect of presence of sealant = b
Female	Numerical value of the combined base effect + the estimate for main effect of being female = c	Numerical value of the combined base effect + the estimate for main effect of presence of sealants+ the estimate for main effect of being female+ the estimate for interaction effect for sealants and sex = d

Where the logits a, b, c, d can be used further to calculate the interaction effects and odds of caries incidence among males and females with presence or absence of sealants.

Suppose, that the values of a, b, c, and d, are 0.2671, 0.3755, (-0.1223) and 1.4243, respectively.

1. Odds of caries incidence among females with sealants/ odds of caries incidence among females without sealants can be derived as follows:

   = d-c

   = (1.4243)- (-0.1223)

   = 1.547

   Then, it is known that the odds of any event can be calculated by exponentiating the regression coefficient associated with that event (as described in the odds ratio interpretation part earlier).

   O.R. = Exp (1.547)

   O.R. = 4.70

2. Odds of caries incidence among males with sealants/ odds of caries incidence among males without sealants can be derived as follows:

   = b-a

   = (0.3755)-0.2671

   = 0.1084

   The odds of any event can be calculated by exponentiating the regression coefficient associated with that event (as described in the odds ratio interpretation part earlier).

O.R. = Exp (0.1084)

O.R. = 1.12

3. Odds of caries incidence among females with sealants vs. odds of caries incidence among males with sealants can be derived as follows:

   =d-b

   = 1.4243- 0.3755

   = 1.0488

   Then, the odds of any event can be calculated by exponentiating the regression coefficient associated with that event (as described in the odds ratio interpretation part earlier).

   O.R. = Exp. (1.0488)

   O.R. = 2.86

4. Odds of caries incidence among females without sealants vs. odds of caries incidence among males without sealants can be derived as follows:

   = c - a
   = (-0.1223)- 0.2671)

   = (-0.3894)

   Then, the odds of any event can be calculated by exponentiating the regression coefficient associated with that event (as described in the odds ratio interpretation part earlier).

   O.R. = Exp. (-0.3894))

   O.R. =0.68

   Thus, the derived odds ratios are as follows:

- Odds of caries incidence among females with sealants/ odds of caries incidence among females without sealants = 4.70
- Odds of caries incidence among males with sealants/ odds of caries incidence among males without sealants = 1.12
- Odds of caries incidence among females with sealants vs. odds of caries incidence among males with sealants = 2.86
- Odds of caries incidence among females without sealants vs. odds of caries incidence among males without sealants = 0.68

Interaction in Negative Binomial Regression Modelling

Although not typically presented here is additional information about the effects of interaction on the incidence rate ratio. In order to describe the interaction effect of variable A (baseline age) and variable B (caries incidence from 9 to 13), a combined base effect of all independent variables in the model, excluding variable A (baseline age), variable B (9-13 increment) and the interaction is first computed.

This can be done by considering the intercept and the median values of the remaining independent variables multiplied by their respective regression coefficients. Suppose, the median value for a given variable is 1.0 (greater than 50% of subjects had sealants) and the regression coefficient of the variable is 0.7817. Then, the dichotomous variable presence of sealants (Y/N) would contribute a part that can be calculated by using the coefficient times its median value, i.e., 0.7187*1.0= 0.7817 to the base model. Suppose that the sum of the products of median values and coefficients of all covariates is -5.587. It should be noted that this summation does not include the main effects of the variables considered in the interaction term and the interaction term itself.

If suppose, the interaction between variable A (baseline age) and variable B (caries incidence from 9 to 13) is considered, then the combined base effect would exclude the main effects of variable A (baseline age) and variable B (caries incidence from 9 to 13) and the interaction effect between variable A (baseline age) and variable B (caries incidence from 9 to 13). If, for instance, the final combined base effect so derived is -5.587, then for consideration of interaction of variable B (caries incidence from 9 to 13) with variable A (baseline age), create a two-by-two table showing the $D_{2-3}FS$ estimates at minimum value for variable A (baseline age =12.4) and maximum variable A (baseline age = 14.9) for subjects with and without 9-13 incidence. Table L-5 provides endpoints for the interaction effect curves.

In the next step, exponentiate the values obtained in each cell since negative binomial regression uses a log link. This exponentiation will result in $D_{2-3}FS$ estimates for each cell of Table L-6. Then, each of the cells would contain the respective values, i.e., exp (a), exp (b), exp (c) and exp (d).

Table L-5 Estimates for net effects for range of baseline age with and without sealant exposure

Caries Incidence from 9 to 13	Baseline age	
	Minimum age	Maximum age
No	Combined base effect+ Min. value of baseline age*estimate for baseline age = -5.587 + (0.3538*12.4) = -1.1998 = a	Combined base effect + Maximum value of baseline age*estimate for baseline age = -5.587 + (0.3538*14.9) = -0.3154 = b
Yes	Combined base effect + the estimate for main effect for positive caries incidence from 9 to 13 + Min. value of baseline age (the addition of coefficient of baseline age and interaction term between estimate of baseline age and caries incidence from 9 to 13). = -5.587 + 0.0268 + = -5.732 + 0.0268 + (12.4*0.4161) = - 0.3738 = c	Combined base effect + the estimate for main effect for positive caries incidence from 9 to 13 + Max. value of baseline age (the addition of coefficient of baseline age and interaction term between estimate of baseline age and caries incidence from 9 to 13) = -5.587 + 0.0268 + + (14.9*0.4161) = 0.6397 = d

Table L-6 Estimates for surface level net cavitated caries incidence for range of baseline age with and without sealant exposure

Caries Incidence 9 to 13	Baseline age	
	Minimum age	Maximum age
No	Exp (a) = Exp (-1.1998) = 0.31	Exp (b) = Exp (-0.3154) = 0.73
Yes	Exp (c)= Exp (- 0.3738) = 0.69	Exp (d) = Exp (0.6397) = 1.90

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