Beverage Consumption Patterns and Oral Health Outcomes:

Do Milk and Water Confer Protective Benefits against Sugary- or Acidic-Beverage Consumption?

by

Lindsay Ellen Gibson

A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree of
Master of Science
in
Health Studies and Gerontology

Waterloo, Ontario, Canada, 2014

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Lindsay E. Gibson

ABSTRACT

Background

Diseases affecting the oral cavity are the most prevalent chronic conditions in the world, and affect all ages, sexes, and nationalities. Diet is a strong predictor of oral health, and beverage consumption may affect oral health outcomes; however, there has been relatively little research on the association between the balance of beverages in the diet and oral health outcomes.

Methods

The current study used data from the Canadian Health Measures Survey (CHMS) to determine the impact of the type and frequency of beverage consumption on oral health, as well as the interaction between beverages. The first round of data collection for the CHMS took place between March 1, 2007 and March 31, 2009, and involved 5604 Canadians between the ages of 6 and 79 from across Canada. The sample targeted individuals in privately occupied dwellings, and is representative of 97% of the Canadian population. The CHMS consisted of two components: a household questionnaire to collect sociodemographic information, health history, and information on personal habits, and a clinical examination to collect anthropometric measures, blood and urine samples, and oral health measures. For our current analysis, age was restricted to age 12-30 inclusive, with 16 participants removed for missing responses giving a final sample size of 1534.

The current analysis examined a number of different types of beverages, including water, milk, regular soft drinks, diet soft drinks, fruit juices, fruit-flavoured drinks, vegetable juices, sport drinks, and alcohol; and four oral health outcomes: dental decay, periodontal health, self-rated oral health (SROH), and a general oral health index (OHX). Descriptive tests and Poisson and Ordinal Regression were used to determine whether an association existed between the variables of interest, and if so, the magnitude of this association. Four models, each consisting of three sub-models, were fitted in order to address the hypotheses and research questions. Due to the complex sampling nature of the CHMS, survey weights were used as outlined by Statistics Canada, and clustering and bootstrapped analyses were carried out in order to account for the complex nature of the data.

Results

A number of the beverage variables, as well as other covariates, were associated with oral health outcomes. Soft drink consumption was associated with all of the oral health outcomes in the main effects models with increased soft drink consumption having a detrimental effect on oral health. Fruit-flavoured beverage consumption was significant with a negative impact in the dental decay main effects model, and water consumption was significant for the SROH main effects model, having a positive effect on SROH as the frequency of water consumption increased. Milk was significant and beneficial in all index models, and the milk and sugary- or acidic-beverage interaction variables were significant in all index models except for the sugary index model for dental decay. A number of the covariates were also found to be significant: age was associated with all dental decay, periodontal health and OHX models with higher age being associated with poorer oral health, sex was significant in the dental decay models as well as the index models for SROH with females having better oral health, income and frequency of dental care were significant in all of the SROH models (higher income and more frequent visits to health care professionals being associated with better SROH), frequency of flossing was associated with all of the dental decay models in a detrimental way, and fibre consumption was significant in the dental decay models as well as the index models for periodontal health and OHX and had a positive impact on oral health. All other beverage variables and covariates were not significant in any model.

Discussion

Consumption of some beverages, specifically regular soft drinks, fruit-flavoured beverages, water and milk, had a small but significant effect on oral health outcomes. It was also found that milk consumption is protective over sugary or acidic beverage interaction, but the interaction between water and sugary and acidic beverages does not seem to be significant. The small magnitude of association suggests oral health outcomes are highly multi-factorial in etiology and oral health status is the result of an accumulation of life exposures. Further investigations would benefit from the inclusion of information regarding access to fluoridated water, as well as longitudinal studies. Overall, the current findings contribute evidence on the importance of minimizing consumption of regular soft drinks and fruit-flavoured beverages, and replacing these drinks with those with more beneficial oral health effects such as milk and water.

ACKNOWLEDGMENTS

This project would not have been possible without the help of many. First and foremost to my thesis advisor Dr. David Hammond – thank you for your support, patience and guidance at every stage of this process. I would also like to acknowledge the help and excellent input received from my other committee members Dr. Rhona Hanning and Dr. Christian Boudreau, with a special thank you to the latter for sharing his expertise at the data analysis stage. Thank you to Dr. Pat Newcombe-Welch and the SWORDC for accommodating my research and for the help received. I would also like to acknowledge the University of Waterloo School of Public Health and Health Systems and the University of Toronto Faculty of Dentistry for their flexibility and accommodation. Last but not least, thank you to my friends, family and colleagues: without your support and guidance this project would not have been possible.

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LIST OF ABBREVIATIONS

BMI – Body Mass Index

CHMS – Canadian Health Measures Survey

CI – Confidence Interval

df – degrees of freedom

dmfs – (primary) decayed, missing or filled surfaces

IRR – Incidence Rate Ratio

NHANES III – National Health and Nutrition Examination Survey III

OHX – Oral Health Index

PHAC – Public Health Agency of Canada

sd – standard deviation

SES – Socioeconomic Status

SROH – Self-Rated Oral Health

SWORDC – South Western Ontario Research Data Centre

WHO – World Health Organization

BACKGROUND

Oral Health

Importance of Good Oral Health

Diseases related to oral health, including periodontal disease and dental caries, are the most prevalent chronic diseases in the world and can affect everyone, from newborns to the elderly (Public Health Agency of Canada [PHAC], 2010). In fact, up to 90% of schoolchildren are affected by dental caries (PHAC, 2010). Oral health is defined by the World Health Organization (WHO) as “being free of chronic mouth and facial pain, oral and throat cancer, oral sores, birth defects such as cleft lip and palate, periodontal (gum) disease, tooth decay and tooth loss, and other disease and disorders that affect the mouth and oral cavity” (WHO, 2007). Due to the widespread prevalence of oral health issues and the possible link between oral and systemic disease, there has been a recent research focus on oral health, including the relationship between oral health and nutrition.

The mouth is involved in a large number of functions essential to everyday life, including eating, drinking, chewing, and verbal and non-verbal communication (Scardina & Messina, 2012). It is important to maintain good oral health in order to preserve the ability to carry out these functions. In particular, tooth pain can make chewing or biting painful and difficult, which affects nutritional intake (Iacopino, 2008). For instance, an Australian study found that tooth loss, characterized by having less than 21 teeth (the normal fully dentate individual has 32 teeth including wisdom teeth), was found to be associated with decreased intake of a variety of fruits and vegetables, especially lettuce (prevalence ratio [PR] = 3.99), stir-fried/mixed vegetables (PR = 2.34), and pitted fruits (PR = 1.91) (Brennan, Singh, Liu, & Spencer, 2010). A similar study found that edentulous older adults were 2.9 times (95% confidence interval 1.1-7.8) more likely to be malnourished (BMI <21 kg/m^2, or serum albumin <33g/L) than those with teeth or properly fitting dentures (Mojon, Budtz-Jorgensen, & Rapin, 1999). Oral health has implications for one's self-esteem and success, as self-confidence issues related to oral health, such as feeling one's smile is not white enough, can hold individuals back from social and professional situations (Klages, Bruckner, & Zentner, 2004). For example, a study examining the oral health related quality of life in university students found that those individuals with lower self-ranked dental aesthetics scored significantly higher on social and general appearance disapproval, and lower on dental self-confidence (Klages et al., 2004). As these examples illustrate, oral health is important to carry out the functions of daily life and it is essential to maintain good oral health.

Conditions Associated with Oral Health

There are a large number of conditions associated with oral health; however, only the two most prevalent oral health indicators/conditions will be examined as a part of the present analysis: dental decay (consisting of dental caries and dental erosion) and gingivitis/periodontitis. Self-rated oral health will be examined for its impact on quality of life and overall experience of oral health, as well as an Oral Health Index compiling a number of oral health indicators in order to capture an overall impression of the individual's oral health status.

Dental Decay

Tooth decay (including caries and erosion) is the most common condition involving oral health, as well as the most common chronic disease (PHAC, 2010). Dental decay affects 56.8% of Canadian children age 6-11 years old, and 58.8% of Canadian adolescents between the ages of 12-19 (Health Canada, 2010). 95.9% of Canadian adults age 19 or older have experienced tooth decay (Health Canada, 2010).

Dental caries are caused by the demineralization of tooth surfaces and the dissolution of the organic component of the tooth (Alvarez, 1995). When bacteria, or plaque, come into contact with sugars in the mouth, acid is produced (Alvarez, 1995). This acid works to break down food, but can also break down the tooth structure (Alvarez, 1995). Although dental caries require the presence of bacteria and sugars or fermentable carbohydrates to form, they can also be influenced by a number of other factors including the susceptibility of the teeth, type of bacteria, fluoride exposure, and salivary secretions (Scardina & Messina, 2012).

Dental erosion is the permanent loss of tooth structure due to chemical dissolution resulting from acidic conditions within the oral cavity, beginning in the enamel and progressing to the underlying dentin (O'Sullivan & Milosevic, 1997). Although both dental caries and erosion involve the irreversible destruction of tooth structure, caries develop as a result of bacterial catalysis of sugars, whereas erosion occurs due to the presence of an acidic oral environment (O'Sullivan & Milosevic, 1997). The most common cause of erosion is consumption of acidic foods and beverages, specifically those foods and drinks which cause the pH of the oral cavity to become lower than the critical pH of 5.5 (O'Sullivan & Milosevic, 1997). Beverages in particular seem to contribute largely to the high rates of dental erosion seen today, partly due to the low viscosity of these substances and ability to easily access most areas of the oral cavity; these acidic drinks include regular and diet soft drinks, fruit juices, sports drinks, and wine (Mandel, 2005).

Certain groups tend to be at increased risk for developing dental caries and erosion; these groups include children, young adults, elderly individuals, and those of low socioeconomic status (SES) (Waldo, 2009). As dental caries are multifactorial in causation, it is difficult to determine why these groups are at increased risk; however, the poor diet quality of many of these groups, especially high sugar sweetened beverage consumption, as well as poor oral hygiene habits, likely contributes to their increased risk (Waldo, 2009). In addition, many of these populations are unable to afford or access regular dental preventive care and treatment (Gillchrist, Brumley, & Blackford, 2001; Rayner, 1970; Teodora Timis, 2005). There is also particular concern with infants and toddlers taking a bottle of juice to bed, as this long-term exposure to sugary- and acidic-beverages is a risk factor for the development of caries and acid erosion (O'Sullivan & Milosevic, 1997).

<u>Periodontal Diseases</u>

Gingivitis is the most common form of periodontal disease and is characterized by inflammation of the gums, sometimes to the point of pain or bleeding (Listgarten, 2005). It most commonly develops as a result of plaque (bacterial biofilm) build-up on tooth surfaces near the gingiva and within the gingival sulcus (Listgarten, 2005). This bacterial build-up causes an immune response in the body, which has been linked to a number of systemic conditions including diabetes, cerebrovascular disease, myocardial infarction, and impaired memory (Soskolne & Klinger, 2001; Wu et al., 2000; Pussinen et al., 2007; Noble et al., 2009). If left untreated, gingivitis can progress to become periodontitis, which is a destructive inflammatory disease affecting the tissues that surround and support the teeth (Savage et al., 2009). Periodontitis may result in tooth loss or decay, abscesses in the oral cavity, and swollen glands (Listgarten, 2005). Gingivitis commonly develops as a result of poor oral hygiene and low calcium intake, which may be a result of low milk consumption (Nishida et al., 2000). Approximately 32% of Canadian adults between the ages of 20 and 79 have gingivitis, with smokers and individuals with lower incomes are more likely to be affected by periodontal disease (Health Canada, 2010).

Oral Health Index (OHX)

Oral health and disease encompasses a wide range of diseases, conditions, anatomical structures, and psychosocial states, and thus it is difficult to measure the overall oral health of an individual; however, several indices have been developed with this aim. Most indices are restricted for use in certain situations, such as for seniors (Atchison & Dolan, 1990; Tubert-Jeannin, Riordan, Moral-Papernot, Porcheray, & Saby-Collet, 2003) or children (Bratthall, 2000; Yusuf, Gherunpong, Sheiham, & Tsakos, 2006), or only focus on one aspect of oral health, such as caries (Bratthall, 2000) or quality of life (Locker, Clarke & Payne, 2000; Slade & Spencer, 1994; Tubert-Jeannin et al., 2003; Yusuf et al., 2006), and thus are not appropriate for use in this study. However, the Oral Health Index (OHX) developed by Burke and Wilson (1995) is applicable to all ages and examines many aspects of oral health, and thus has been adapted for use in this investigation. There are some other composite measures of oral health with a broader focus, such as the Oral Health Status Index (Marcus, Koch & Gershen, 1980), but the OHX was deemed to be the best fit with the variables available from the CHMS.

The OHX consists of assessments for caries, restorations, tooth fracture, wear, periodontal disease, mucosa, occlusion, dentures and patient satisfaction, covering many aspects of oral health, although some areas, such as root canal treatment, cannot be included due to the solely visual and verbal nature of the examination (Burke & Wilson, 1995). Weightings are assigned to each area based on its overall importance to oral health, and although these weightings are somewhat arbitrary, they are consistent with other measures of oral health and are related to overall function of and severity of impact to the oral cavity and individual as a whole (Burke and Wilson, 1995). Although only certain sections of the OHX were used in this analysis, this is not generally seen as an issue as the OHX was developed for such use, due to the inherent problem of not all assessment sections being relevant to each patient (such as the denture assessment) (Burke & Wilson, 1995). The OHX score is usually presented as a percentage achieved of the total possible score, although for this analysis, we have expressed the score as the raw value of the assessment (out of a total possible score of 60), as the sections used were the same for each study participant (Burke & Wilson, 1995). Oral health, rather than disease, is viewed and scored positively, with positive scores being awarded for an acceptable state, and a zero score for unacceptable assessments, and thus the OHX is a measure of oral health with higher scores indicating better oral health (Burke & Wilson, 1995).

Beverages and Oral Health

Nutrition plays an important role in maintaining good oral health through numerous functions such as helping to provide the nutrients necessary to the physiological functioning of the oral cavity, as well as promoting salivary release through mastication (Scardina & Messina, 2012). For instance, peanuts and sugarless chewing gum mechanically stimulate the secretion of saliva, which helps to protect the teeth against dental caries and acid erosion (Scardina & Messina, 2012). As well, increased consumption of fibre can be beneficial to the oral cavity in a number of ways including increasing salivary output and decreasing appetite and therefore the number of potentially harmful substances the mouth is subject to (Sheiham, 2005). It also helps to control systemic disease and inflammation which may affect the gingival tissues, as is the case in diabetes (Sheiham, 2005). Other behaviours such as smoking tobacco increase one's risk for a variety of oral conditions including oral cancer, stained teeth, and recession of the gum line (Canadian Dental Association [CDA], 2012b; Sands, 2006). Along with solid foods, beverages play an important role in determining oral health status. For the most part, the association between certain types of beverages consumed and oral health outcomes have been well established in the literature.

Water and Oral Health

Water helps to prevent dental decay and oral diseases by rinsing the mouth of food debris and bacteria (Scardina & Messina, 2012). Fluoridated water has the additional benefit of remineralizing the teeth, which helps to protect against dental caries and other oral diseases, and has been shown to reduce dental caries by up to 40% (Gordon, 2007). The average Canadian consumes 4 250mL servings of water per day, which is approximately half of the recommended amount (Jones et al., 2006). However, like most foods/beverages, the frequency of water consumption has a bigger impact on oral health than the amount; water offers the most protective benefits if consumed after eating or drinking other substances, especially those that are high in sugar or acidity (Touger-Decker & van Loveren, 2003).

Milk and Oral Health

Milk consumption also confers benefits for oral health. Although the primary compound of milk is a sugar, lactose is much less cariogenic as compared with other sugars (Merritt, Qi, & Shi, 2006). Milk also helps to remineralize the teeth due to its high calcium and phosphorus contents (Merritt, Qi, & Shi, 2006). In fact, milk has been found to be protective against dental caries in children with poor oral hygiene, frequent sugar consumption and who did not use fluoride (Petti, Simonetti, & Simonetti D'Arca, 1997). In addition to its role in remineralization, milk also acts as a salivary buffer, raising the pH of the mouth and helping to protect against dental decay and erosion (Fejerskov & Kidd, 2008). The probiotic cultures in milk products may also help to combat oral infections, including periodontal diseases, by replacing pathogenic bacteria with more harmless microorganisms (Calgar, Kargul, & Tanboga, 2005). However, there is also limited evidence to suggest that the presence of lactobacilli is associated with a more carious oral environment (Calgar, Kargul, & Tanboga, 2005).

Over the past 20 years, milk consumption in Canada has declined significantly, with the exception of chocolate milk. As of 2011, the average Canadian consumed 78.7L of fluid milk products per year, or about 220mL of milk per day (Canadian Dairy Information Centre, 2012). This is concerning because it indicates many individuals are not receiving the protective oral health benefits milk confers, among other health benefits. Also, chocolate milk (and other flavoured milk) is higher in sugar content than white milk, which can increase the risk for developing dental caries, although the added benefits of consuming a dairy product make flavoured milks a healthier option than other sweetened beverages, especially in terms of oral health (Levine, 2001). Although there is no recommended level of milk consumption in order to improve oral health, the Canadian Food Guide recommends between 2 and 4 servings of milk products each day, depending on age and sex, and it is generally recommended to increase dairy consumption to protect oral health (Health Canada, 2011; CDA, 2012a). Although milk consumption is generally lower than ideal among all sociodemographic groups, those of low SES are particularly at risk for poor oral health due to low milk consumption (Wang et al., 2007).

Regular Soft Drinks and Oral Health

On the other hand, some beverages have detrimental impacts on oral health. Regular soft drinks are high in sugar content, and as a result, can lead to caries development if consumed frequently (Touger-Decker & van Loveren, 2003). Due to their acidic properties, regular soft drinks can also contribute to dental erosion by lowering the pH of the mouth (Dugmore & Rock, 2004). The impact of regular soft drinks on dental health has become so great that they often emerge as the single nutritional item affecting oral health in multifactorial analysis; this is largely due to their frequent and widespread consumption among many populations (Burt et al., 2006; Dugmore & Rock, 2004).

However, the relationship between these sugary and acidic beverages and oral health is complex. Dental caries and erosion, along with many other oral diseases, have a multifactorial etiology, and as a result, a direct causative association between sugary and/or acidic beverages and disease of the oral cavity has not been established (Ismail, Burt, & Eklund, 1984; Fejerskov & Kidd, 2008). Dental caries develop as a result of the long-term presence of bacteria and enzymes in the oral cavity, especially if the neutralizing capabilities of saliva have been compromised (Scardina & Messina, 2012). Specifically, the frequency of food intake affects its cariogenicity: Ismail and colleagues (1984) recorded a 1.79 increased odds for decayed, missing or filled teeth (DMFT – a common indicator of dental caries) if soft drinks were consumed between meals three or more times per day. Interestingly, DMFT score was not associated with meal-time consumption of soft drinks (Ismail et al., 1984). Certain groups tend to be at heightened risk for dental caries: children, young adults, elderly individuals, and those of low SES

(Waldo, 2009). As dental caries are multifactorial in causation, it is difficult to determine why these groups are at increased risk; however, it is likely the poor diet quality, especially high sugar sweetened beverage consumption, of many of these groups plays a role, as well as poor oral hygiene habits (Waldo, 2009).

Diet Soft Drinks and Oral Health

Diet soft drinks are often selected as an alternative to regular soft drinks as they are lower in caloric content, and thus are thought to be a healthier, or at least less obesogenic, option. Unlike regular soft drinks, diet soft drinks are not sweetened with sugar, and thus, most of the risk for dental caries is ameliorated. However, diet soft drinks are generally acidic (pH between 3.00 and 3.70), which can lower the pH of the saliva in the mouth, contributing to dental erosion as well as a decreased ability to combat the formation of dental caries (Jain, Nihill, Sobkowski, & Agustin, 2007; von Fraunhofer & Rogers, 2004). However, there is some evidence to suggest that diet soft drinks, specifically Diet Coke, pose a lesser acid challenge to the enamel than regular Coke (Roos & Donly, 2002). Like other acidic beverages, it is less harmful for one's oral health to consume diet soft drinks in low quantities and frequencies, and at meal times, which allows for the other foods being consumed to neutralize the acidity of these drinks (von Fraunhofer & Rogers, 2004).

Sport Drinks and Oral Health

Sport drinks also tend to be high in sugar, generally over 10g of sugar per 250mL, which equates to between 6-8% carbohydrate composition, depending on the manufacturer (Coombes, 2005). Sports drinks also tend to be high in acidity (pH of between 2.4 and 4.5), and thus affect oral health in a way similar to other sugary and acidic beverages (Coombes, 2005). The erosive potential of sport drinks has been shown to be similar to diet soft drinks, but not as high as regular soft drinks and orange juice (Rytomaa et al., 1988). It has also been indicated that sport drinks can contribute to dental erosion but not dental caries in a rat population (Sorvari, 1989). In human populations, no link has been found between sport drinks and dental caries; however, sport drinks are comparable in cariogenicity to fruit juices, fruit flavoured drinks and regular soft drinks, so an association between sport drinks and caries cannot be overlooked (Birkhead, 1984). Again, many researchers have suggested it is the frequency and timing of sport drink consumption that affects oral health, as opposed to the amount consumed (Coombes, 2005). The type of sports drink also affects its erosive potential, as the acidity and sugar content of sport drinks varies between drinks (Milosevic, 1997). The group at highest risk for poor oral health outcomes due to consumption of sport drinks is athletes and other active individuals, as well as those with genetic factors which make their teeth more susceptible to decay (Coombes, 2005). Compared to water, however, sport drinks confer only negligible benefits for most recreationally active individuals, while they may lead to significantly poorer oral health outcomes (Coombes & Hamilton, 2000).

Fruit Juices and Oral Health

100% fruit juices impact oral health in a similar way to regular soft drinks, by promoting the development of dental decay (Touger-Decker & van Loveren, 2003). Although the sugar content in fruit juices originates from a natural source, it still requires the presence of bacteria to break down these fermentable carbohydrates in the oral cavity, and this can contribute to the formation of dental caries (Landon, 2007). Fruit juices also tend to be acidic, ranging in pH from about 2.00 (lime and lemon juices) to 4.19 (orange juice) (United States Food and Drug Administration [USFDA], 2007). The low pH of these beverages lowers the salivary pH, which impairs the ability of the saliva to protect against dental decay (Landon, 2007). Like other sugary and acidic beverages, the timing and frequency of fruit juice consumption influences its impact on oral health, with more frequent consumption outside of meal time being associated with poorer oral health outcomes (Landon, 2007).

However, drinking 100% fruit juice with a high Vitamin C content may actually help to protect dental health. Vitamin C promotes collagen synthesis, wound healing, and acts as a powerful anti-toxin, and in addition, improves the oral immune response by creating a protective barrier against bacterial endotoxins (Rubinoff, Latner, & Pasut, 1989). Due to vitamin C's role in improving immune function, it may help to combat periodontal disease, especially aspects involving gingival inflammation and bacterial infection (Rubinoff et al., 1989). Fruit juices seem to be the primary source of Vitamin C in an individual's diet; in Australia, fruit juices provide 33% of the Vitamin C in children's diets, and almost 25% of the Vitamin C adults consume (Record, 2001).

Fruit-Flavoured Drinks and Oral Health

Like regular soft drinks and fruit juices, fruit flavoured drinks tend to be acidic and high in sugar content, and thus affect oral health in a similar way. The high sugar content of these drinks, usually about 11-12g of sugar per 355mL (1 can), promotes the development of dental caries (Winnipeg Regional Health Authority, 2010). Fruit flavoured drinks are also low in pH, which can promote acid erosion of the teeth (Ligh, Fridgen, & Saxton, 2011). Like other sugary and acidic beverages, the impact of fruit flavoured drinks on oral health depends on their frequency and timing of consumption (Touger-Decker & van Loveren, 2003). Children, teenagers, and those of low SES are more likely to consume fruit flavoured drinks, and are thus at higher risk for poor oral health as a result of this consumption (Nicklas, 2003).

Vegetable Juices and Oral Health

Like many of the other drinks discussed, vegetable juices are low in pH, and thus increase the risk for dental erosion. However, although vegetable juices are generally acidic, with a pH ranging from 3.90 to 4.30, they are less acidic than most fruit juices (USFDA, 2007). There is limited evidence examining the association between vegetable juice and oral health, likely due to the low consumption patterns of this beverage (Ruxton, Gardner, & Walker, 2006).

Alcohol and Oral Health

Alcohol consumption can also have an impact on oral health. Many types of alcohol, especially wine, are highly acidic and thus contribute to the risk of dental erosion (Mandel, 2005). Some alcohols are high in sugar content, and thus contribute to caries formation (Petti & Scully, 2009). High alcohol consumption, generally defined as over 50g per day or frequent binge drinking episodes, has also been linked to an increased risk of oral cancer (Petti & Scully, 2009). Individuals who abuse alcohol are much more likely to experience dental decay, periodontal disease, and poor oral health in general; in fact, up to 80% of alcohol abusers have an impaired oral health status (Araujo, Dermen, Lalonde, Connors, & Ciancio, 2003).

Other Beverages and Oral Health

Other beverages, including coffee and tea, also have an impact on oral health. Although these beverages will not be examined as a part of the present analysis, as CHMS did not investigate the consumption patterns of each of these beverages, it is important to recognize their impact on oral health.

Tea can have both a protective and detrimental impact on oral health. Black tea can aid in fluoride remineralization of the teeth, which helps to protect against dental caries (Moynihan, 2000). The pH of tea is around 7.20, which means it does not contribute to the lowering of salivary pH, and thus is not a significant risk factor for dental erosion (USFDA, 2007). The polyphenols in tea may also help to combat halitosis, by inhibiting the growth of bacteria that cause bad breath (Xu, Zhou, & Wu, 2010). However, tea is often sweetened with sugar or honey, and this can increase the risk for dental caries if consumed frequently (Touger-Decker & van Loveren, 2003). Also, frequent tea consumption can stain the teeth so they do not appear as white as most individuals would prefer (Addy & Moran, 1995). Like tea, coffee can also stain the teeth, and frequent consumption of sweetened coffee may increase the risk for dental caries (Addy & Moran, 1995; Touger-Decker & van Loveren, 2003). The average pH of coffee is about 5.1 to 5.2; because this value is lower than 5.5, coffee may contribute to acid erosion of the dental enamel; however, its erosive potential is not as high as the acidic drinks being examined in this analysis (USFDA, 2007). On a positive note, the tannins in coffee may also help to reduce to cariogenic potential of other foods and drinks, by reducing plaque formation (Touger-Decker & van Loveren, 2003).

Balance of Beverages in the Diet

Although the association between oral health and each specific type of beverage has been established, the combination and balance of these beverages in the diet and the effects on oral health has not been extensively examined. This is an area of importance as individuals rarely, if ever, consume solely one type of drink, and the type of drink consumed has significant impact on oral health. For instance, Edwards and colleagues (2001) examined the buffering effect certain beverages had on salivary pH, as those with an increased resistance to salivary buffering capacity, specifically fruit juices and fruit-based carbonated beverages, may cause a prolonged drop in oral pH, a risk factor for dental decay, especially when compared to more alkaline beverages like sparkling and still mineral water. This has lead dental professional associations and other bodies to recommend balancing soft drink consumption with milk and water intake, or replacing sugary- and acidic-beverage consumption with healthier options such as water or milk (CDA, 2012a; WHO, 2012).

The balance of drinks in the diet is especially of concern as there is a growing notion that increased sugary- and acidic-beverage consumption replaces milk and water in the diet, although this has only been supported by a few studies (Lee & Brearley Messer, 2011; Jacobson, 2005). For instance, the annual consumption of soft drinks has increased 500% over the last 50 years, and the average 13- to 18-year old now consumes twice as much soda (regular and diet) as milk (Putnam & Allshouse, 1999; Jacobson, 2005). Soda pop consumption continues to rise; compared to data collected from 1994-1996, soda pop contributed about 25% more of teens' calories in 1999-2002 (Jacobson, 2005). Soft drink consumption has also been found to be associated with lower intake of milk (Vartanian, Schwartz & Brownell, 2006). These contemporary changes in beverage consumption are likely the result of a fast-paced lifestyle; for instance, regular and diet soft drinks are readily available at fast-food and other restaurants, and drinking bottled water does not always have the added protection of fluoridation (Lee & Brearley Messer, 2011). Thus, it is also important to examine how the balance of the type of beverages in the diet affects oral health.

Existing Body of Evidence

To date, I am aware of five main studies that have examined the association between the balance of drinks in one's diet and oral health outcomes. Marshall and colleagues (2003) examined the association between dental caries and the consumption of dairy foods, sugared beverages, and micronutrients such as vitamins C and B12 in members of the Iowa Fluoride Study. Nutritional data were collected at ages 1 through 5 using 3-day food and beverage diaries, and caries were identified through a dental examination by a dentist at 4 to 7 years of age (Marshall et al., 2003). The study found that contemporary changes in beverage consumption, especially increased sugar-sweetened soda pop, powered beverage, and 100% fruit juice intake, has the potential to increase the rate of caries in children (Marshall et al., 2003). Specifically, those children with caries experience consumed on average 260g of sugared beverages per day, as compared to 232g of sugared beverages in those without caries (Marshall et al., 2003). The study also found that milk had a neutral association with caries, and that the risk for dental caries is likely dependent on the sugar composition of the drink or its role in the diet and the habits surrounding its use (Marshall et al., 2003). The number of tooth surfaces with caries was positively associated with age and negatively associated with fluoride exposure (Marshall et al., 2003). The results also suggested an interaction between detrimental effects from sugary-beverage consumption and protective benefits of fluoridated water as fluoride exposure was associated with reduced extent of caries, but not caries prevalence; however, this was not specifically examined as a part of the study design (Marshall et al., 2003). The authors did not report on whether there were differences in caries or nutritional experience based on SES, although individuals excluded from the analysis due to missing information were more likely to be of low SES (Marshall et al., 2003).

Data obtained from the 24-hour dietary recall interviews in the National Health and Nutrition Examination Survey (NHANES) III was also used to investigate the relationship between fluid consumption patterns and dental caries in children aged 2-10 (Sohn, Burt, & Sowers, 2006). Using cluster analysis, four fluid consumption patterns were identified: high carbonated soft drinks, high juice, high milk, and high water (Sohn et al., 2006). When compared to high intakes of water, milk or juice, children who had a high consumption of soft drinks (over 6oz per day in children aged 1-6, and over 12oz per day in children aged 7-18) were almost two times more likely to experience dental caries, and about 13% of children fell into this group (Sohn et al., 2006). Children in the milk group were found to have the lowest caries experience of any of the groups (Sohn et al., 2006).

A similar study looking at low-income African-American children found that those children who increased their consumption soft drinks over the three year study period had 1.75 times more new caries, as compared to those who were consistently low consumers of soft drinks, or who consumed 100% fruit juice or milk (Lim et al., 2008). Consumption patterns were analyzed using 4 groups clustered by their regular consumption pattern of each beverage (Lim et al., 2008). Again, age was positively associated with caries experience; however, the design of the study focused on low-income children, and as a result, it is not possible to determine whether there are any differences between SES levels (Lim et al., 2008).

The association between dental caries and beverage consumption patterns was also investigated in another study using data from the Iowa Fluoride Study (Hamasha, Warren, Levy, Broffitt & Kanellis, 2006). In this study, low and high SES children were followed from 6 to 108 months of age, with dental exams conducted at 5 and 9 years of age (Hamasha et al., 2006). Although no significant difference existed between the two groups in terms of tooth-brushing frequency, use of dentifrice or fluoride concentration in drinking water, low SES children consistently consumed more soda pop and powder-based beverages than their high SES counterparts, and had significantly higher decayed, missing or filled surfaces (dmfs) scores (Hamasha et al., 2006). This study concluded that beverage consumption patterns seem to be a key difference in caries experience between low and high SES children, and decreasing or eliminating soda pop and powder-based beverage consumption may help to reduce the caries burden on low SES children (Hamasha et al., 2006).

The balance of beverages in the diet has also been examined in the context of dental erosion. A case-control study matched 309 children on the basis of age and gender to dental erosion, caries-active or caries-free groups (O'Sullivan & Curzon, 2000). Structured dietary histories were taken to determine the type and frequency of acidic foods and drinks consumed, as well as the habits surrounding this consumption that prolonged dental exposure to acid (O'Sullivan & Curzon, 2000). It was found that those children with erosion drank acidic beverages more frequently than those children in the caries-active and caries-free groups (O'Sullivan & Curzon, 2000). Fruit, vinegar, and vitamin C supplement consumption was also highest in the erosion group (O'Sullivan & Curzon, 2000). Children with erosion also drank milk and water significantly less often than the children in the other groups (O'Sullivan & Curzon, 2000). Overall, the results suggested that consuming acidic food and drinks more frequently, especially combined with a swishing or holding habit, may contribute to the development of dental erosion in some children (O'Sullivan & Curzon, 2000).

Research Gaps

Research to date has established that a diet high in regular soft drinks is associated with greater caries and erosion experience in children than diets high in water, milk and 100% fruit juice. However, there are still significant gaps in the literature. Previous studies have focused on children and dental caries or erosion, and the association between beverage consumption and oral health outcomes has also not been examined in a Canadian population. Finally, previous studies have not looked at the interaction effects of the different types of beverages in the diet, which is important to consider in order to determine whether regular consumption of one type of beverage, such as water, confers protective benefits over other beverages.

RESEARCH RATIONALE

Rationale

The association between oral health and the consumption of certain beverages has been well established: soft drinks and other sugar-sweetened beverages are generally cariogenic due to their high sugar levels and low pH, while milk tends to confer a protective benefit on oral health by calcium remineralization of the teeth (Scardina & Messina, 2012). Water consumption is also protective to oral health by rinsing the mouth of food debris and bacteria. (Scardina & Messina, 2012). Although the associations between oral health and certain types of drinks have been established, the interaction between the frequency of consumption of each of the beverages and the subsequent oral health outcomes is an area that has not yet been studied in depth. This area is of interest because few, if any, individuals consume only one type of beverage, and to date, this has not been extensively examined in the literature.

Purpose and Research Questions

The current analysis examined the association between the balance of type and frequency of beverages consumed and oral health outcomes.

The specific research questions addressed were:

1. What is the association between the frequency of milk and water consumption and oral health?

2. What is the association between the frequency of drinking sugary/acidic drinks and oral health?

3. What, if any, is the interaction between the frequency of consumption of milk/water and sugary/acidic-drinks and oral health?

4. What sociodemographic factors are associated with oral health outcomes after adjustment for beverage consumption?

METHODS

Canadian Health Measures Survey

The Canadian Health Measures Survey (CHMS) was first conducted in 2007 to address significant data gaps and limitations in existing population health information. The CHMS contains two major components: a computer-assisted household questionnaire, and direct physical measures collected through a mobile examination centre (MEC). The household questionnaires were used to collect information on demographic, socioeconomic and environment/housing characteristics, as well as nutrition, physical activity, substance use, medical history, current health status, sexual behaviour, and lifestyle. The clinic questionnaires collected a wide variety of measures, including height and weight, blood pressure, blood measures including lipid profile and Vitamin D status, and urine measures such as creatinine and iodine, and also included an oral health examination. Each variable collected during the household questionnaire corresponded to and was verified by a clinic measure, apart from sociodemographic information. Clinic measures were taken at 15 collection sites spread throughout Canada (1 in Atlantic Canada, 4 in Quebec, 6 in Ontario, 2 in the Prairies and 2 in British Columbia) for ease of access for study participants. Scheduling was organized so that collection periods at each site differed over the year and season collected, and the MEC stayed in each site for approximately 6 to 8 weeks at a time. Each clinic visit took approximately 2 hours, and each section started by determining eligibility criteria in order to reduce the chance of any adverse effects.

The first cycle of data collection took place from March 1, 2007 to March 31, 2009. The second cycle of data collection began in September 2009 and was completed in 2011. Planning for future cycles is currently underway. For this investigation, we used the first wave of CHMS data as the second wave did not include measures addressing oral health. (Statistics Canada, 2010)

Study Participants

The CHMS targets Canadians in all 10 provinces and 3 territories between 6 and 79 years of age, who live in a privately occupied residence; the specific age groups used for CHMS sampling are 6-11, 12-19, 20-39, 40-59, and 60-79 years. Overall, about 97% of Canadians are represented by the survey; however, residents of institutions, full-time members of the Canadian Forces, persons living on Indian Reserves or Crown Land, and residents of some remote communities are excluded from CHMS. CHMS used a cross-sectional survey design, with 10 age-gender groups as described above, and aimed to have at least 500 individuals per group. The households sampled were identified using 2006 Census data, and were stratified according to location and age of residents. In total, 5604 individuals took part in both the household and MEC components of CHMS.

From each household, one participant (or two participants if one was aged 11 or under) was selected to take part in CHMS. To facilitate travel to the MEC, the homes of participants were located within 50km of the clinic location, or 100km for rural areas. Approximately 350 individuals were sampled for each clinic location, from an initial selection of 9349 dwellings. Dwellings were contacted by telephone in a random order until the required number and distribution of respondents had agreed to participate. From the criteria specified above, participants were selected randomly, and a vector with variable selection probabilities by age group was used.

For the purposes of this study (rationale discussed below), a restricted age range of 12 to 30 inclusive was used for the analysis, for a total of 1550 respondents. Due to the nature in which the household and clinic questionnaires were administered, there was minimal missing data; however, 16 participants were removed from the analysis due to missing responses on one or more of the variables used. All participants had data for all of the sociodemographic variables, although 50 respondents chose not to disclose their education and 164 declined to provide their income. These individuals were kept in the analysis, with their response recoded as "not stated". Seven individuals were missing information used to determine dental decay, periodontal health and OHX scores, and thus were eliminated from the analysis. Alcohol consumption data were originally missing for 553 participants; however, further investigation revealed that 542 of these did not consume alcohol in the past 12 months and thus were excluded from the weekly alcohol consumption question – these individuals were recoded as consuming 0 drinks per week. Of the 11 respondents remaining, 8 were excluded from the question as they were 11 years of age at the household interview (but 12 years of age at the clinic visit and thus included in the analysis), and thus it was assumed they did not consume alcohol and were recoded as having 0 drinks per week. The remaining 3 participants were excluded from the analysis. A similar situation arose for smoking habits: 12 participants had missing information, and 8 were excluded from the question as they were 11 years old at the household interview, and thus were presumed to have never smoked. The final four individuals were removed from the analysis. Finally, one respondent was missing information on fruit-flavoured drink consumption, and one did not respond to the frequency of visiting a dental professional, and thus they were both eliminated from the analysis, bringing the total number of study participants to 1534, with no missing data on any measure.

Measures

A comprehensive list of the specific questions and derived variables taken from CHMS can be found in Appendices A and B.

Sociodemographic Variables

The sociodemographic variables used in the analysis were: age (AWC_Q04), sex (SEX_Q01), income and education. It was important to include age in the analysis, as the most prevalent chronic oral conditions differ by age. For instance, dental caries are common in young children, whereas seniors are much more likely to be edentulous (National Institute of Dental and Craniofacial Research [NIDCR], 2000). For the purposes of this investigation, only respondents from 12 to 30 years of age were included and age was split into 4 groups: age 12-15, 16-19, 20-24 and 25-30. The purpose of this age restriction was to simplify the analysis as oral health conditions vary widely with age, and preliminary data analysis identified several "breaks" in oral health trends based on age. For instance, oral health appears to become significantly poorer between ages 30 and 40, and the outcome of dental fluorosis was only measured in the 6-11 age group. Additionally, using data from participants ages 12 to 30 ameliorated complications related to deciduous, permanent or mixed dentition, as well as teeth counts related to edentulism due to old age.

Education was measured using the highest level of education achieved by a member of the household: Highest level of education – household, 4 levels (EDUDH04): *Less than secondary school graduation, secondary school graduation but no post-*

secondary education, some post-secondary education, post-secondary degree/diploma, and not stated. Due to low prevalence of respondents in the lowest two education groups, *less than secondary graduation* and *secondary school graduation but no post-secondary education* were grouped into one category: *no post-secondary education*.

Income was determined using the total household income – 5 categories (INCDDIA5): *lowest income, lower middle income, middle income, upper middle income, highest income grouping, and not stated.* Again, due to low prevalence of respondents in the lowest two income groups, *lowest income* and *lower middle income* were grouped into one category: *lowest incomes*. The education and income variables were analyzed separately, as well as by creating an interaction SES variable by multiplying the values for income and education, with higher scores indicating higher SES. SES was included in the analysis as it can greatly affect an individual's oral health outcomes; specifically, those of low SES tend to be at greater risk for most oral health conditions, due to their diet and inability to access dental care on a regular basis (NIDCR, 2000).

Oral Health Variables

The current study examined both self-reported and clinical oral health outcomes. These outcomes included dental decay, periodontal health and self-reported oral health, as well as the oral health index. Dental decay, which includes caries and erosion, was assessed by examining the condition of each tooth and calculating the total number of teeth exhibiting decay. Dental decay was determined by the addition of four scores together to determine the total number of sound and never decayed teeth in the oral cavity: OHEDAC01 (Number of permanent crowns that are sound, never decayed or restored), OHEDAC02 (Number of permanent crowns that are sound – crown sealed, never decayed or otherwise restored), OHEDDT01 (Number of deciduous teeth recorded as sound, never decayed or restored), and OHEDDT02 (Number of deciduous teeth that are sound – crown sealed, never decayed or otherwise restored) to get the total number of teeth that have never experienced decay, from a minimum of 0 to a maximum of 28 (wisdom teeth were not included in the analysis as many individuals are congenitally or surgically missing these teeth, and they are not viewed as essential for oral function) (Meyer-Lueckel & Paris, 2013).

The gingivitis score was used in order to determine the extent of periodontal disease. Each of the six gingivitis scores have 5 response options: *0 = no inflammation, 1 = mild inflammation, 2 = moderate inflammation, 3 = severe inflammation, 4 = tooth missing.* These six scores were added together and recoded into one periodontal health, with a range from 0 to 24, and the values reverse coded so that higher scores indicated better oral health.

Perceived oral health was assessed using self-rated oral health; specifically with the question: In general, would you say the health of your mouth is: *Excellent, very good, good, fair, poor* (OHM_Q11). Each category was given a score of 1-5 (i.e. the excellent category was scored 5, very good was 4, etc.) with higher scores indicating better oral health.

Although the impact beverages and other variables have on oral health outcomes were examined separately for each outcome, an oral health index was also used in order to investigate the overall impact on oral health. The oral health index is essentially an indicator of the proportion of healthy teeth in an individual's mouth, with higher scores indicating better oral health. The index used in this study was based on the Oral Health Index (OHX) developed by Burke and Wilson (1995). Only sections of the OHX to which there is related data in CHMS were included: specifically, caries, periodontal disease, mucosa, and patient assessment. The wear, occlusion and denture assessments were not included as there was not direct correspondence to sections in the CHMS.

In order to calculate the oral health index, the following steps were taken:

1) Caries/standing teeth was determined from the variable derived for dental decay (sum of OHEDAC01, OHEDAC02, OHEDDT01 and OHEDDT02) out of a possible 28.

2) For periodontal disease, the measures OHEDGS12-OHEDGS44 were used and recorded into 2 scores – those with a score of 0 on this measure were recorded as a 1 (sound periodontal health), and those with a 1 or higher were given a zero. This measure was given as a score out of a possible six (one point for each tooth measured) with higher scores indicating better periodontal health.

3) To determine the presence of subgingival calculus (an indicator associated with periodontal disease), OHEDCS01-OHEDCS06 were recoded into 2 scores - those with a score of 0 on this measure were recorded as a 1 (no calculus), and those with a 1 or higher were given a zero. This measure was given as a score out of a

possible six (one point for each tooth measured) with higher scores indicating better periodontal health.

4) To determine the health of the participants' mucosa, OHE_N14 was used. A score of 1 on this measure was awarded 5 points, and every other score was given a 0 (out of a possible 5).

5) Patient Assessment was captured using three questions: OHM_Q23, OHM_Q22, and OHM_Q12.

    a. The first part of the OHX patient assessment was determined by the response to the question "is your mouth free from pain?". This approximates to the CHMS measure "In the past 12 months, how often have you had any other persistent or ongoing pain anywhere in your mouth?" (OHM_Q23). The responses rarely and never were coded as 5, with all other responses recoded as 0 (out of a possible 5).

    b. The second question in the OHX patient assessment is "can you comfortably chew an unrestricted diet?". The CHMS question "(in the past 12 months) how often have you avoided eating particular foods because of problems with your mouth?" was used for this measure; rarely and never were scored as 5, and all other responses as 0 (out of a possible 5).

    c. The final component of the OHX patient assessment is "are you happy with the appearance of your teeth?". OHM_Q12 ("how satisfied are you with the appearance of your teeth and/or dentures?") was used, with very satisfied and satisfied recoded as 5, and all other responses as 0 (out of a possible 5).

In this way, a patient assessment score out of fifteen was determined.

The scores of these four components were added together to give a possible score out of 60. In summary, the scoring of the OHX was as follows:

1) Dental Decay (/28) +
2) Periodontal Disease (/6) +
3) Subgingival Calculus (/6) +
4) Mucosal Health (/5) +
5) Patient Assessment
    a. Pain (/5) +
    b. Restricting diet (/5) +
    c. Satisfaction with Appearance (/5)

This approach was consistent with the published measure, as were the relative weightings given to each component; the modification to the index was simply whether or not certain components were included based on their applicability and inclusion in the CHMS.

Beverage Variables

The beverages of interest in this analysis were: water (Drinks water – times per year – WSDD21Y), milk (Drinks milk – times per year – MDCD11Y), regular soft drinks (Drinks regular soft drinks – times per year – WSDD11Y), diet soft drinks (Drinks diet soft drinks – times per year – WSDD12Y), sport drinks (Drinks sport drinks – times per year – WSDD13Y), fruit juices (Drinks fruit juices – times per year – WSDD14Y), fruit flavoured drinks (Drinks fruit flavoured drinks – times per year – WSDD15Y), vegetable juices (Drinks vegetable juices – times per year – WSDD16Y), and alcohol (Alcohol – weekly consumption (ALCDWKY)). All of these variables, except for alcohol consumption, were then recoded into times consuming the beverage per week by dividing by 52. Each of these beverages was examined separately in order to better understand their impact on oral health.

Beverage Consumption Indices (Sugary and Acidic)

In addition, some of the variables were grouped into sugary beverages and acidic beverages in order to determine how these broad categorizations of beverages impact oral health outcomes. The drinks that were classified as sugary beverages were those that contain sugar, as it seems to be the frequency sugar is consumed that affects oral health, as opposed to the amount of sugar (Ismail et al., 1984). These drinks included: regular soft drinks, fruit juices, fruit flavoured drinks, sport drinks, and alcohol [SUGARY BEVERAGES: Sum of: Drinks regular soft drinks – times per year (WSDD11Y), Drinks sport drinks – times per year (WSDD13Y), Drinks fruit juices – times per year (WSDD14Y), Drinks fruit flavoured drinks – times per year (WSDD15Y); total count then divided by 52 to determine weekly consumption; and Alcohol consumption – times per week (ALCDWKY)]. Although milk also contains sugar, the primary sugar is lactose, which has been found to be much less cariogenic than other sugars, as it produces a less acidic salivary environment, and thus was not classified as a sugary beverage (Scardina & Messina, 2012).

The drinks included as acidic beverages are those with a pH of less than 5.5, as those drinks that are more acidic than this critical pH have been suggested to lower the pH of the mouth to a point that can negatively affect the tooth structure (Mandel, 2005). Specifically, acidic beverages include regular and diet soft drinks, vegetable juices, fruit juices, fruit flavoured drinks, sport drinks, and alcohol [ACIDIC BEVERAGES: Sum of: Drinks regular soft drinks – times per year (WSDD11Y), Drinks diet soft drinks – times per year (WSDD12Y), Drinks sport drinks – times per year (WSDD13Y), Drinks fruit juices – times per year (WSDD14Y), Drinks fruit flavoured drinks – times per year (WSDD15Y) ; total count then divided by 52 to determine weekly consumption; and Alcohol consumption – times per week (ALCDWKY)].

Other Variables

The analysis also examined dietary factors, specifically fibre consumption [Eats fibre, times per year: Sum of: Eats hot or cold cereal – times per year (GFVD11Y), Eats brown bread, including bagels, rolls, pita bread, or tortillas – times per year (GFVD12Y), Eats white bread, including bagels, rolls, pita bread or tortillas – times per year (GFVD13Y), Eats any kind of pasta – times per year (GFVD14Y), Eats any kind of rice – times per year (GFVD15Y), Eats fruit – times per year (GFVD17Y), Eats lettuce or green leafy salad – times per year (GFVD19Y), Eats spinach, mustard greens, or collards – times per year (GFVD20Y), Eats french fries, home fries or hash brown potatoes – times per year (GFVD21Y), Eats other potatoes – times per year (GFVD22Y) and Eats all other types of vegetables – times per year (GFVD23Y); total count then divided by 52 to determine weekly consumption] and consumption of (non-milk) dairy products [Eats diary, times per year: Sum of: Eats cottage cheese – times per year (MDCD13Y), Eats yogurt – times per year (MDCD14Y), Eats ice cream or frozen yogurt – times per year (MDCD15Y); total count then divided by 52 to determine weekly consumption].

Smoking habits [Type of Smoker (SMKDSTY) – *Current daily smoker, occasional smoker (former daily smoker), occasional smoker (never a daily smoker or has smoked less than 100 cigarettes in lifetime), non-smoker (former daily smoker), non-smoker (former occasional smoker, at least 100 cigarettes in lifetime), never smoked (at least 100 cigarettes), missing information, population exclusions*; to simplify analysis, the smoking variable was recoded into three different responses – current smoker (consisting of *current daily smoker, occasional smoker (former daily smoker), and occasional smoker (never a daily smoker or has smoked less than 100 cigarettes in lifetime)*), former smoker (consisting of *non-smoker (former daily smoker), and non-smoker (former occasional smoker, at least 100 cigarettes in lifetime)*), and never smoked (consisting of *never smoked (at least 100 cigarettes)*)] were also included in the analyses.

Oral health behaviours, such as flossing [Number of times teeth flossed per year (OHMD32Y); total count then divided by 52 to determine weekly habit], brushing [Number of times teeth brushed per year (OHMD31Y); total count then divided by 52 to determine weekly habit], and visiting a dental professional [Do you usually see a dental professional? *More than once a year for check-ups or treatment, about once a year for check-ups for treatment, less than once a year for check-ups or treatment, only for* *emergency care, never*. (OHM_Q33); analyzed as a categorical variable], also have an impact on oral health and were examined here.

Hypotheses

The study tested the following hypotheses:

1) Individuals who consume water more often will be less likely to have negative oral health outcomes.

2) Individuals who consume milk more often will be less likely to have negative oral health outcomes.

3) Individuals who consume regular soft drinks more often will be more likely to have negative oral health outcomes, especially dental decay.

4) Individuals who consume diet soft drinks more often will be more likely to have negative oral health outcomes, especially dental decay.

5) Individuals who consume sports drinks more often will be more likely to have negative oral health outcomes, especially dental decay.

6) Individuals who consume fruit juices more often will be more likely to have negative oral health outcomes, especially dental decay.

7) Individuals who consume fruit flavoured drinks more often will be more likely to have negative oral health outcomes, especially dental decay.

8) Individuals who consume vegetable juice more often will be more likely to have negative oral health outcomes, especially dental decay.

9) Individuals who consume alcohol more often will be more likely to experiences negative oral health outcomes, especially dental decay.

10) Individuals who consume sugary beverages more often will be more likely to experiences negative oral health outcomes, especially dental decay.

11) Individuals who consume acidic beverages more often will be more likely to experiences negative oral health outcomes, especially dental decay.

ANALYSIS

Data analysis was completed using Stata Version 12 at the South-Western Ontario Research Data Centre (SWORDC) in Waterloo, Ontario, Canada. Statistical analysis included the following:

1. Analyses were conducted on weighted data. The SVY function was used to obtain more accurate estimations of results. In accordance with the design of the CHMS, the syntax: svyset SITE [pweight=WGT_FULL], strata(prov) was used to cluster data by collection site and stratify by province, and the full sample weights provided by Statistics Canada were applied, using the pweight function to rescale the weights to the number of survey participants. Through this design, p-values were based on 11 degrees of freedom.

2. Descriptive analyses were conducted to examine proportions, means and standard deviations for all relevant measures using the SVY function as described above. In order to meet Statistics Canada confidentiality and vetting requirements for releasing proportions and frequencies (i.e., a minimum of 30 cases per cell), some response options were grouped together for reporting. For sociodemographic variables and other covariates, this was done as outlined in the Measures section, and these groupings were kept consistent throughout the analysis. For beverage variables, these groupings were used solely for the purpose of reporting proportions and frequencies, and the raw count data was used when fitting models.

3. Models were run for four outcome measures: 1) dental decay, 2) periodontal health, 3) self-reported oral health and 4) the oral health index. The outcomes of dental decay,

periodontal health and oral health index were counts, whereas self-reported oral health was a categorical measure. For each outcome measure, three models were run; the first in which each beverage type was included as a separate variable, the second in which sugary beverages were grouped, and acidic beverages being grouped together in the third outcome. The models were fitted using the SVY function to examine differences between frequency of consumption of milk, water, regular soft drinks, diet soft drinks, sports drinks, fruit juices, fruit-flavoured drinks, vegetable juices, and alcohol, as well as between milk and water and sugary or acidic beverages. Models included socio-demographic variables (age, gender, education, and household income), oral health behaviours such as brushing, flossing, and visiting a dental professional, smoking, and diet variables, specifically (non-milk) dairy and fibre consumption. Two-way interactions were examined between education and income in exploratory analysis; however, only one of the level contrasts was significant for one of the outcome measures, so it was not included in the final models in order to better examine the individual effects of income and education. Two-way interactions were examined between types of beverages, specifically water and sugary beverages, water and acidic beverages, milk and sugary beverages, and milk and acidic beverages, in order to examine whether water and milk confer a protective benefit to oral health over other types of beverages. It was important to include age and gender to the list of covariates, as they play a key role in the sampling design. Further contrasts were also run to examine significant differences between different beverage types in order to better interpret results.

For the outcomes measured using count data (dental decay, periodontal health and the oral health index), Poisson regression was used to obtain model estimates. Poisson regression is generally used for predictive modelling of count data for rare events and "expresses the log outcome rate as a linear function of a set of predictors" (Oxford Journals (OJ), 2013, p. 136). In order to verify the assumption that the data fit a Poisson distribution and thus Poisson regression was the most appropriate function to use, negative binomial regression models were also run using the same lists of variables. Negative binomial regression is also used to model count data but accounts for over-dispersion, which is often observed in count variables, and a negative binomial distribution is more commonly seen in social data (Piza, 2012). The Poisson regression and negative binomial regression models were then compared for consistency between the two models in order to ensure that assumptions for Poisson regression had been met. For the dental decay and periodontal health outcomes, the Poisson and negative binomial regression models appeared to be identical; therefore, only the results from the Poisson regression models are displayed here. The Poisson models were chosen as Poisson regression is a more commonly used and understood model for count data. Although not identical, the results obtained from the Poisson and negative binominal regression models for the oral health index were highly consistent, with the same variables being significant, variables having the same direction of effect, and the magnitudes of the incidence-rate ratio (IRR) being within 0.01 of each other. Thus, Poisson regression models were also chosen to be displayed for the OHX for purposes of consistency. The results of the Poisson regression models were given as the incidence-rate ratio (IRR), in addition to p-values and 95%

confidence intervals. The IRR is also often referred to as simply the “rate ratio”, and is comparable to an odds ratio, but for Poisson regression (OJ, 2013). The IRR is the ratio of the expected incidence rate at x+1 and the expected incidence rate at x (OJ, 2013).

Self-perceived oral health was a categorical outcome, and thus ordinal regression was used to obtain model estimates. Ordinal regression, more specifically the ordered logit models, is used for ordered data which meets the proportional odds assumption that the relationship between any of the two outcome groups is essentially the same (Heeringa, West & Berglund, 2010). Based on this assumption, the coefficients are the same in all of the models (for each level), meaning the only difference between the models is in the intercept terms, and the estimates from the separate binary models can be pooled together to give one set of regression coefficients (Heeringa et al., 2010). As the data analysis centre did not have the resources necessary to test the assumption that ordinal regression would be suitable for this model, multiple linear regression models were also run using the same list of variables. Linear regression is used to model the relationship between variables that are assumed to depend linearly on their parameters (Heeringa et al., 2010). Linear regression is based upon a conditional probability distribution of y given the value of x, as opposed to a joint probability distribution of both x and y as is the case in multivariate linear regression (Heeringa et al., 2010). Ordinal scales can often generate data with skewed distributions, whereas linear regression is less prone to this limitation, so accordance between the two methods reduces the likelihood of inaccurate results (Norris et al., 2006). Upon comparison, the ordinal and linear regression models were found to be very similar, in terms of which variables were significant and the direction of their effects. There was variation in the magnitude of the effects, and the acidic beverage consumption models differed with sex being significant in the ordinal model but not the linear regression model; otherwise, any differences between models were unlikely to affect results and conclusions. Due to the high degree of similarity, only the ordinal regression models are displayed here, as theoretically this was the correct model to fit for the categorical data.

4. In order to better illustrate the effects of the beverage variables on the outcomes, participants were divided into four or five groups based on their consumption pattern of a specific beverage. The mean score of each outcome was then calculated and graphed in order to observe any trends in the association between a specific beverage and outcome. Due to the large number of beverage variables with very few emerging as significant predictors, these analyses were only run for water, milk, the Sugary Beverage Consumption Index, the Acidic Beverage Consumption Index and any other beverage variables found to be significant in the models.

5. In order to determine the effect of the interaction between different beverage types, the lincom command was used to determine the linear combination of estimators. This analysis was completed for the beverage interactions as described above (water and sugary beverages, water and acidic beverages, milk and sugary beverages, and milk and acidic beverages in all relevant models). The results were then compared graphically as to the outcome when the consumption of one beverage was held constant and the other increased, and vice versa.

6. Bootstrapping analysis using the SVY function was completed on final models, descriptives and other analyses in order to obtain more precise estimates and confidence intervals, as this analysis took into account the complex sampling frame and clustering of households.

Regression analyses allowed for examination of socio-demographic predictors of beverage consumption and oral health outcomes in the Canadian population within the previously described analyses. All analyses were conducted using the survey weights, as described in the Data User Guide for Cycle 1 (Statistics Canada, 2011). Stata Version 12.1 SVY module was used for all analyses. These estimation procedures used Taylor linearization to compute variance estimates that account for the complex survey design used to collect the data; see Binder (1983). However, the CHMS Data User Guide (section 11.3) indicated that Taylor linearization does not fully account for the complex survey design used to collect the CHMS sample, and recommended using the Bootstrapped weights created by Statistics Canada. Although exploratory analyses were done using the SVY function and took into account clustering by collection site, stratifying by province and the survey weights (WGT_FULL) created by Statistics Canada, all final analyses used the bootstrapped weights. This was a reasonable method of analysis as Taylor linearization gave close estimations of our final results for exploratory analyses without the significant time investment the bootstrapping function took to perform. All final and reported results were acquired using bootstrapping to obtain the most accurate results and as per Statistics Canada requirements

Models

Four models were run with each of the four oral health indicators as an outcome: dental decay, periodontal health, self-rated oral health, and the oral health index. For each of the models, the following covariates were used: age, sex, education, income, visits to dental professional, brushing, flossing, smoking habits, (non-milk) dairy consumption and fibre consumption. An SES variable (education x income interaction) was also used in exploratory analysis, but as only one of the nine possible interaction levels was significant in only one of the models, this variable was excluded from the final models so as not to obscure the effects of the income and education variables singularly.

In order to examine differences between individual types of beverages versus beverage categories (i.e., sugary beverage index and acidic beverage index), three sub-models were fitted for each of the four outcomes: Model A included individual beverage types and covariates included as predictor variables; Model B included milk, water, diet soft drinks, vegetable juices, covariates, and the sugary beverage index; and Model C included milk, water, covariates and the acidic beverage index. In total, 12 models were fitted.

Two-way interaction terms were examined between milk or water, and the sugary or acidic beverage indices in Models B and C, respectively.

The variables and outcomes used in each model were as described in Table 1 below.

Table 1. Models

Model	Outcome	Predictors	Covariates
1a – Main Effects	Dental Decay	Water, milk, regular soft drinks, diet soft drinks, sports drinks, fruit juices, fruit-flavoured drinks, vegetable juice, alcohol	age, sex, education, income, visits to dental professional, brushing, flossing, smoking habits, dairy consumption, fibre consumption
1b – Sugary Beverage Consumption	Dental Decay	Water, milk, sugary beverage index, diet soft drinks, vegetable juices, water x sugary beverage index (interaction variable), milk x sugary beverage index (interaction variable)	
1c – Acidic Beverage Consumption	Dental Decay	Water, milk, acidic beverage index, water x acidic beverage index (interaction variable), milk x acidic beverage index (interaction variable)	
2a – Main Effects	Periodontal Health	Water, milk, regular soft drinks, diet soft drinks, sports drinks, fruit juices, fruit-flavoured drinks, vegetable juice, alcohol	
2b – Sugary Beverage Consumption	Periodontal Health	Water, milk, sugary beverage index, diet soft drinks, vegetable juices, water x sugary beverage index (interaction variable), milk x sugary beverage index (interaction variable)	
2c – Acidic Beverage Consumption	Periodontal Health	Water, milk, acidic beverage index, water x acidic beverage index (interaction variable), milk x acidic beverage index (interaction variable)	
3a – Main Effects	Self-Rated Oral Health	Water, milk, regular soft drinks, diet soft drinks, sports drinks, fruit juices, fruit-flavoured drinks, vegetable juice, alcohol	
3b – Sugary Beverage Consumption	Self-Rated Oral Health	Water, milk, sugary beverage index, diet soft drinks, vegetable juices, water x sugary beverage index (interaction variable), milk x sugary beverage index (interaction variable)	
3c – Acidic Beverage Consumption	Self-Rated Oral Health	Water, milk, acidic beverage index, water x acidic beverage index (interaction variable), milk x acidic beverage index (interaction variable)	
4a – Main Effects	Oral Health Index	Water, milk, regular soft drinks, diet soft drinks, sports drinks, fruit juices, fruit-flavoured drinks, vegetable juice, alcohol	

4b – Sugary Beverage Consumption	Oral Health Index	Water, milk, sugary beverage index, diet soft drinks, vegetable juices, water x sugary beverage index (interaction variable), milk x sugary beverage index (interaction variable)	
4c – Acidic Beverage Consumption	Oral Health Index	Water, milk, acidic beverage index, water x acidic beverage index (interaction variable), milk x acidic beverage index (interaction variable)	

RESULTS

Descriptive Analyses

Descriptive analyses were carried out on all predictor and outcome variables included in the analysis. Means, standard deviations (sd) and proportions, both raw values and percentages, are displayed below for each of the variables. The data have been stratified by province, clustered by collection site and CHMS survey weights have been applied. Weighted and bootstrapped data have been used, and some responses have been grouped in accordance with Statistics Canada confidentiality and vetting rules. Due to rounding, the reported proportions may not sum to the expected amounts (1534 and 100%).

Sociodemographic Variables

Descriptive analyses of the sociodemographic variables are displayed in Table 2, and were roughly equal to those characteristics in the Canadian population. Descriptive statistics for the other covariates included in the analysis are also displayed in Table 2.

Table 2. Sociodemographic and Covariate Descriptive Statistics (n=1543)

Variable	Mean	Standard Deviation	Proportion
Age	21.1	5.5	
12-15			20.5%
16-19			20.2%
20-24			27.8%
25-30			31.5%
Sex			
Male			51.3%
Female			48.7%
Education			
No Post-Secondary			10.7%
Other Post-Secondary			10.4%
Post-Secondary Graduate			75.6%
Education Not Stated			3.3%
Income			
Lowest Incomes			6.8%
Middle Income			12.4%
Upper Middle Income			30.5%
Highest Income			39.5%
Smoking Habits	2.5	0.8	
Current Smoker			20.8%
Former Smoker			9.3%
Never Smoked			69.9%
Brushing (times per week)	12.8	4.8	
Flossing (times per week)	2.2	3.2	
Frequency Visiting Dental Professional	4.0	1.1	
Never			3.1%
Emergency			9.4%
< Once per Year			11.2%
Once per Year			38.5%
> Once per Year			37.8%
Dairy Consumption (times per week)	4.2	4.0	
Fibre Consumption (times per week)	37.8	15.6	

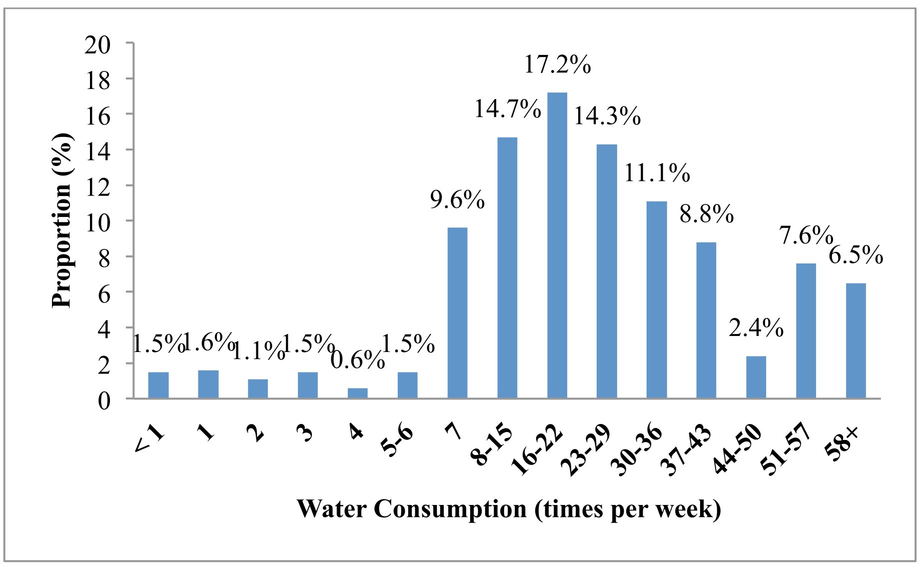
Beverage Variables

Means, standard deviations, and proportions were also calculated for the beverage variables and are displayed in the tables and graphs below. Please note that all values have been weighted, clustered and stratified as described above.

Beverage Variables – Water

The mean weekly water consumption for the weighted sample was 28.9 times per week (sd=20.9). As the relatively large standard deviation suggests, there was a lot of variation in the frequency of water consumed on a weekly basis. Most 12-30 year old Canadians consumed water at least one time per day on average. After consuming water 7 times per week, response options have been grouped to roughly equate to unit increases in the number of times water was consumed per day, in order to comply with Statistics Canada confidentiality and vetting rules.

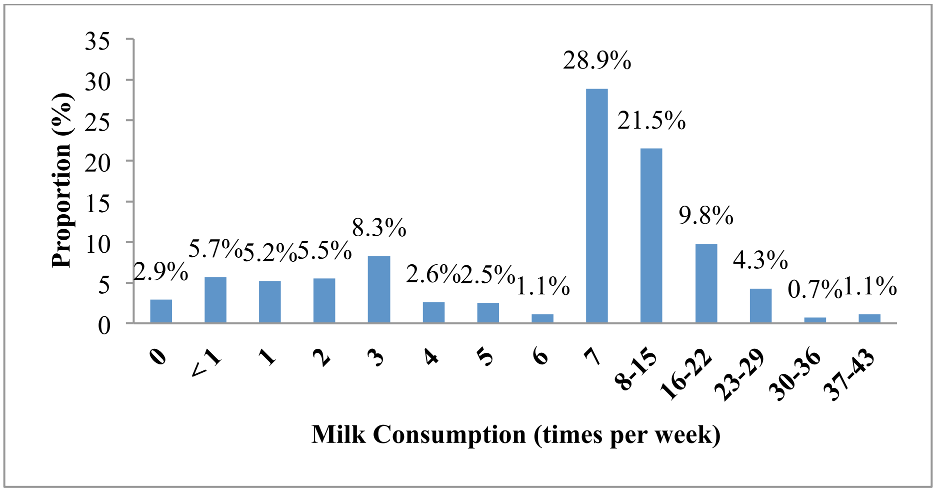
Figure 1. Response Proportions of Weekly Water Consumption



Beverage Variables – Milk

The average milk consumption in the weighted sample was 9.7 times per week (sd=8.5). Again, as the relatively large standard deviation suggests, there was a lot of variation in the amount of milk consumed on a weekly basis. Over 50% of 12-30 year old Canadians consumed milk at least one time per day on average.

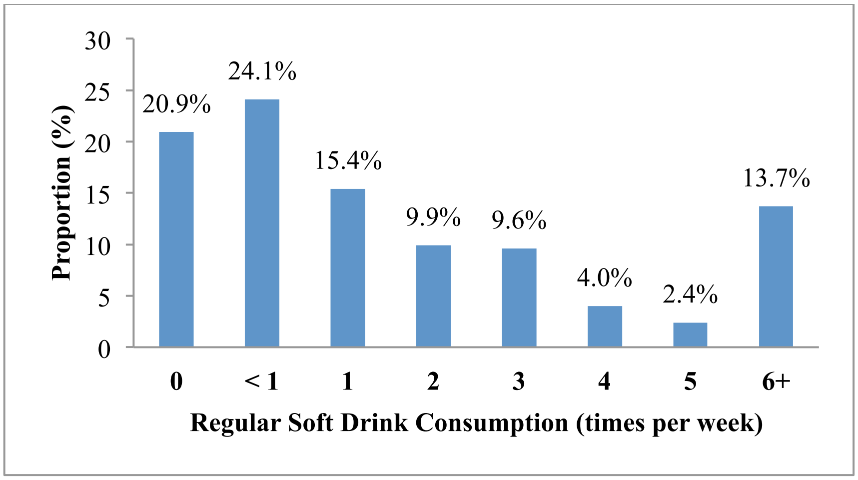
Figure 2. Response Proportions of Weekly Milk Consumption



Beverage Variables – Regular Soft Drinks

On average, soft drinks were consumed 2.6 times per week (sd=4.8), with a large variation in individual responses. Almost half of the weighted study population reported consuming soft drinks less than one time per week. 210 respondents (13.7%) consumed soft drinks 6 or more times per week.

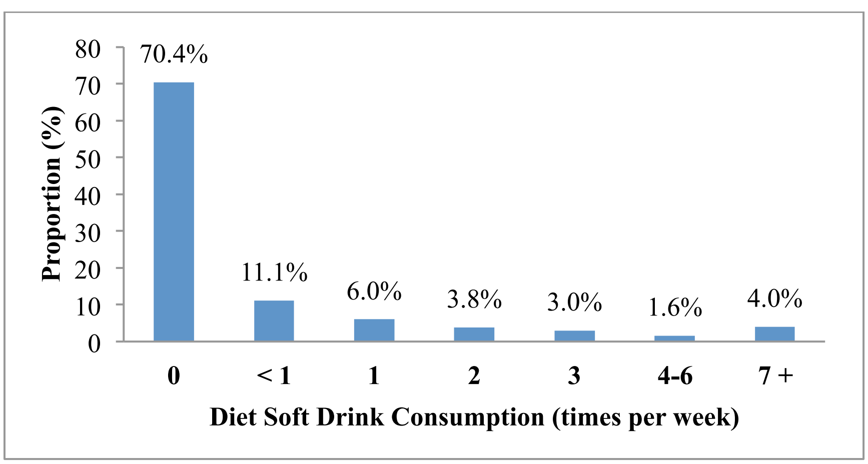
Figure 3. Response Proportions of Weekly Soft Drink Consumption



Beverage Variables – Diet Soft Drinks

The average number of times diet soft drinks were consumed per week by the weighted sample was 0.8 (sd=2.7). 70.4% of the weighted sample did not consume diet soft drinks on a regular basis, and another 11.1% consumed diet soft drinks less than once per week.

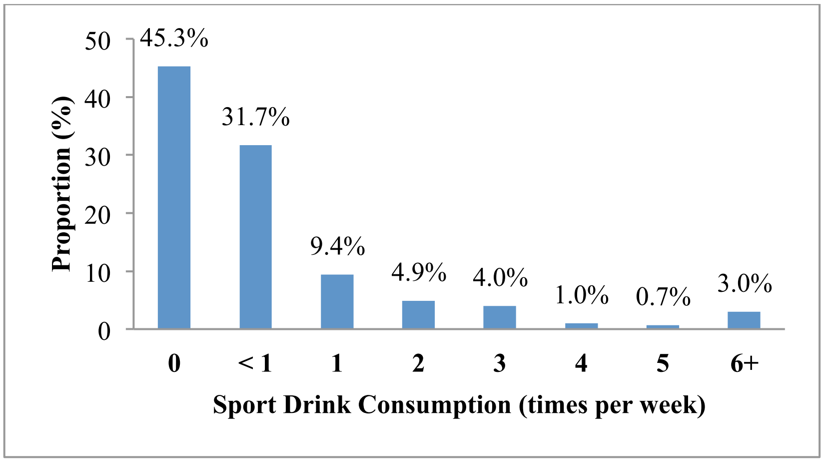
Figure 4. Response Proportions of Weekly Diet Soft Drink Consumption



Beverage Variables – Sports Drinks

Sports drinks were consumed a mean number of 0.8 times per week (sd=2.1) by the sample population. Most did not regularly consumed sports drinks (45.3%), or consumed them less than one time per week (31.2%).

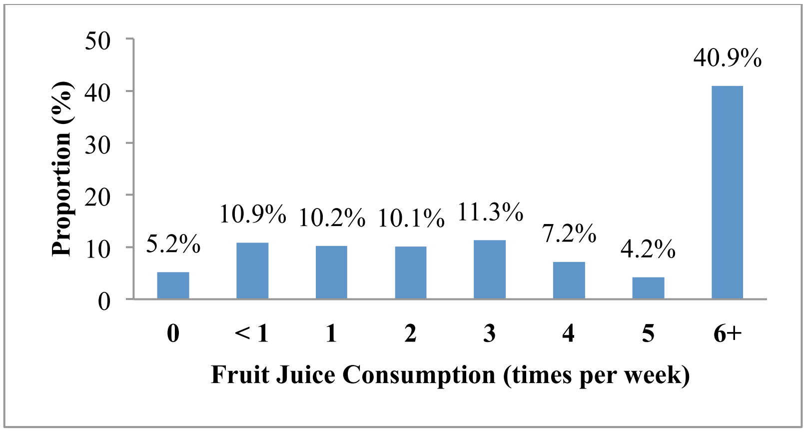
Figure 5. Response Proportions of Weekly Sports Drink Consumption



Beverage Variables – Fruit Juices

On average, the weighted study population consumed fruit juices 5.5 times per week (sd =6.0). The largest consumption group consumed fruit juices on 6 or more occasions each week (40.9%), although there was great variation in responses.

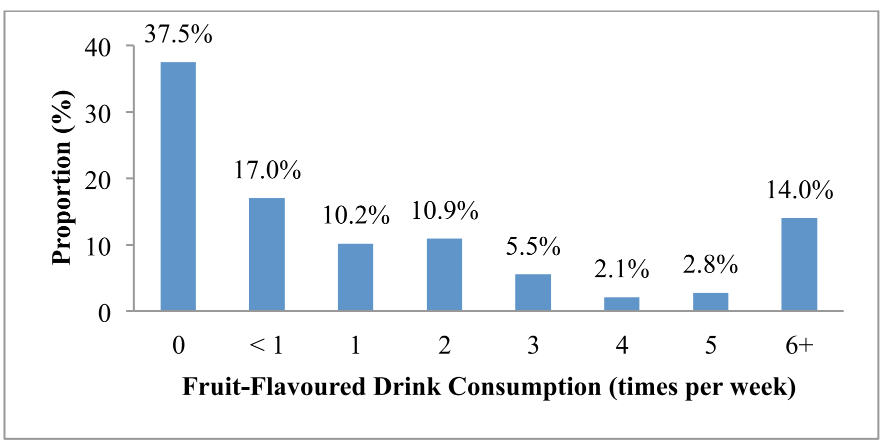
Figure 6. Response Proportions of Weekly Fruit Juice Consumption



Beverage Variables – Fruit-Flavoured Beverages

The weighted average study participant consumed 2.1 fruit-flavoured beverages per week (sd=4.2). Just over half of all respondents consumed either a frequency of zero (37.5%) or less than one (17.0%) fruit-flavoured beverage during the average week, with only 14.0% consuming fruit-flavoured beverages six or more times each week.

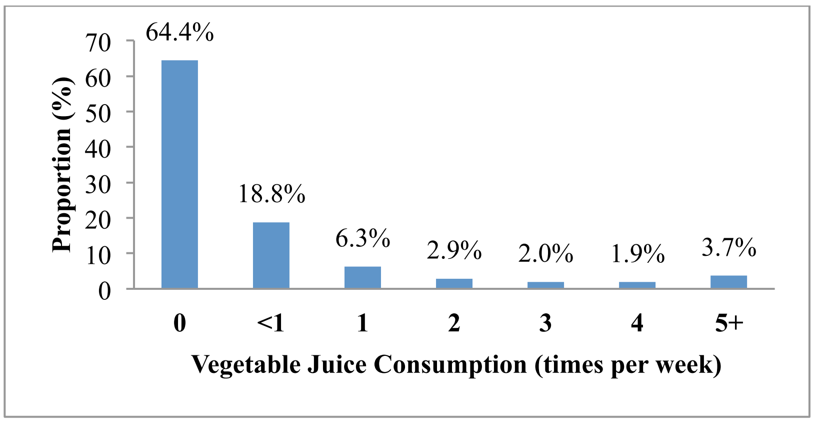
Figure 7. Response Proportions of Weekly Fruit-Flavoured Drink Consumption



Beverage Variables – Vegetable Juice

Vegetable juice consumption was generally low in the weighted study population, with participants consuming vegetable juice an average of 0.6 times (sd=1.7) per week. The vast majority of participants (64.4%) did not consume vegetable juice at all, and 18.8% consumed it less than once per week.

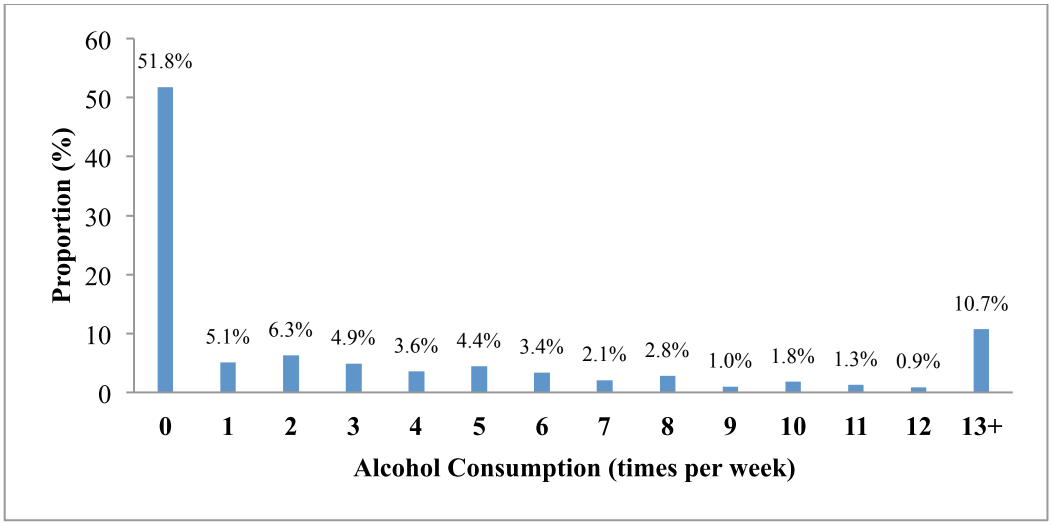
Figure 8. Response Proportions of Weekly Vegetable Juice Consumption



Beverage Variables – Alcohol

The average weekly alcohol consumption of the weighted sample was 4.3 times per week (sd=8.5). Just over half (51.8%) did not consume any alcohol, due predominantly to the fact that a large proportion of the study population was not of legal age to consume alcohol in Canada.

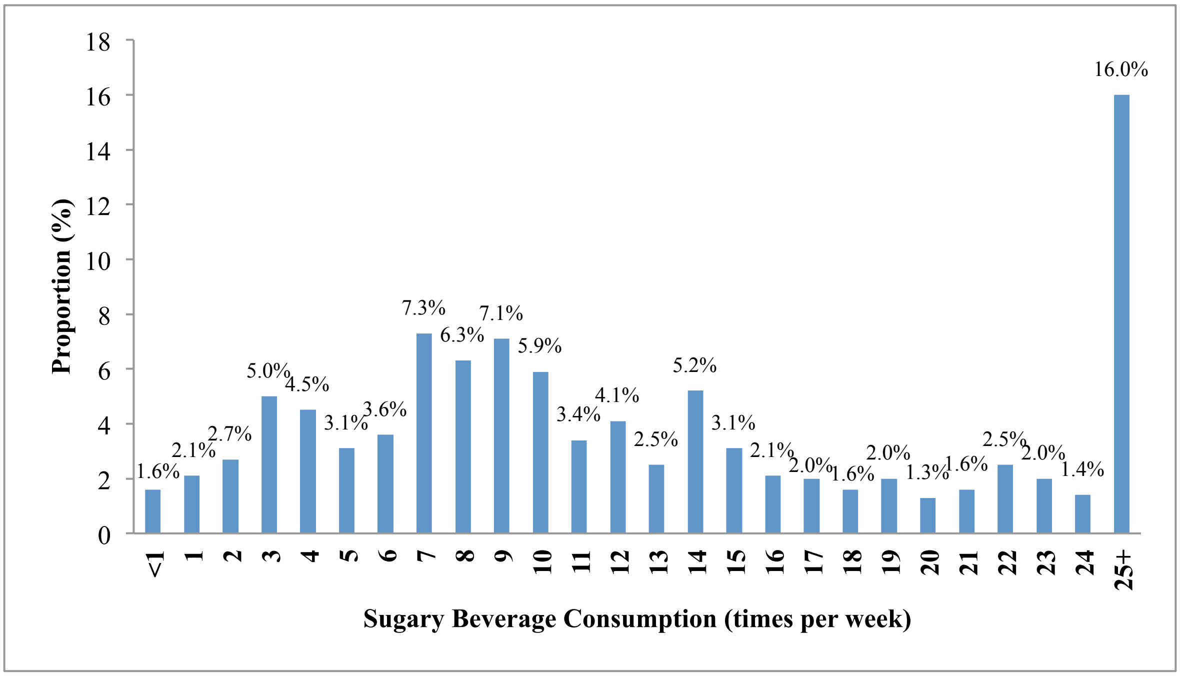
Figure 9. Response Proportions of Weekly Alcohol Consumption



Beverage Variables – Sugary Beverage Index

As the sugary beverage consumption index consisted of the consumption sums of five different beverages, there was great variation in responses given for how often respondents drank sugary beverages each week. On average, sugary beverages were consumed 15.3 times per week (sd=13.3) by the weighted sample, and almost all individuals consumed at least one sugary beverage each week (n=1510; 98.4%).

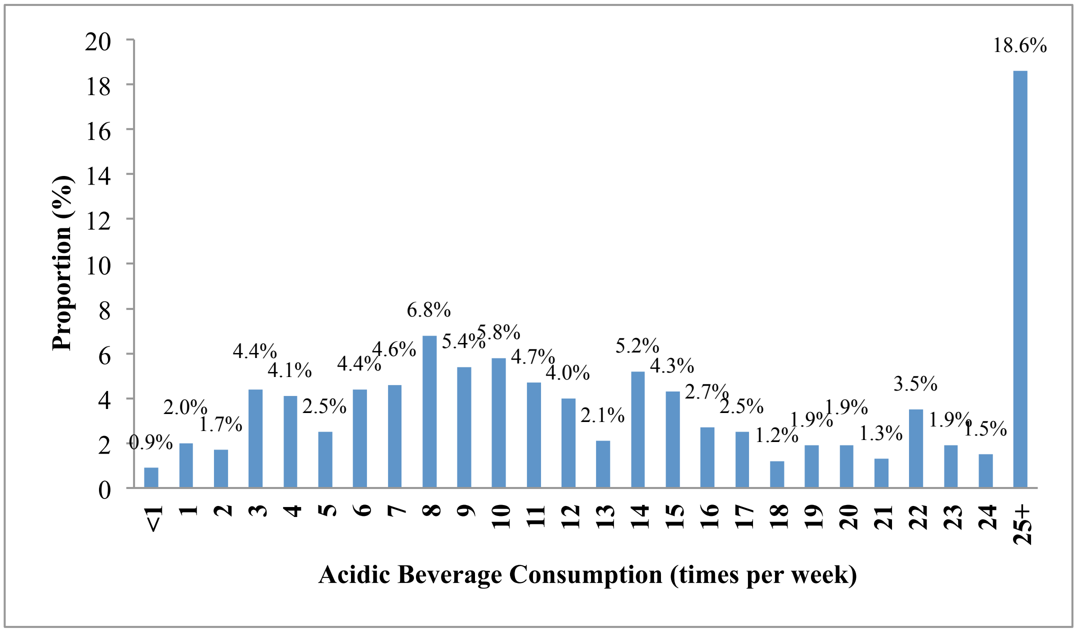
Figure 10. Response Proportions of Weekly Sugary Beverage Consumption



Beverage Variables – Acidic Beverage Index

The Acidic Beverage Consumption Index also showed a lot of variation between individual responses, as again it is a compilation index, this time of seven separate beverages. The mean frequency of acidic beverages consumed in a week by the weighted sample was 16.6 times (sd=13.7), with only 0.9% consuming acidic drinks less than once per week.

Figure 11. Response Proportions of Weekly Acidic Beverage Consumption



Outcome Variables

Descriptive analyses, including means, standard deviations, and proportions are displayed below in table and graphical format for each of the four outcome variables. Please note that all values have been weighted, clustered and stratified as described above.

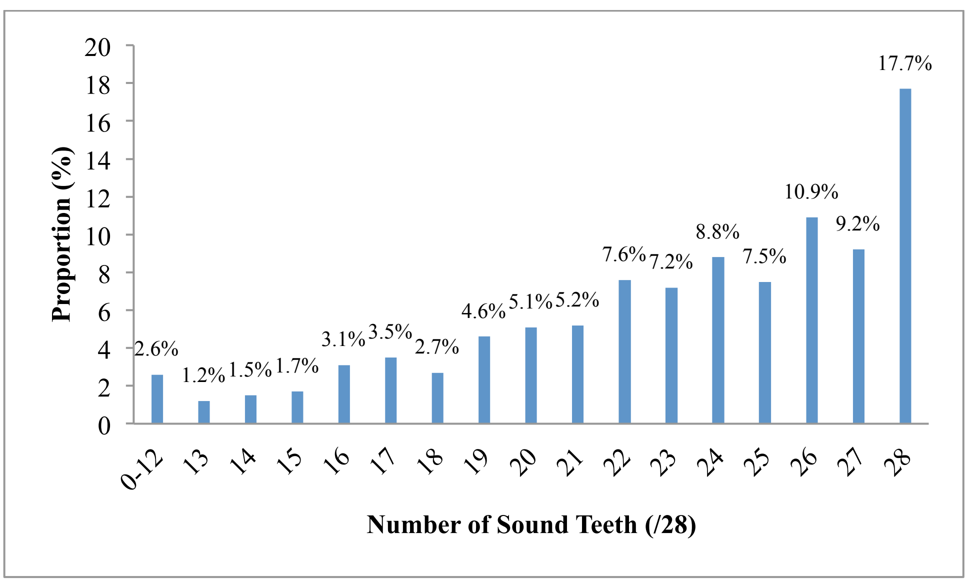
Outcome Variables – Dental Decay

The average patient in the weighted study sample had 23 sound teeth (never decayed nor restored) out of a possible 28 in their mouth, with a standard deviation of 4.6. Of the weighted sample, 17.7% had a full 28 sound teeth, so did not have a decayed, restored or missing tooth in their mouth. Participants with 12 or less sound teeth in their mouth have been grouped together for reporting purposes, in order to comply with Statistics Canada guidelines.

Table 3. Dental Decay Descriptive Statistics (n=1534)

Number of Sound, Never Decayed Teeth	Mean	Standard Deviation	Proportion
Dental Decay	23.0	4.6	
0-12			2.6%
13			1.2%
14			1.5%
15			1.7%
16			3.1%
17			3.5%
18			2.7%
19			4.6%
20			5.1%
21			5.2%
22			7.6%
23			7.2%
24			8.8%
25			7.5%
26			10.9%
27			9.2%
28			17.7%

Figure 12. Response Proportions of Dental Decay



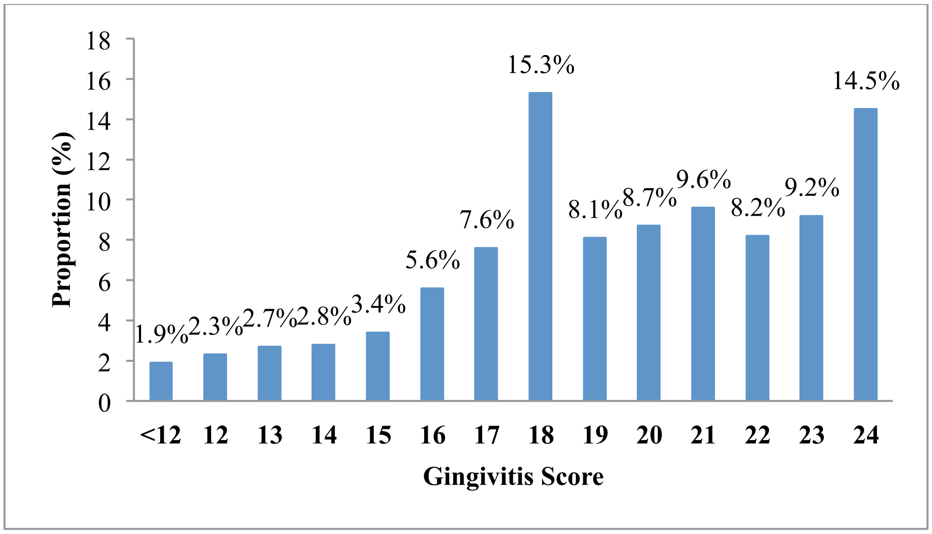
Outcome Variables –Periodontal Health

The Periodontal Health outcome is expressed as a score out of 24 with higher scores indicating better periodontal health. The mean gingivitis score of the weighted study population was 19.4 (sd=3.5). Of the weighted sample, 14.5% had perfect gingivitis scores of 24, whereas only 1.9% fell into the lowest score groups of having a gingivitis score of less than 12.

Table 4. Periodontal Health Descriptive Statistics (n=1534)

Gingivitis Score	Mean	Standard Deviation	Proportion
Periodontal Health	19.4	3.5	
<12			1.9%
12			2.3%
13			2.7%
14			2.8%
15			3.4%
16			5.6%
17			7.6%
18			15.3%
19			8.1%
20			8.7%
21			9.6%
22			8.2%
23			9.2%
24			14.5%

Figure 13. Response Proportions of Gingivitis Score



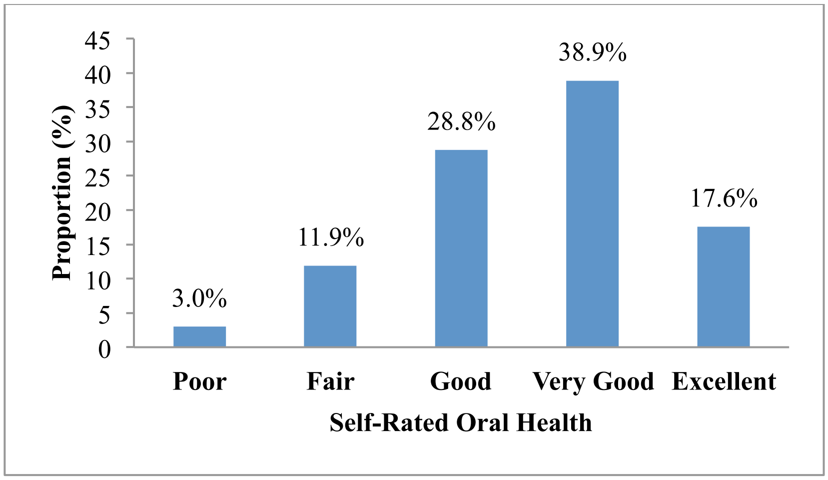
Outcome Variables – Self-Rated Oral Health

The average respondent from the weighted sample rated their oral health as falling somewhere between good and very good. The greatest proportion of respondents self-rated their oral health as very good (38.9%), with 3.0% claiming to have poor oral health, 11.9% reporting fair oral health, 28.8% responding with good oral health, and 17.6% perceiving their oral health as excellent.

Table 5. Self-Rated Oral Health Descriptive Statistics (n=1534)

Self-Rated Oral Health	Mean	Standard Deviation	Proportion (n)
Self-Rated Oral Health	3.6	1.0	
Poor (1)			3.0%
Fair (2)			11.9%
Good (3)			28.8%
Very Good (4)			38.9%
Excellent (5)			17.6%

Figure 14. Response Proportions for Self-Rated Oral Health



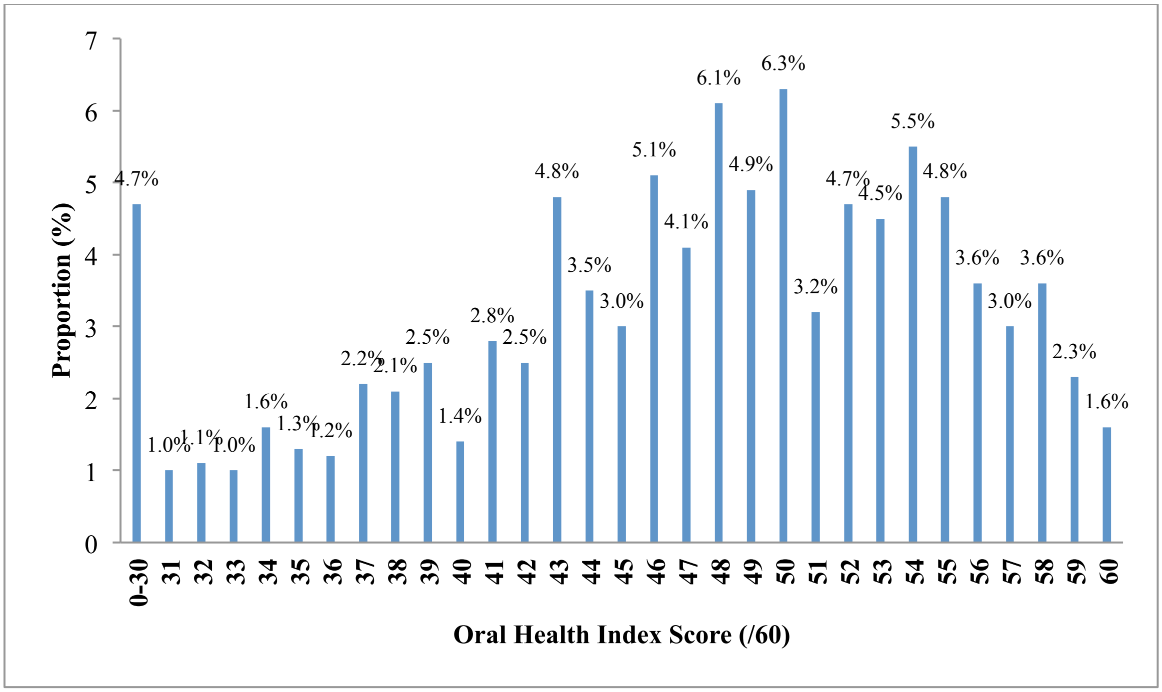
Outcome Variables – OHX

The calculated Oral Health Index scores for the weighted study participants varied widely, with an average score of 46.9 and a standard deviation of 8.4. 1.6% of the weighted study population had a perfect Oral Health Index score of 60. In order to comply with Statistics Canada confidentiality and vetting rules, scores of 30 or less have been combined for reporting purposes.

Table 6. Oral Health Index Descriptive Statistics (n=1534)

Oral Health Index	Mean	Standard Deviation	Proportion (n)
OHX	46.9	8.4	
0-30			4.7%
31			1.0%
32			1.1%
33			1.0%
34			1.6%
35			1.3%
36			1.2%
37			2.2%
38			2.1%
39			2.5%
40			1.4%
41			2.8%
42			2.5%
43			4.8%
44			3.5%
45			3.0%
46			5.1%
47			4.1%
48			6.1%
49			4.9%
50			6.3%
51			3.2%
52			4.7%
53			4.5%
54			5.5%
55			4.8%
56			3.6%
57			3.0%
58			3.6%
59			2.3%
60			1.6%

Figure 15. Response Proportions for Oral Health Index Scores



Models

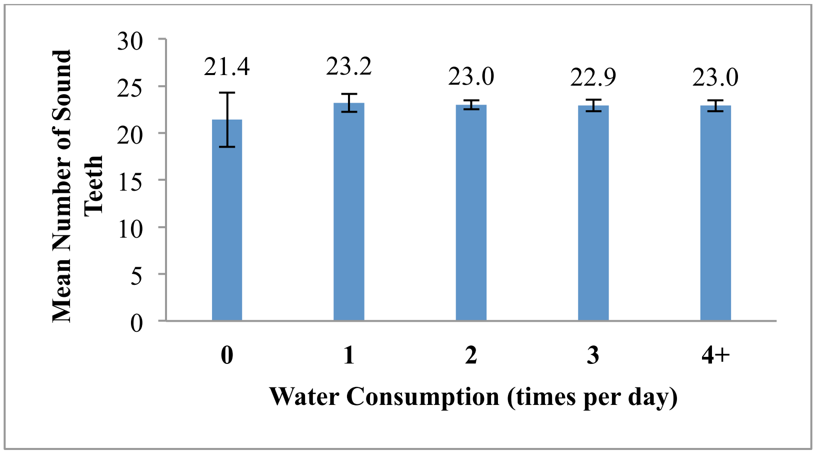
After completing initial exploratory analyses, 12 models were fitted in order to better understand the association between the predictor variables, especially beverage consumption variables, and each of the four outcomes. The models were fitted as described in the Analysis section. Below, the incidence-rate ratios (IRR), 95% confidence intervals (CI) and p-values for each of the variables in the models are displayed in table format, with significant predictor variables bolded. For each of the categorical covariates, the multiple degrees of freedom test was reported as the overall p-value for the category. Overall degrees of freedom tests are reported for age (3 degrees of freedom (3df)), education (3df), income (4df), smoking habits (2df), and frequency of dental care (3df).

Main Effects Model – Dental Decay

The first model fitted looked at the outcome of dental decay with each of the nine beverage variables being included separately in the model. As shown in Table 7, regular soft drink consumption, fruit-flavoured drink consumption, age, sex, frequency of flossing teeth and fibre consumption were significantly associated with dental decay. Regular soft drink consumption had a detrimental impact on dental decay, with every increase of 1 regular soft drink per week causing the number of sound teeth in the mouth to decrease by 1.004 times (or increase by 0.996 times; 95% CI = 0.993-0.998). Fruit-flavoured beverage consumption also had a negative impact on the number of sound teeth in the patient's mouth, causing a decrease in the number of sound teeth by 1.003 times (95% CI = 0.994 – 0.9995) for each one unit increase in number of fruit-flavoured beverages consumed each week. Consumption of water, milk, diet soft drinks, fruit juices, sports drinks, vegetable juice and alcohol were not significant in this model.

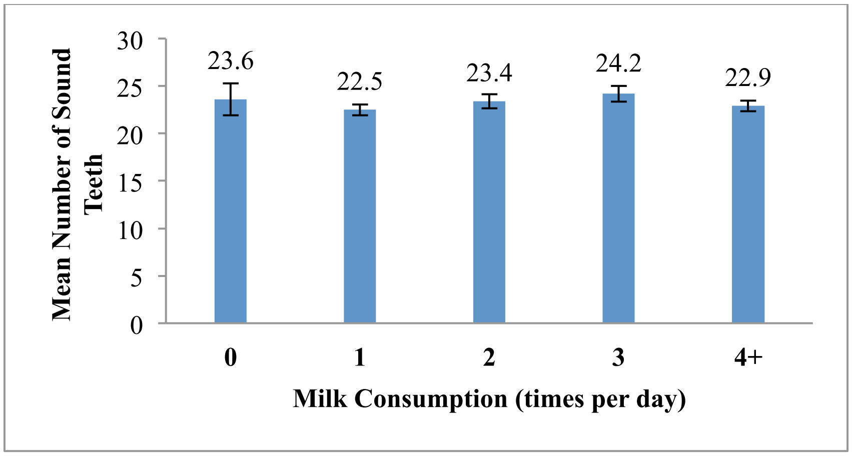
In order to further investigate the effects of beverage consumption on dental decay, the mean number of sound teeth was calculated for differing consumption patterns of certain beverages, and is displayed below. Although the categories chosen were arbitrary and restricted by Statistics Canada reporting requirements, some interesting trends can be seen. These differences for water consumption are displayed in Figure 16 below. Since water consumption was not a significant variables it is not surprising that no clear pattern emerges in the graph; however those who do not consume water (0 times per day) have much fewer sound teeth on average than those who consumed at least one glass of water per day. Thus, this graph suggests that not consuming water on a regular basis has a harmful effect on one's teeth in terms of dental decay, although the effect is not significant.

Figure 16. Effect of Water Consumption on Dental Decay



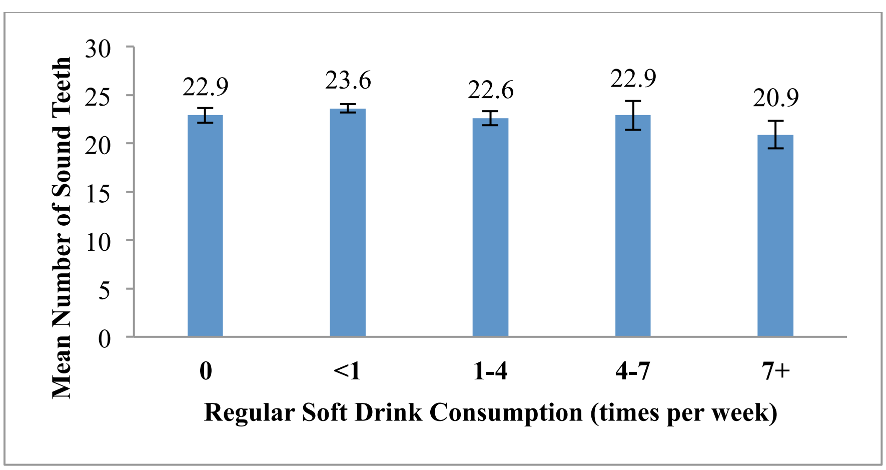
The association between milk consumption and dental decay was also not significant in the main effects model and did not exhibit a clear pattern. In Figure 17, it can be seen that drinking 3 glasses of milk per day had the most positive effect on dental decay and drinking 1 glass of milk per day had the most detrimental effect, but no clear overall trend was displayed. However, milk consumption had a significant impact on dental decay in the sugary and acidic index models

Figure 17. Effect of Milk Consumption on Dental Decay



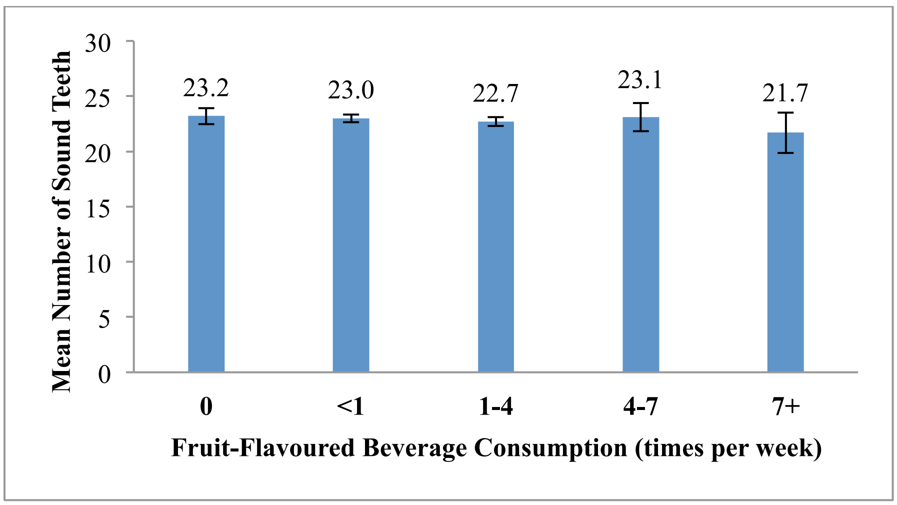
Of particular interest in the main effects model for dental decay are the two significant beverages, namely regular soft drinks and fruit-flavoured beverages. In Figure 18 below, it can be observed that regular soft drink consumption did not show a clear trend in regards to its effect on dental decay, which may be due to the presentation of the data in arbitrary groupings. However, it does seem that those participants in the highest consumption category (7 or more times consuming soft drinks per week) had lower average scores than any of the other consumption groups.

Figure 18. Effect of Regular Soft Drink Consumption on Dental Decay



The effect of fruit-flavoured beverages on dental decay was similar to regular soft drinks, but to a lesser magnitude, as displayed in Figure 19. Like above, no clear trend was exhibited, but respondents in the highest consumption group had fewer sound teeth on average than other participants, although this impact was not as severe as for regular soft drinks.

Figure 19. Effect of Fruit-Flavoured Beverage Consumption on Dental Decay



In addition to the beverage variables, age as an overall predictor was significant in the model with higher age having a detrimental impact on decay in the mouth: all age contrasts except between the highest two age groups (20-24 vs. 25-30) were significant predictors of dental decay. Interestingly, as the difference in ages being compared became larger, so did the incidence rate ratio in the number of sound teeth; for instance, being of age 16-19 as opposed to age 12-15 was associated with 1.030 times (95% CI = 0.951 – 0.991) fewer sound teeth in the oral cavity whereas being in the 20-24 age group as opposed to between ages 12-15 lead to a 1.108 times (95% CI = 0.847 – 0.939) greater chance of having dental decay in the oral cavity. Sex was also significant with females having 1.038 times less dental decay as males (males had 0.962 times more sound teeth than women; 95% CI = 0.935-0.989). Frequency of flossing teeth was also a significant predictor of dental decay in this model, but surprisingly, an increase in the number of times flossing per week lead to a decrease in the number of sound teeth by 1.004 times fewer sound teeth (95% CI = 0.995 – 0.998). Finally, fibre consumption was also a significant predictor of oral health with each increase of 1 time consuming fibre each week leading to 1.001 times (95% CI = 1.000 – 1.002) more sound and never decayed teeth in the mouth.

Table 7. Correlates of Dental Decay, Main Effects Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.000	0.999 - 1.001	0.489
Milk	1.001	0.999 - 1.003	0.109
Regular Soft Drinks	**0.996**	**0.993 - 0.998**	**<0.001**
Diet Soft Drinks	1.001	0.997 - 1.005	0.433
Sports Drinks	0.999	0.992 - 1.005	0.712
Fruit Juices	1.000	0.998 - 1.001	0.725
Fruit-Flavoured Drinks	**0.997**	**0.994 - 0.9995**	**0.021**
Vegetable Juices	0.999	0.993 - 1.005	0.797
Alcohol	0.999	0.997 - 1.002	0.479
Age			**<0.001**
12-15 vs 16-19	**0.970**	**0.951 - 0.991**	**0.004**
12-15 vs 20-24	**0.892**	**0.847 - 0.939**	**<0.001**
12-15 vs 25-30	**0.850**	**0.795 – 0.908**	**<0.001**
16-19 vs 20-24	**0.919**	**0.881 – 0.959**	**<0.001**
16-19 vs 25-30	**0.876**	**0.826 – 0.928**	**<0.001**
20-24 vs 25-30	0.952	0.896 – 1.013	0.120
Sex	**0.962**	**0.935 - 0.988**	**0.005**
Education			0.571
< Post-Secondary vs Other Post-Secondary	1.045	1.011 – 1.080	0.010
< Post-Secondary vs Post-Secondary Grad	1.032	1.010 – 1.054	0.005
< Post-Secondary vs Not Stated	1.050	0.995 – 1.109	0.077
Other Post-Secondary vs Post-Secondary Grad	0.987	0.962 – 1.014	0.343
Other Post-Secondary vs Not Stated	1.005	0.953 – 1.060	0.849
Post-Secondary Grad vs Not Stated	1.018	0.966 – 1.073	0.504
Income			0.938
Lowest income vs Middle income	1.100	1.033 – 1.171	0.003
Lowest income vs Upper middle income	1.097	1.017 – 1.183	0.017
Lowest income vs Highest income	1.110	1.025 – 1.201	0.010

Lowest income vs Not stated	1.105	1.012 – 1.206	0.026
Middle income vs Upper middle income	0.997	0.958 – 1.037	0.871
Middle income vs Highest income	1.009	0.971 – 1.048	0.660
Middle income vs Not stated	1.004	0.952 – 1.059	0.878
Upper middle income vs Highest income	1.012	0.974 – 1.052	0.541
Upper middle income vs Not stated	1.007	0.959 – 1.058	0.767
Highest income vs Not stated	0.996	0.956 – 1.036	0.827
Smoking Habits			0.889
Current smoker vs Former smoker	1.027	0.950 – 1.111	0.501
Current smoker vs Never smoked	1.022	0.958 – 1.090	0.513
Former smoker vs Never smoked	0.995	0.921 – 1.074	0.889
Frequency of dental care			0.508
Never vs Emergency	1.012	0.905 – 1.130	0.839
Never vs < Once per Year	1.039	0.949 – 1.137	0.409
Never vs Once per Year	1.037	0.946 – 1.137	0.440
Never vs > Once per Year	1.027	0.939 – 1.123	0.558
Emergency vs < Once per Year	1.027	0.955 – 1.104	0.470
Emergency vs Once per Year	1.025	0.957 – 1.098	0.478
Emergency vs > Once per Year	1.015	0.946 – 1.089	0.671
< Once per Year vs Once per Year	0.998	0.956 – 1.042	0.933
< Once per Year vs > Once per Year	0.989	0.952 – 1.026	0.546
Once per year vs > Once per Year	0.990	0.973 – 1.009	0.299
Brushing Teeth	0.999	0.997 - 1.001	0.390
Flossing Teeth	**0.996**	**0.995 – 0.998**	**<0.001**
Dairy Consumption	0.998	0.996 - 1.000	0.054
Fibre Consumption	**1.001**	**1.000 – 1.002**	**0.009**

Sugary Beverage Index Model – Dental Decay

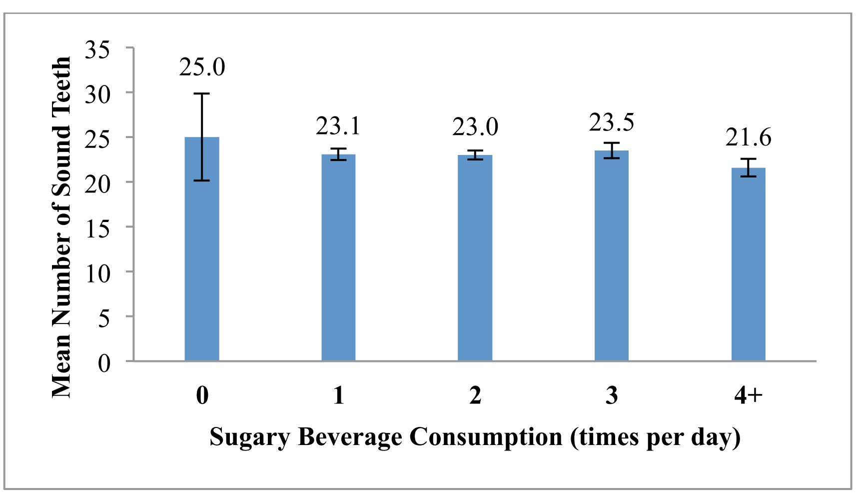
In Model 1b, regular soft drinks, sports drinks, fruit juices, fruit-flavoured beverages and alcohol were added together to create a sugary beverage consumption index. To investigate for any protective or detrimental interaction effect, interactions between water and the Sugary Beverage Index and milk and the Sugary Beverage Index were also included as predictors in the model. Results are given in Table 8.

In this model, the sugary beverage consumption index emerges as being significantly associated with dental decay, with each additional time of sugary beverage consumption each week leading to 1.002 times fewer sound teeth in the mouth

(IRR=0.998; 95% CI = 0.996 – 0.9999).   Milk was also found to be significant in the model and had a protective effect on dental decay; each one unit increase in the number times milk was consumed each week lead to 1.002 times more sound teeth in the oral cavity (95% CI = 1.000 – 1.004). Water, diet soft drink and vegetable juice consumption were not significant in this model, nor were the two interaction variables.

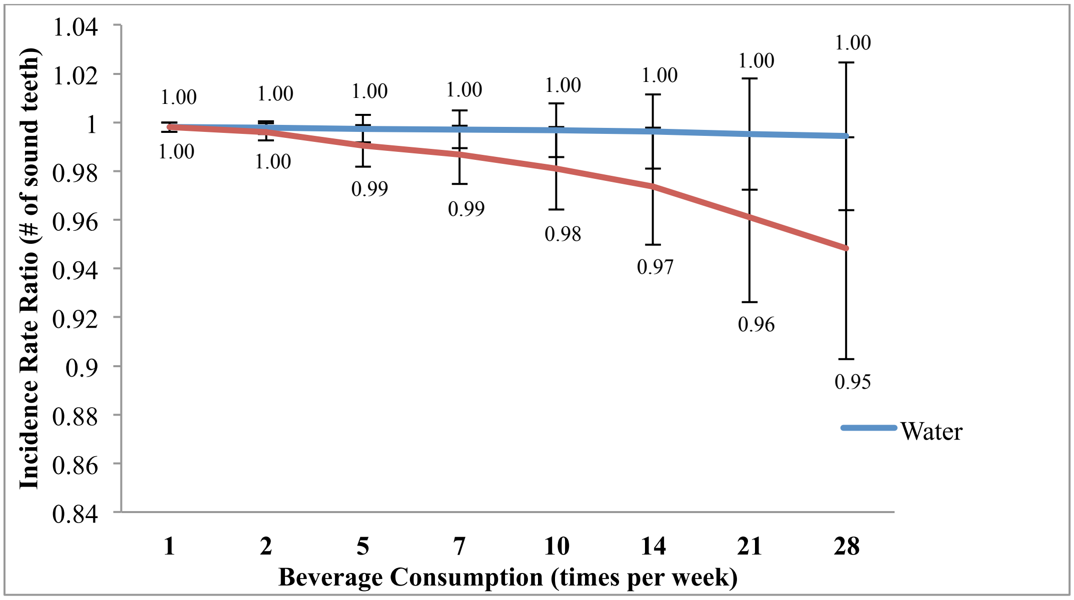
In order to better conceptualize the effect of sugary beverage consumption on dental decay, the mean number of sound teeth for each group was calculated and graphed, after being grouped by average number of times sugary beverages were consumed per week. As displayed in Figure 20, those who did not consume any sugary beverages in a day had less dental decay on average than those who consumed sugar-containing beverages at least once per day. Furthermore, those who drank 4 or more sugary beverages per day had much fewer sound teeth on average than those who consumed less sugary beverages. Participants who drank 1, 2 or 3 sugary beverages per day had about the same number of sound teeth on average.

Figure 20. Effect of Sugary Beverage Consumption on Dental Decay



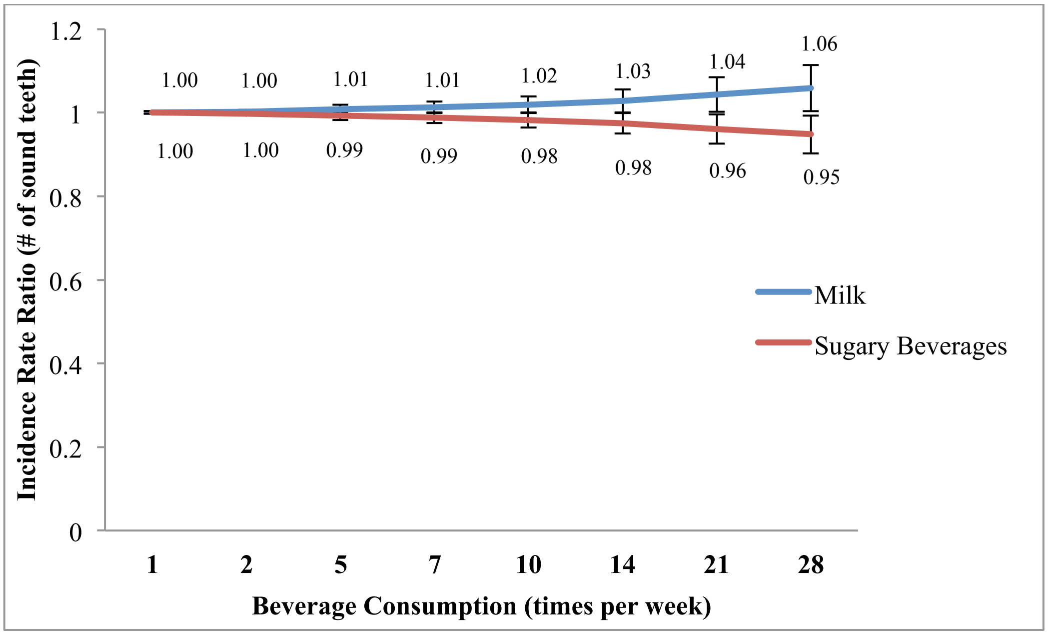
Not only were the individual beverages consumed of interest, but also the interactions between beverages hypothesized to be harmful and beneficial to oral health. The interaction between water and sugary beverage consumption is displayed in Figure 21 below. The interaction between water and sugary beverages, as well as water on its own, were not significant, and thus do not seem to have a particular impact on oral health. Although not significant, both water and sugary beverage consumption appeared to cause a reduction in the number of sound teeth in the mouth. The reduction due to increased water consumption was rather minimal, with each extra time consuming water interacting with one sugary beverage leading to 0.0002 reduced incidence odds ratio. Clinically, this effect is negligible, as even increasing water consumption by 10 times per day would only lead to an IRR of 1.014 times more sound teeth. An increase of sugary beverage consumption, when holding water consumption constant, lead to 1.0019 times fewer sound teeth in the oral cavity. Thus, consuming sugary beverages 10 more times per day would lead to 1.142 times fewer sound teeth in the oral cavity.

Figure 21. Interaction of Water and Sugary Beverage Consumption



The interaction between milk and sugary beverage consumption was also not significant. For each increase in number of times milk was drank per week (holding sugary beverage consumption constant), the number of sound teeth in the mouth increased 1.00210 times. Holding milk consumption constant, sugary beverage consumption reduced the number of sound teeth 1.00198 times for each extra time sugary drinks were consumed. In more clinically significant terms, if a patient were to increase their milk consumption by 10 times per day, the IRR for number of sound teeth would increase to 1.158 times, and consuming sugary beverages an additional 10 times would lower the IRR 1.149 times. The effect of the interaction is illustrated in Figure 22 below.

Figure 22. Interaction of Milk and Sugary Beverage Consumption



Age, sex, frequency of flossing teeth and fibre consumption remained significant predictors of dental decay. All age contrasts except between the two highest age groups (20-24 and 25-30) were found to be significant, and as in the main effects model, higher age was associated with higher chance of experiencing dental decay and greater extent of dental decay. Sex also had a similar effect, with females having 1.038 times more sound teeth than males (95% CI = 0.936 – 0.988). Flossing again was found to have a damaging effect on dental decay (IRR = 0.996; 95% CI = 0.994 – 0.998), and fibre continued to have a slight protective effect against caries and other dental decay (IRR = 1.001; 95% CI = 1.000 – 1.002).

Table 8. Correlates of Dental Decay, Sugary Beverage Index Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.000	0.999 - 1.001	0.780
Milk	**1.002**	**1.000 - 1.004**	**0.029**
Sugary Beverage Consumption Index	**0.998**	**0.996 – 0.9999**	**0.035**
Diet Soft Drinks	1.002	0.998 - 1.005	0.390
Vegetable Juices	1.000	0.993 - 1.006	0.982
Milk and Sugary Beverage Interaction	1.000	1.000 - 1.000	0.138
Water and Sugary Beverage Interaction	1.000	1.000 - 1.000	0.186
Age			**<0.001**
12-15 vs 16-19	**0.975**	**0.954 – 0.996**	**0.019**
12-15 vs 20-24	**0.897**	**0.855 – 0.940**	**<0.001**
12-15 vs 25-30	**0.855**	**0.800 – 0.914**	**<0.001**
16-19 vs 20-24	**0.918**	**0.884 – 0.957**	**<0.001**
16-19 vs 25-30	**0.877**	**0.828 – 0.929**	**<0.001**
20-24 vs 25-30	0.954	0.901 – 1.010	0.103
Sex	**0.962**	**0.936 - 0.988**	**0.005**
Education			0.674
< Post-Secondary vs Other Post-Secondary	1.046	1.012 – 1.081	0.008
< Post-Secondary vs Post-Secondary Grad	1.036	1.015 – 1.058	0.001
< Post-Secondary vs Not Stated	1.053	0.994 – 1.115	0.079
Other Post-Secondary vs Post-Secondary Grad	0.990	0.965 – 1.016	0.451
Other Post-Secondary vs Not Stated	1.006	0.952 – 1.064	0.828
Post-Secondary Grad vs Not Stated	1.016	0.963 – 1.072	0.557
Income			0.916
Lowest income vs Middle income	1.097	1.032 – 1.167	0.003
Lowest income vs Upper middle income	1.093	1.013 – 1.180	0.022
Lowest income vs Highest income	1.107	1.022 – 1.199	0.013
Lowest income vs Not stated	1.103	1.010 – 1.203	0.028
Middle income vs Upper middle income	0.912	0.857 – 0.969	0.003
Middle income vs Highest income	0.996	0.955 – 1.039	0.860
Middle income vs Not stated	1.009	0.972 – 1.048	0.637
Upper middle income vs Highest income	1.013	0.976 – 1.052	0.503
Upper middle income vs Not stated	1.009	0.959 – 1.062	0.737
Highest income vs Not stated	0.996	0.956 – 1.037	0.844
Smoking Habits			0.918
Current smoker vs Former smoker	1.029	0.951 – 1.113	0.479
Current smoker vs Never smoked	1.025	0.963 – 1.091	0.443
Former smoker vs Never smoked	0.996	0.924 – 1.073	0.917
Frequency of dental care			0.389
Never vs Emergency	1.010	0.905 – 1.128	0.853
Never vs < Once per Year	1.044	0.955 – 1.140	0.343
Never vs Once per Year	1.043	0.952 – 1.142	0.365
Never vs > Once per Year	1.032	0.946 – 1.126	0.475
Emergency vs < Once per Year	1.033	0.961 – 1.110	0.376
Emergency vs Once per Year	1.032	0.965 – 1.104	0.360
Emergency vs > Once per Year	1.021	0.953 – 1.094	0.548

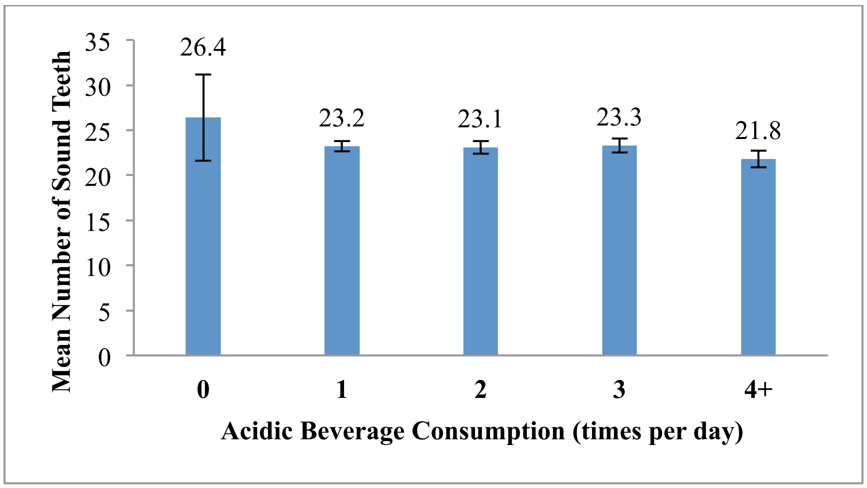
< Once per Year vs Once per Year	0.999	0.958 – 1.042	0.968
< Once per Year vs > Once per Year	0.989	0.954 – 1.025	0.544
Once per year vs > Once per Year	0.990	0.972 – 1.007	0.255
Brushing Teeth	0.999	0.997 - 1.001	0.489
Flossing Teeth	**0.996**	**0.994 – 0.998**	**<0.001**
Dairy Consumption	0.998	0.996 – 1.000	0.088
Fibre Consumption	**1.001**	**1.000 – 1.002**	**0.001**

Acidic Beverage Index Model – Dental Decay

The final model investigating the association between dental decay and beverage consumption was the acidic beverage index model. In this model, all beverages except for milk and water (soft drinks, diet soft drinks, sports beverages, fruit juices, fruit-flavoured drinks, vegetable juices and alcohol) were grouped together to create an acidic beverage consumption index to compile the number of times acid is consumed in beverage form within a one week span. Results are given in Table 9. Milk was found to be associated with reduced dental decay in the acidic beverage consumption model and had a positive effect on the number of sound teeth in the mouth, raising this number by 1.002 times (95% CI = 1.001 – 1.004) for each extra time milk was consumed per week. The milk and acidic beverage interaction was also significant to dental decay (IRR = 0.9999; 95% CI = 0.9998 – 0.9999). The effect of this interaction will be discussed further in reference to Figure 25 below. Water, acidic beverage consumption and the water and acidic beverage interaction variables were not found to be significant.

Although it was not significant, further investigation of the effect of acidic beverage consumption on dental decay revealed a trend similar to that shown for sugary beverage consumption. Again, those respondents that did not drink acidic beverages had much less dental decay on average than those who consumed at least one acidic beverage per day. In addition, drinking acidic beverages four or more times per day had a harmful effect on the teeth, lowering the average number of sound teeth in the mouth in relation to less acid consumption. Similar outcomes in terms of dental decay were exhibited in those participants who drank acidic beverages 1, 2 or 3 times per day.

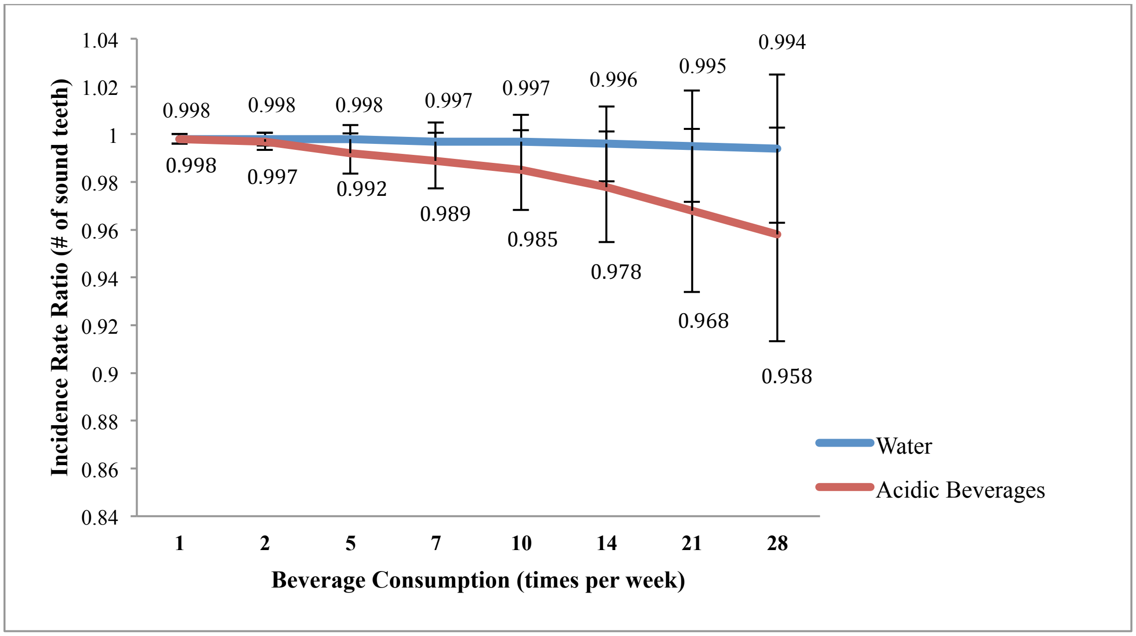
Figure 23. Effect of Acidic Beverage Consumption on Dental Decay



When modelling the interaction, it was found that both water and acidic beverage consumption had a negative impact on dental decay, although this interaction was not statistically significant. With each increase in number of times water was consumed per week, the interaction between it and acidic beverage consumption caused the IRR to drop by 0.0002. Again, this represents a negligible effect, this time detrimental, with an increase of water consumption 10 times per day lowering the IRR 1.0140 times. As acidic beverage consumption increased and water was held constant, the IRR dropped by 0.0016 for each extra time acidic beverages were consumed per week, corresponding to a decrease of 1.1185 for 10 additional times acidic beverages were consumed in a day.

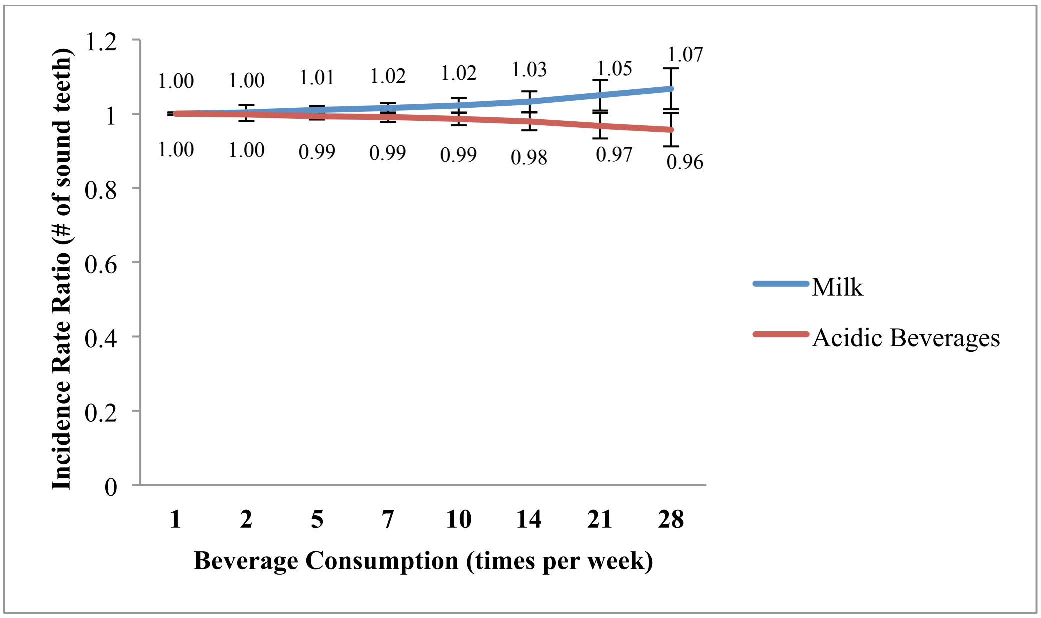
However, this interaction was not significant in the model and thus the interaction between water and acidic beverage consumption does not seem to have an impact on dental decay. These results are shown in Figure 24 below.

Figure 24. Interaction of Water and Acidic Beverage Consumption



As it was significant, the milk and acidic beverage consumption interaction is of particular interest. When examining the milk and acidic beverage interaction, it was found that milk has a protective effect over acidic beverage consumption, raising the IRR for number of sound teeth 1.0024 times for each extra time milk was consumed per week. For an increase in 10 times of milk consumption per day, this would correspond to an increased IRR of 1.1829. Acidic beverage consumption had a detrimental effect on the interaction between itself and milk, with each additional time consuming an acidic beverage lowering the IRR 1.0016 times, or by 1.1185 for each additional 10 acidic beverages consumed in a day. From the data obtained from the CHMS, it was seen as well that the protective effect of milk was stronger than the detrimental effect of acidic beverage consumption in the interaction between the two (IRR = 1.0024 vs. IRR= 1.0016).

Figure 25. Interaction between Milk and Acidic Beverage Consumption



Age continued to be a significant predictor of dental decay, and was significant at all levels of contrast except between the highest two age groups (20-24 and 25-30). Again, higher age was associated with fewer sound teeth in the mouth, and the magnitude of this difference increased as the difference in age grew. Sex was also found to predict dental decay, with males having 1.037 times fewer sound teeth in their mouths than females (95% CI = 0.938 – 0.989). Frequency of flossing teeth and fibre consumption continued to be associated with dental decay; as before, flossing caused a 1.004 times reduction (95% CI = 0.994 – 0.998) in the number of sound teeth in the mouth and fibre consumption was found to increase the number of sound teeth 1.001 times (95% CI = 1.000 – 1.002) for each increase in number of times fibre is consumed per week.

Table 9. Correlates of Dental Decay, Acidic Beverage Index Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.000	0.999 – 1.001	0.749
Milk	**1.002**	**1.001 – 1.004**	**0.012**
Acidic Beverage Consumption Index	0.998	0.997 – 1.000	0.076
Milk and Acidic Beverage Interaction	**0.9999**	**0.9998 – 0.9999**	**0.042**
Water and Acidic Beverage Interaction	1.000	1.000 – 1.000	0.170
Age			**<0.001**
12-15 vs 16-19	**0.975**	**0.954 – 0.997**	**0.026**
12-15 vs 20-24	**0.897**	**0.855 – 0.940**	**<0.001**
12-15 vs 25-30	**0.856**	**0.802 – 0.914**	**<0.001**
16-19 vs 20-24	**0.919**	**0.883 – 0.957**	**<0.001**
16-19 vs 25-30	**0.878**	**0.831 – 0.928**	**<0.001**
20-24 vs 25-30	0.955	0.903 – 1.010	0.107
Sex	**0.963**	**0.938 – 0.989**	**0.006**
Education			0.731
< Post-Secondary vs Other Post-Secondary	1.045	1.012 – 1.079	0.007
< Post-Secondary vs Post-Secondary Grad	1.035	1.015 – 1.056	0.001
< Post-Secondary vs Not Stated	1.050	0.993 – 1.110	0.088
Other Post-Secondary vs Post-Secondary Grad	0.991	0.966 – 1.017	0.496
Other Post-Secondary vs Not Stated	1.005	0.952 – 1.061	0.858
Post-Secondary Grad vs Not Stated	1.014	0.962 – 1.069	0.605
Income			0.914
Lowest income vs Middle income	1.100	1.034 – 1.170	0.002
Lowest income vs Upper middle income	1.094	1.014 – 1.181	0.020
Lowest income vs Highest income	1.109	1.024 – 1.202	0.011
Lowest income vs Not stated	1.106	1.012 – 1.209	1.106
Middle income vs Upper middle income	0.995	0.954 – 1.037	0.815
Middle income vs Highest income	1.008	0.970 – 1.049	0.674
Middle income vs Not stated	1.005	0.953 – 1.061	0.842
Upper middle income vs Highest income	1.013	0.976 – 1.052	0.480
Upper middle income vs Not stated	1.010	0.961 – 1.063	0.687
Highest income vs Not stated	0.997	0.957 – 1.039	0.887
Smoking Habits			0.936
Current smoker vs Former smoker	1.028	0.950 – 1.111	0.495
Current smoker vs Never smoked	1.024	0.963 – 1.090	0.448
Former smoker vs Never smoked	0.997	0.925 – 1.074	0.936
Frequency of dental care			0.370
Never vs Emergency	1.012	0.905 – 1.132	0.834
Never vs < Once per Year	1.045	0.956 – 1.143	0.328
Never vs Once per Year	1.043	0.953 – 1.142	0.359
Never vs > Once per Year	1.033	0.946 – 1.128	0.467
Emergency vs < Once per Year	1.033	0.961 – 1.110	0.377
Emergency vs Once per Year	1.031	0.963 – 1.103	0.378
Emergency vs > Once per Year	1.031	0.951 – 1.095	0.568
< Once per Year vs Once per Year	0.998	0.957 – 1.041	0.930
< Once per Year vs > Once per Year	0.988	0.954 – 1.024	0.513

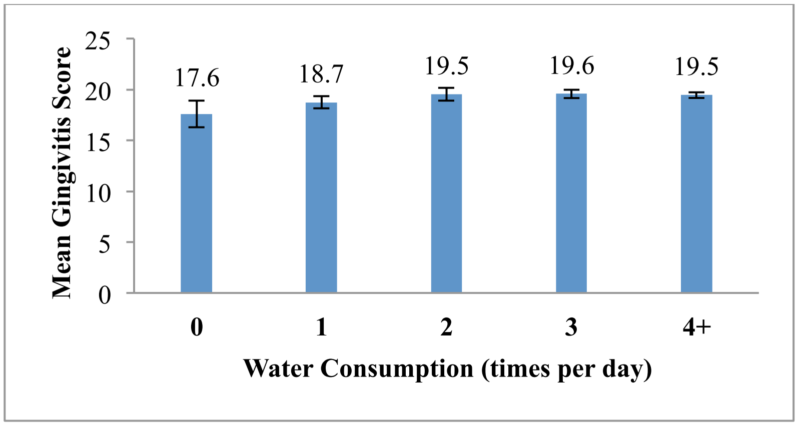
Once per year vs > Once per Year	0.990	0.972 – 1.008	0.278
Brushing Teeth	0.999	0.997 – 1.001	0.433
Flossing Teeth	**0.996**	**0.994 – 0.998**	**<0.001**
Dairy Consumption	0.998	0.996 – 1.000	0.112
Fibre Consumption	**1.001**	**1.000 – 1.002**	**<0.001**

Main Effects Model – Periodontal Health

In the main effects model investigating the link between consumption of individual beverage types and gingival disease, regular soft drink consumption and age were the only significant variables. These results are shown in Table 10 below. Like dental decay, regular soft drinks had a harmful effect on gingivitis scores, with each increase in the number of times soft drinks were consumed per week leading to 1.007 times (95% CI = 0.989 – 0.997) poorer gingivitis score. Water, milk, diet soft drink, fruit juices, fruit-flavoured beverage, vegetable juice and alcohol consumption were not significant predictors of gingivitis score.

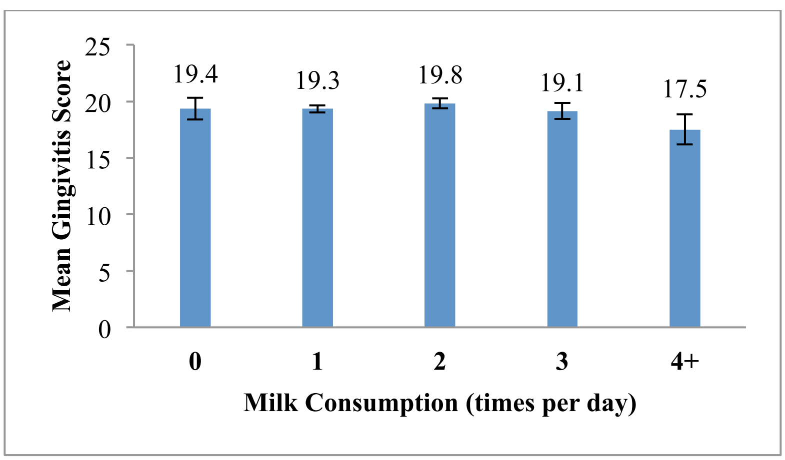
Although not significant, a slight pattern can be observed regarding the association between water consumption and gingival health. Based on the graph below, those who did not consume water on a daily basis had the worst periodontal health scores compared to other consumption groups, and consuming water once per day was the second more detrimental in terms of gingivitis scores. Therefore, it can be observed that as participants increased their daily water consumption, their gingivitis score improved, although once respondents consumed water at least twice per day, the effect seemed to level off.

<u>Figure 26. Effect of Water Consumption on Periodontal Health</u>



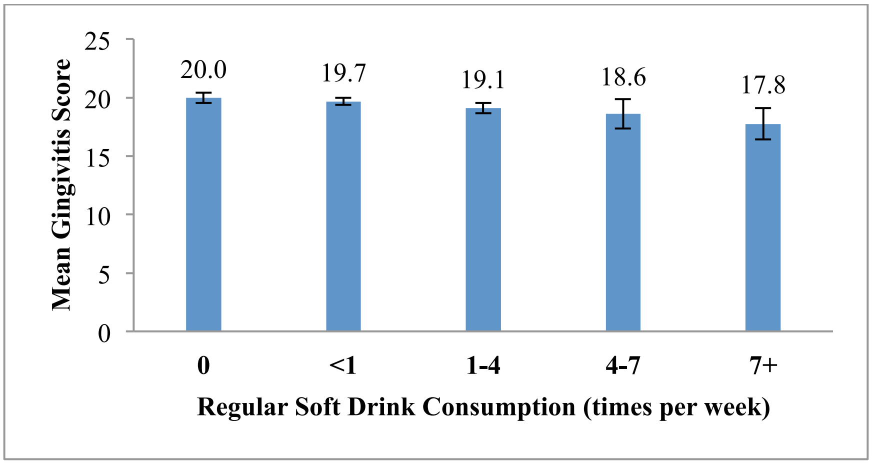
For the most part, periodontal health did not seem to be related to milk consumption, and it was not significant in the main effects model. However, participants in the 4 times consuming milk per day group had much lower scores than other consumption groups. This may be suggestive of a threshold effect, where consuming milk more than 3 times per day has a harmful effect on the gingiva.

Figure 27. Effect of Milk Consumption on Periodontal Health



A somewhat linear association was exhibited between regular soft drink consumption and gingivitis scores. Those participants that did not consume soft drinks had the best probing scores on average. As frequency of consumption of soft drinks increased, periodontal health decreased: the highest regular soft drink consumption group (7 or more times per week) had the worst gingival health. Therefore, the data from CHMS suggests that consuming any regular soft drinks can have a detrimental effect on one's gingival health, with more frequent consumption being linked to worse periodontal health.

Figure 28. Effect of Regular Soft Drink Consumption on Periodontal Health



Only two of the level contrasts for age were found to be significant; compared to the 12-15 year old age group, 20-24 year olds had a gingivitis score 1.076 times poorer (95% CI = 0.891 – 0.957) and the gingivitis score of 25-30 year olds was 1.074 times poorer (95% CI = 0.887 – 0.967).

Table 10. Correlates o Periodontal Health, Main Effects Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.000	0.999 – 1.001	0.974
Milk	1.000	0.999 – 1.001	0.912
Regular Soft Drinks	**0.993**	**0.989 – 0.997**	**0.001**
Diet Soft Drinks	1.000	0.997 – 1.004	0.821
Sports Drinks	1.004	0.998 – 1.009	0.211
Fruit Juices	1.000	0.998 – 1.001	0.579
Fruit-Flavoured Drinks	0.998	0.995 – 1.000	0.062
Vegetable Juices	1.000	0.996 – 1.005	0.879
Alcohol	1.000	0.997 – 1.002	0.857
Age			**0.002**
12-15 vs 16-19	0.984	0.962 – 1.006	0.159
12-15 vs 20-24	**0.924**	**0.891 – 0.957**	**<0.001**
12-15 vs 25-30	**0.926**	**0.887 – 0.967**	**0.001**
16-19 vs 20-24	0.959	0.910 – 1.011	0.122
16-19 vs 25-30	0.976	0.930 – 1.024	0.328
20-24 vs 25-30	1.018	0.961 – 1.079	0.544
Sex	0.989	0.968 – 1.010	0.295
Education			0.918
< Post-Secondary vs Other Post-Secondary	1.028	0.990 – 1.068	0.152
< Post-Secondary vs Post-Secondary Grad	1.022	0.991 – 1.053	0.161
< Post-Secondary vs Not Stated	1.026	0.972 – 1.084	0.354
Other Post-Secondary vs Post-Secondary Grad	1.015	0.980 – 1.051	0.407
Other Post-Secondary vs Not Stated	1.013	0.914 – 1.122	0.806
Post-Secondary Grad vs Not Stated	0.998	0.900 – 1.108	0.972
Income			0.184
Lowest income vs Middle income	1.059	0.998 – 1.124	0.058
Lowest income vs Upper middle income	1.063	0.992 – 1.138	0.083
Lowest income vs Highest income	1.082	1.014 – 1.154	0.018
Lowest income vs Not stated	1.077	1.007 – 1.151	0.030
Middle income vs Upper middle income	1.013	0.970 – 1.058	0.558
Middle income vs Highest income	1.022	0.979 – 1.069	0.316
Middle income vs Not stated	1.006	0.961 – 1.053	0.797
Upper middle income vs Highest income	1.010	0.981 – 1.039	0.519
Upper middle income vs Not stated	0.993	0.949 – 1.039	0.762
Highest income vs Not stated	0.984	0.943 – 1.026	0.437
Smoking Habits			0.727
Current smoker vs Former smoker	1.039	0.965 – 1.119	0.306
Current smoker vs Never smoked	1.056	1.014 – 1.099	0.009
Former smoker vs Never smoked	0.959	0.900 – 1.022	0.194
Frequency of dental care			0.176
Never vs Emergency	1.026	0.915 – 1.150	0.664
Never vs < Once per Year	1.103	1.000 – 1.216	0.050
Never vs Once per Year	1.106	1.002 – 1.222	0.045
Never vs > Once per Year	1.103	0.996 – 1.221	0.060
Emergency vs < Once per Year	1.034	0.953 – 1.122	0.425
Emergency vs Once per Year	1.026	0.938 – 1.121	0.577
Emergency vs > Once per Year	1.019	0.937 – 1.108	0.663
< Once per Year vs Once per Year	0.992	0.945 – 1.041	0.740
< Once per Year vs > Once per Year	0.985	0.938 – 1.035	0.556
Once per year vs > Once per Year	0.993	0.974 – 1.013	0.512
Brushing Teeth	1.000	0.998 – 1.002	0.750

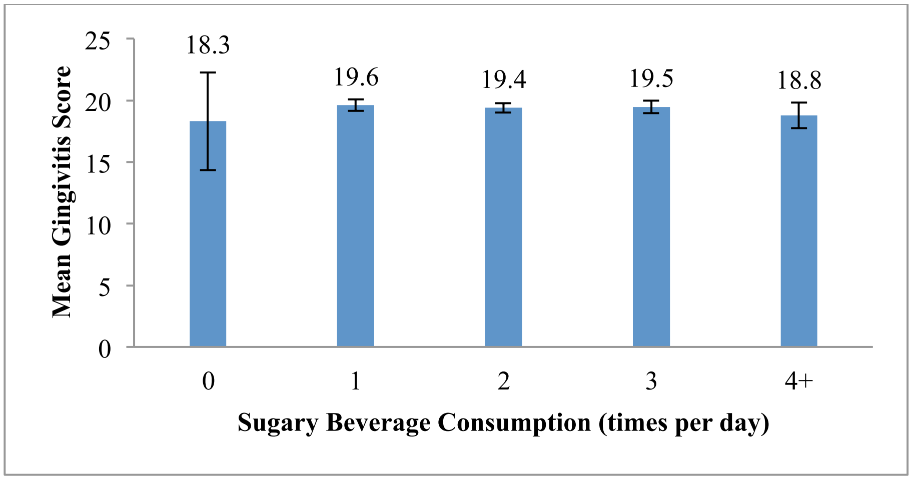
Flossing Teeth	1.000	0.998 – 1.003	0.958
Dairy Consumption	1.000	0.998 – 1.002	0.699
Fibre Consumption	1.001	1.000 – 1.002	0.057

Sugary Beverage Index Model- Periodontal Health

In the sugary beverage consumption index model, milk was associated with gingival health. Results are given in Table 11 below. Milk was found to improve gingivitis scores 1.003 times (95% CI = 1.001 – 1.005) for every increase in the number of times milk was drank per week. The interaction between milk and sugary beverages was also significant (IRR = 1.000; 95% CI = 0.998 – 1.000), and will be discussed further below. Water, diet soft drink, vegetable juice and sugary beverage consumption were not significant, and neither was the interaction between water and sugary beverage consumption.

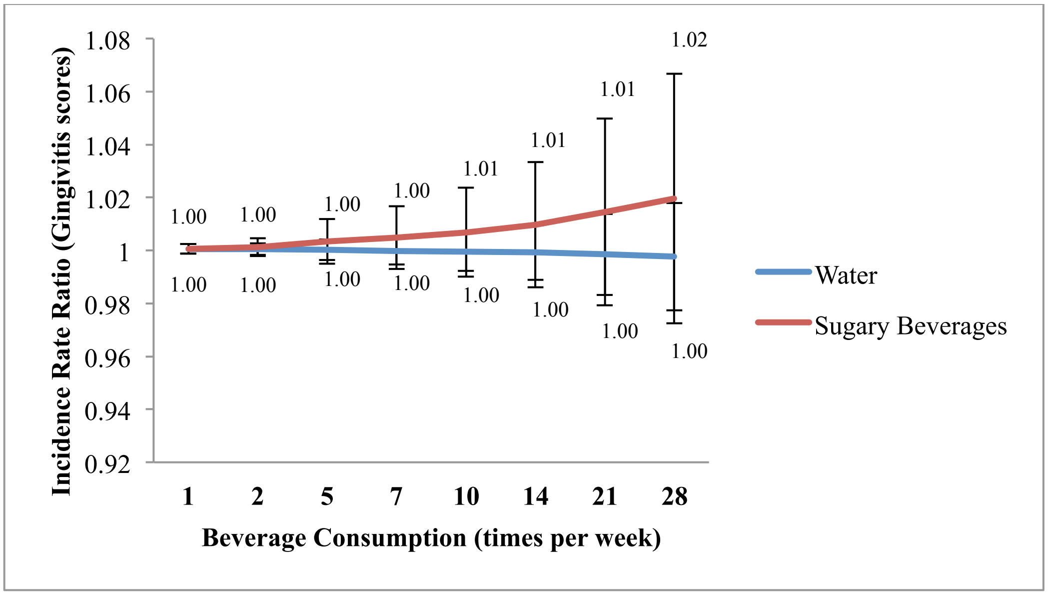
In accordance with the fact sugary beverage consumption was not found to have a significant effect on gingival health, further investigation of mean gingival score by sugary beverage consumption group showed no distinct pattern. Those participants that did not consume sugary beverages had lower average gingivitis scores than the rest of the consumption groups, suggesting that any consumption of sugary beverages may positively affect periodontal health; however, the large confidence interval for the lowest consumption group does not support this suggestion.

<u>Figure 29. Effect of Sugary Beverage Consumption on Periodontal Health</u>



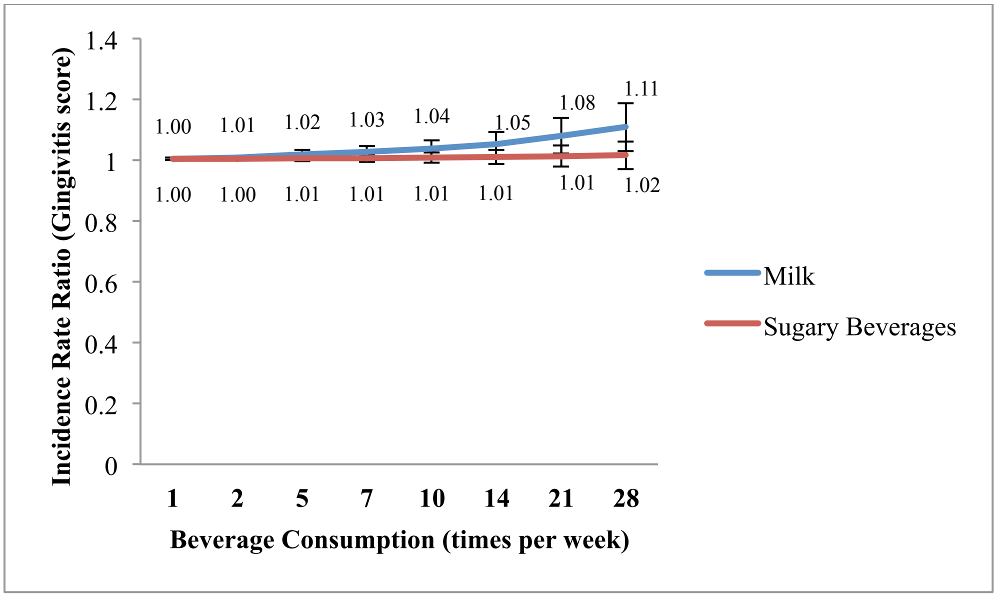
In the sugary beverage and water interaction for gingivitis, it was found this interaction did not have a significant effect on periodontal health. Water was found to lower the IRR for probing scores, whereas sugary beverage consumption caused it to increase. For every extra time water was drank each week, the IRR lowered slightly, by 0.0001. Like in dental decay, water seems to have only negligible effect on periodontal health outcomes, with 10 additional times consuming water per day leading to a decreased IRR of 1.007 times. For every extra time sugary beverages are consumed in a week in comparison to water, the IRR increased by 1.0007, corresponding to an increase of 1.0502 for an additional 10 times sugary beverages are consumed in a day. Thus, the data surprisingly suggests that sugary beverage consumption may be protective over water consumption in terms of gingival health, although the interaction was not significant. Results are displayed in Figure 30 below.

Figure 30. Interaction of Water and Sugary Beverage Consumption



When examining the interaction between sugary beverage and milk consumption for the gingivitis outcome, it was found that increasing the frequency of consumption of either of the beverage types leads to a significant improvement in probing scores. Increasing milk consumption had a greater magnitude of effect than increasing sugary beverage consumption; for each extra time milk was consumed per week, the IRR increased by 0.0037, whereas increased sugary beverage consumption lead to an increase in IRR by 0.0004. Clinically, this would correspond to an increased IRR of 1.2956 times and 1.0284 times if one were to increase their beverage consumption by a frequency of 10 times per day for milk or sugary beverages, respectively. This trend for the interaction is illustrated in Figure 31 below.

Figure 31. Interaction between Milk and Sugary Beverage Consumption



Age, specifically the contrast between ages 12-15 and ages 20-24 as well as between ages 12-15 and ages 25-30, was again significant to gingival health, with higher age being associated with worse gingivitis scores (IRR = 0.933 (95% CI = 0.902 – 0.965) and IRR = 0.934 (95% CI = 0.894 – 0.977), respectively). Fibre also had an impact on gingival health in the sugary beverage model, with each extra time consuming fibre in a week leading to a gingivitis score 1.001 times higher (95% CI = 1.000 – 1.002).

Table 11. Correlates of Periodontal Health, Sugary Beverage Index Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	0.999	0.998 – 1.000	0.194
Milk	**1.003**	**1.001 – 1.005**	**0.009**
Sugary Beverage Consumption Index	0.999	0.998 – 1.000	0.081
Diet Soft Drinks	1.001	0.997 – 1.005	0.599
Vegetable Juices	1.001	0.996 – 1.006	0.689
Milk and Sugary Beverage Interaction	**1.000**	**0.998 – 1.000**	**<0.001**
Water and Sugary Beverage Interaction	1.000	1.000 – 1.000	0.209
Age			**0.002**
12-15 vs 16-19	0.989	0.966 – 1.012	0.349
12-15 vs 20-24	**0.933**	**0.902 – 0.965**	**<0.001**
12-15 vs 25-30	**0.934**	**0.894 – 0.977**	**0.003**
16-19 vs 20-24	0.967	0.918 – 1.019	0.210
16-19 vs 25-30	0.982	0.937 – 1.031	0.483

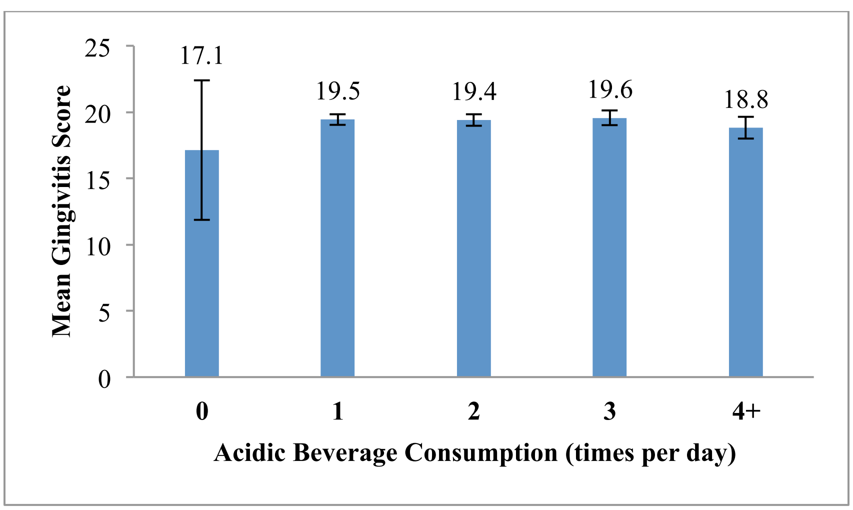
20-24 vs 25-30	1.016	0.953 – 1.084	0.624
Sex	0.988	0.966 – 1.010	0.279
Education			0.888
< Post-Secondary vs Other Post-Secondary	1.027	0.990 – 1.065	0.161
< Post-Secondary vs Post-Secondary Grad	1.024	0.993 – 1.056	0.127
< Post-Secondary vs Not Stated	1.035	0.985 – 1.088	0.171
Other Post-Secondary vs Post-Secondary Grad	1.016	0.978 – 1.055	0.420
Other Post-Secondary vs Not Stated	1.026	0.927 – 1.135	0.626
Post-Secondary Grad vs Not Stated	1.010	0.910 – 1.120	0.857
Income			0.072
Lowest income vs Middle income	1.052	0.996 – 1.113	0.069
Lowest income vs Upper middle income	1.057	0.998 – 1.132	0.109
Lowest income vs Highest income	1.079	1.012 – 1.151	0.019
Lowest income vs Not stated	1.073	1.006 – 1.114	0.033
Middle income vs Upper middle income	1.015	0.971 – 1.061	0.505
Middle income vs Highest income	1.028	0.980-1.077	0.258
Middle income vs Not stated	1.009	0.962 – 1.058	0.723
Upper middle income vs Highest income	1.012	0.983 – 1.042	0.411
Upper middle income vs Not stated	0.994	0.949 – 1.041	0.784
Highest income vs Not stated	0.982	0.940 – 1.025	0.398
Smoking Habits			0.703
Current smoker vs Former smoker	1.042	0.974 – 1.113	0.232
Current smoker vs Never smoked	1.059	1.018 – 1.101	0.004
Former smoker vs Never smoked	0.958	0.901 – 1.019	0.176
Frequency of dental care			0.052
Never vs Emergency	1.012	0.900 – 1.137	0.847
Never vs < Once per Year	1.103	0.997 – 1.220	0.058
Never vs Once per Year	1.109	1.002 – 1.229	0.046
Never vs > Once per Year	1.104	0.994 – 1.226	0.066
Emergency vs < Once per Year	1.047	0.966 – 1.136	0.264
Emergency vs Once per Year	1.042	0.952 – 1.141	0.376
Emergency vs > Once per Year	1.032	0.947 – 1.125	0.469
< Once per Year vs Once per Year	0.995	0.946 – 1.046	0.837
< Once per Year vs > Once per Year	0.986	0.936 – 1.037	0.576
Once per year vs > Once per Year	0.991	0.972 – 1.010	0.350
Brushing Teeth	1.000	0.998 – 1.002	0.844
Flossing Teeth	1.000	0.997 – 1.002	0.869
Dairy Consumption	1.000	0.998 – 1.002	0.730
Fibre Consumption	**1.001**	**1.000 – 1.002**	**0.007**

Acidic Beverage Index Model – Periodontal Health

In terms of significant predictors, the acidic beverage model had the same result as the sugary beverage model, as displayed in Table 12. Milk appeared to have a protective effect on gingival health, improving the gingivitis score 1.003 times (1.001 – 1.006) for each time milk was consumed per week. The milk and acidic beverage interaction was also found to be a significant predictor (IRR = 1.000; 95% CI = 1.000 – 1.000), as will be discussed further in Figure 34 below. Water consumption, acidic beverage consumption and the interaction between these two variables were not significant.

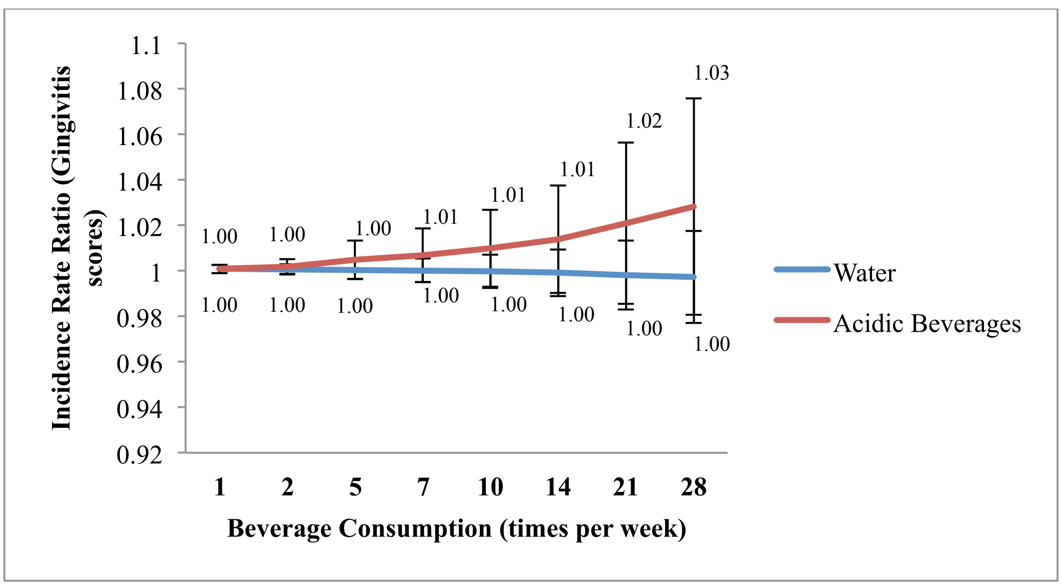
Like sugary beverage consumption above, acidic beverage consumption also does not seem to be associated with gingivitis scores. Again, average probing scores are much lower in those participants that did not consume acidic beverages, but the large confidence interval makes it difficult to rely on this finding.

Figure 32. Effect of Acidic Beverage Consumption on Periodontal Health



Further examination of the interaction between acidic beverage and water consumption for gingivitis revealed that acidic beverage consumption may have a protective effect on water consumption; however this effect was not statistically significant. For each increase in number of acidic beverages consumed per week, the IRR increased by 1.0010, with water consumption being held constant at a consumption frequency of once per week. If acidic beverage consumption were to be increased by 10 times per day, this would lead to an increased IRR of 1.0725 times. When holding acidic beverage consumption constant, water lowered the IRR for gingivitis by 1.0001 for each extra time water was consumed, or lowered the IRR by 1.0070 for every 10 times consuming water in a day. These results are shown in Figure 33 below.

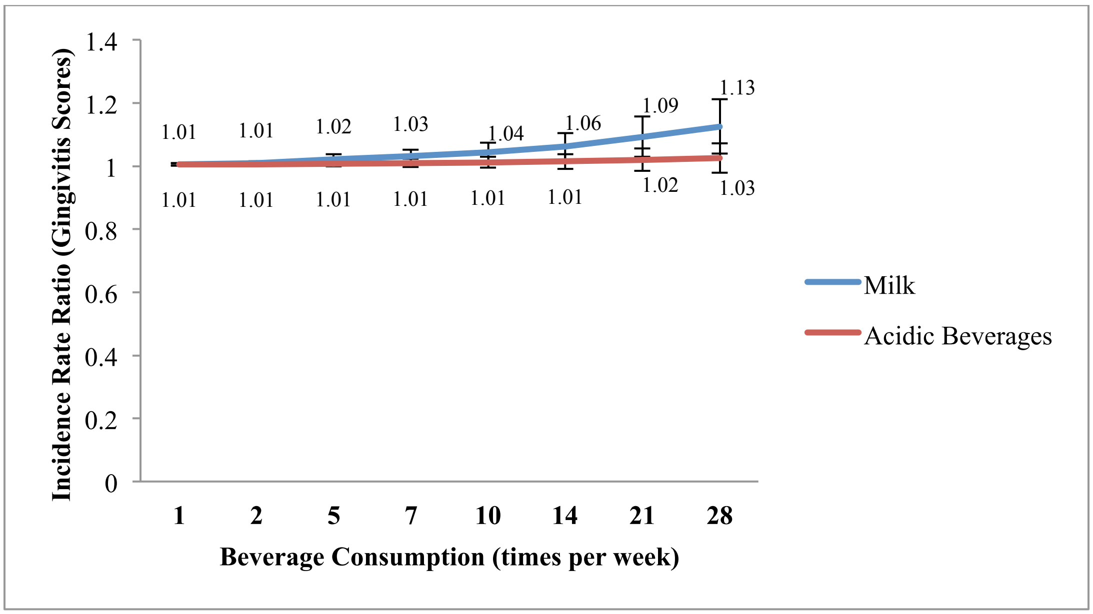
Figure 33. Interaction between Water and Acidic Beverage Consumption



The interaction between acidic beverages and milk had a synergistic and significant effect, with both beverages raising incidence rate ratios for gingival health. The effect of milk was of a larger magnitude, raising the IRR by 0.0044 for each extra time consuming milk when acidic beverage consumption was held constant. This is a relatively large effect, and for each 10 additional times milk was consumed per day, the

IRR would increase by 0.3607. Acidic beverages raised the IRR by 0.0007 for each extra drink consumed in a week, or raised the IRR by 1.0502 for each additional 10 times acidic beverages were consumed in a day. These results are displayed in the Figure 34.

Figure 34. Interaction between Milk and Acidic Beverage Consumption



Age was again significant, with the 12-15 year old age group having a 1.067 times (95% CI = 0.902 – 0.965) higher gingivitis score than the 20-24 year olds and 1.064 times (95% CI = 0.897 – 0.976) higher score than 25-30 year olds. Fibre consumption was also associated with gingival health, with each increase in frequency of fibre consumption per week leading to a 1.001 times (95% CI = 1.000 – 1.002) improvement in gingivitis scores.

Table 12. Correlates of Periodontal Health, Acidic Beverage Index Model, Poisson Regression (n=1534)

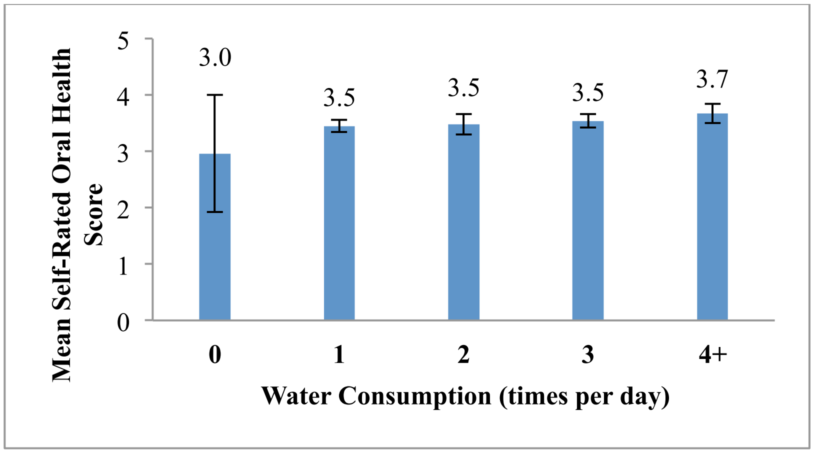
Variable	IRR	95% CI	p-value
Water	0.999	0.998 – 1.000	0.158
Milk	**1.003**	**1.001 – 1.006**	**0.003**
Acidic Beverage Consumption Index	0.999	0.998 – 1.000	0.253
Milk and Acidic Beverage Interaction	**1.000**	**1.000 – 1.000**	**<0.001**
Water and Acidic Beverage Interaction	1.000	1.000 – 1.000	0.181
Age			**0.002**
12-15 vs 16-19	0.990	0.966 – 1.013	0.386
12-15 vs 20-24	**0.933**	**0.902 – 0.965**	**<0.001**
12-15 vs 25-30	**0.936**	**0.897 – 0.976**	**0.002**
16-19 vs 20-24	0.966	0.917 – 1.018	0.198
16-19 vs 25-30	0.984	0.938 – 1.032	0.504
20-24 vs 25-30	1.018	0.957 – 1.083	0.568
Sex	0.989	0.967 – 1.011	0.324
Education			0.932
< Post-Secondary vs Other Post-Secondary	1.025	0.989 – 1.063	0.176
< Post-Secondary vs Post-Secondary Grad	1.024	0.933 – 1.056	0.130
< Post-Secondary vs Not Stated	1.032	0.983 – 1.085	0.203
Other Post-Secondary vs Post-Secondary Grad	1.017	0.979 – 1.057	0.375
Other Post-Secondary vs Not Stated	1.025	0.924 – 1.136	0.643
Post-Secondary Grad vs Not Stated	1.007	0.906 – 1.119	0.894
Income			0.091
Lowest income vs Middle income	1.055	0.997 – 1.116	0.063
Lowest income vs Upper middle income	1.058	0.990 – 1.132	0.096
Lowest income vs Highest income	1.081	1.015 – 1.152	0.016
Lowest income vs Not stated	1.075	1.008 – 1.147	0.028
Middle income vs Upper middle income	1.017	0.971 – 1.065	0.470
Middle income vs Highest income	1.028	0.980 – 1.079	0.261
Middle income vs Not stated	1.009	0.962 – 1.059	0.717
Upper middle income vs Highest income	1.011	0.983 – 1.039	0.447
Upper middle income vs Not stated	0.992	0.948 – 1.038	0.725
Highest income vs Not stated	0.981	0.940 – 1.024	0.389
Smoking Habits			0.698
Current smoker vs Former smoker	1.041	0.973 – 1.114	0.246
Current smoker vs Never smoked	1.058	1.019 – 1.099	0.003
Former smoker vs Never smoked	0.957	0.898 – 1.020	0.178
Frequency of dental care			0.058
Never vs Emergency	1.013	0.898 – 1.142	0.839
Never vs < Once per Year	1.105	0.998 – 1.223	0.054
Never vs Once per Year	1.110	1.002 – 1.230	0.045
Never vs > Once per Year	1.105	0.993 – 1.230	0.067
Emergency vs < Once per Year	1.053	0.969-1.142	0.220
Emergency vs Once per Year	1.045	0.954 – 1.144	0.344
Emergency vs > Once per Year	1.035	0.950 – 1.128	0.432
< Once per Year vs Once per Year	0.992	0.944 – 1.043	0.762
< Once per Year vs > Once per Year	0.983	0.934 – 1.035	0.511
Once per year vs > Once per Year	0.991	0.971 – 1.010	0.346
Brushing Teeth	1.000	0.998 – 1.002	0.873
Flossing Teeth	1.000	0.997 – 1.002	0.893
Dairy Consumption	1.000	0.998 – 1.002	0.908
Fibre Consumption	**1.001**	**1.000 – 1.002**	**0.006**

Main Effects Model – Self-Rated Oral Health

The third set of models focused on the participants' self-rated oral health (SROH). In the main effects model, water consumption, regular soft drink consumption, income and frequency of visiting a dental professional were found to be associated with SROH. These results are displayed in Table 13 below. Water consumption had a positive impact on SROH, with every increase in the number of times water was consumed on a weekly basis leading to 1.009 (95% CI = 1.002 – 1.017) times better SROH. Regular soft drinks, on the other hand, had a detrimental effect in this model, lowering the SROH 1.059 times (95% CI = 0.916 – 0.968) for every extra time a regular soft drink was consumed each week. Milk, diet soft drink, fruit juice, fruit-flavoured beverage, sports drink, vegetable juice and alcohol consumption were not significant in this model.

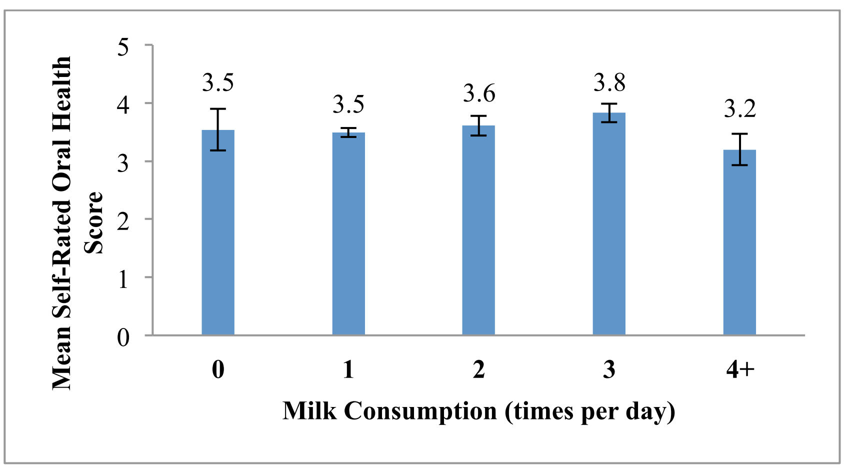
A distinct trend in the association between water consumption and self-rated oral health was shown in the CHMS data. Water consumption had a positive effect on average self-perceived oral health scores, and as water consumption increased, the participants' oral health was self-reported in a more positive manner.

Figure 35. Effect of Water Consumption on Self-Rated Oral Health



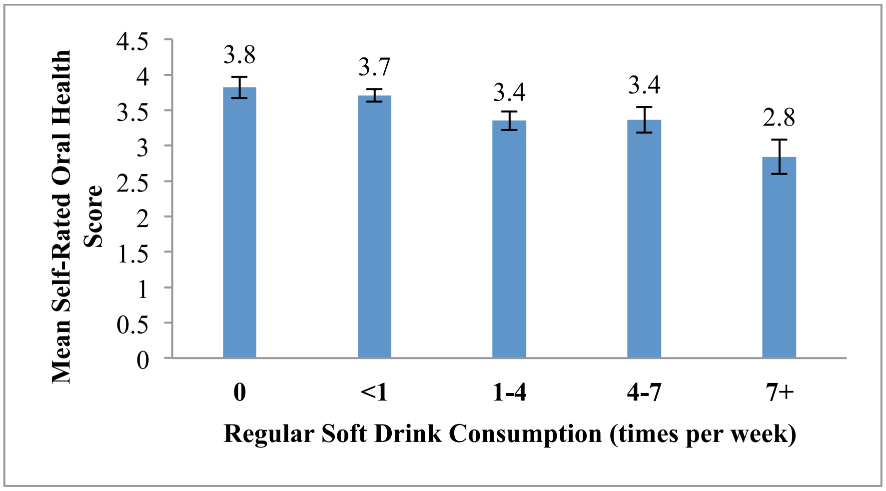
As seen in Figure 36 below, no clear trend was exhibited between milk consumption and self-rated oral health. Those respondents who drank milk 3 times per day had the best self-perceived oral health, and those that drank milk 4 or more times per day have the worst self-rated oral health.

Figure 36. Effect of Milk Consumption on Self-Rated Oral Health



As displayed in Figure 37, regular soft drink consumption had a negative effect on self-perceived oral health. As regular soft drink consumption increased, average self-rated oral health scores generally went down. There was one exception to this trend, that being between 1-4 and 4-7 soft drinks per week, although the average SROH scores in this category were only 0.01 points different. As of interest is the rather large difference in average SROH scores between 4-7 times per week and 7 or more times per week.

Figure 37. Effect of Regular Soft Drink Consumption on Self-Rated Oral Health



In addition to beverage variables, the highest income category was found to be significantly different from the other three income levels, specifically lowest income (IRR = 2.415; 95% CI = 1.045 – 5.582), middle income (IRR = 1.988; 95% CI = 1.497 – 2.639), and upper middle income (IRR = 1.506; 95% CI = 1.084 – 2.091). This finding suggests that those respondents in the highest income group generally had better SROH, and the level of SROH was proportionate to one's income level. All other income level contrasts were not significant. Finally, visiting a dental professional was also associated with SROH. Visiting a dental professional once per year as opposed to on an emergency basis lead to 2.620 times (95% CI = 1.223 – 5.616) better SROH, and yearly visits, in contrast with less than yearly visits to a dental professional, were linked to 1.738 times (95% CI = 1.095 – 2.757) higher SROH. Visiting a dental professional more than once per year was associated with 3.287 times (95% CI = 1.676 – 6.450) better SROH than going on an emergency basis, and 2.180 times (95% CI = 1.202 – 3.951) better SROH than going less than once per year.

Table 13. Correlates of Self-Rated Oral Health, Main Effects Model, Ordinal Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	**1.009**	**1.002 – 1.017**	**0.011**
Milk	1.015	0.993 – 1.037	0.189
Regular Soft Drinks	**0.941**	**0.916 – 0.968**	**<0.001**
Diet Soft Drinks	1.004	0.952 – 1.059	0.891
Sports Drinks	0.936	0.861 – 1.018	0.121
Fruit Juices	1.010	0.985 – 1.035	0.439
Fruit-Flavoured Drinks	0.977	0.943 – 1.011	0.181
Vegetable Juices	1.024	0.964 – 1.088	0.439
Alcohol	1.001	0.970 – 1.034	0.941
Age			0.704
12-15 vs 16-19	0.748	0.492 – 1.137	0.174
12-15 vs 20-24	1.016	0.545 – 1.894	0.961
12-15 vs 25-30	0.871	0.508 – 1.493	0.615
16-19 vs 20-24	1.358	0.606 – 3.042	0.458
16-19 vs 25-30	1.164	0.713 – 1.902	0.544
20-24 vs 25-30	0.857	0.386 – 1.903	0.705
Sex	1.151	0.939 – 1.411	0.175
Education			0.986
< Post-Secondary vs Other Post-Secondary	0.720	0.417 – 1.243	0.238
< Post-Secondary vs Post-Secondary Grad	0.690	0.524 – 0.908	0.008
< Post-Secondary vs Not Stated	0.716	0.277 – 1.851	0.490
Other Post-Secondary vs Post-Secondary Grad	0.959	0.566 – 1.622	0.876
Other Post-Secondary vs Not Stated	0.955	0.337 – 2.933	0.992
Post-Secondary Grad vs Not Stated	1.037	0.390 – 2.757	0.942
Income			**<0.001**
Lowest income vs Middle income	1.215	0.599 – 2.465	0.589
Lowest income vs Upper middle income	1.604	0.683 – 3.765	0.278
Lowest income vs Highest income	**2.415**	**1.045 – 5.582**	**0.039**
Lowest income vs Not stated	1.548	0.536 – 4.470	0.419
Middle income vs Upper middle income	1.320	0.898 – 1.940	0.158
Middle income vs Highest income	**1.988**	**1.497 – 2.639**	**<0.001**
Middle income vs Not stated	1.274	0.725 – 2.240	0.400
Upper middle income vs Highest income	**1.506**	**1.084 – 2.091**	**0.015**
Upper middle income vs Not stated	0.965	0.602 – 1.549	0.883
Highest income vs Not stated	0.641	0.358 – 1.148	0.134
Smoking Habits			0.166
Current smoker vs Former smoker	0.852	0.352 – 2.061	0.722
Current smoker vs Never smoked	1.379	0.919 – 2.067	0.121
Former smoker vs Never smoked	1.619	0.819 – 3.201	0.166

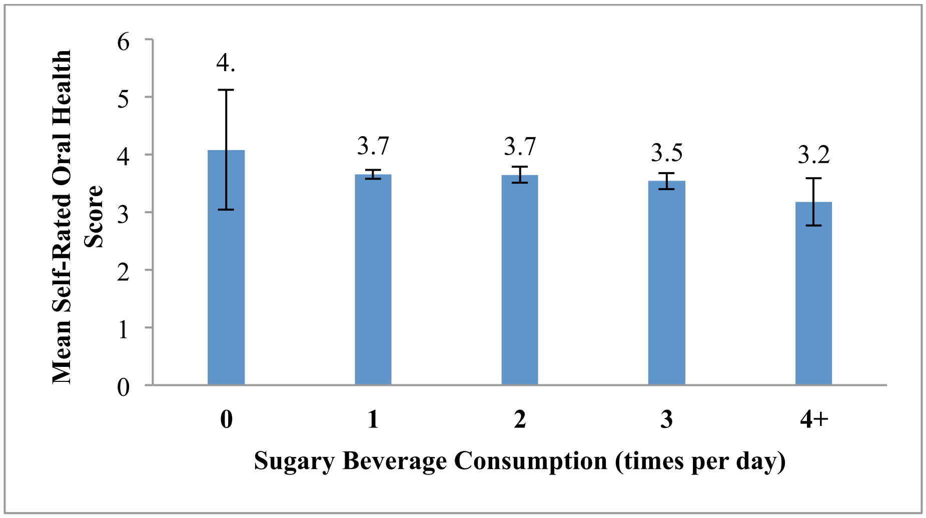
Frequency of dental care			**<0.001**
Never vs Emergency	0.686	0.123 – 3.829	0.667
Never vs < Once per Year	1.034	0.299 – 3.578	0.958
Never vs Once per Year	1.797	0.402 – 8.029	0.443
Never vs > Once per Year	2.255	0.492 – 10.329	0.295
Emergency vs < Once per Year	1.508	0.539 – 4.220	0.434
Emergency vs Once per Year	**2.620**	**1.223 – 5.616**	**0.013**
Emergency vs > Once per Year	**3.287**	**1.676 – 6.450**	**0.001**
< Once per Year vs Once per Year	**1.738**	**1.095 – 2.757**	**0.019**
< Once per Year vs > Once per Year	**2.180**	**1.202 – 3.951**	**0.010**
Once per year vs > Once per Year	1.254	0.916 – 1.718	0.158
Brushing Teeth	1.031	0.991 – 1.072	0.134
Flossing Teeth	1.029	0.992 – 1.066	0.122
Dairy Consumption	1.011	0.978 – 1.046	0.523
Fibre Consumption	1.009	0.995 – 1.023	0.219

Sugary Beverage Index Model – Self-Rated Oral Health

Interestingly, in the sugary beverage consumption model, the effect of the beverage variables changed quite a bit, with milk and the milk and sugary beverage interaction (IRR = 0.999; 95% CI = 0.998 – 1.000) being predictor variables. This can be seen in Table 14 below. Milk had a positive effect on SROH, raising it 1.039 times (95% CI = 1.005 – 1.074) for every time milk was drank per week. Milk helped to attenuate the effect of sugary beverages on SROH, with an IRR of 0.999 (95% CI = 0.998 – 1.000). This effect will be discussed further in reference to Figure 40 below. Water, sugary beverage, diet soft drink and vegetable juice consumption was not significant, nor was the interaction between water and sugary beverage consumption.

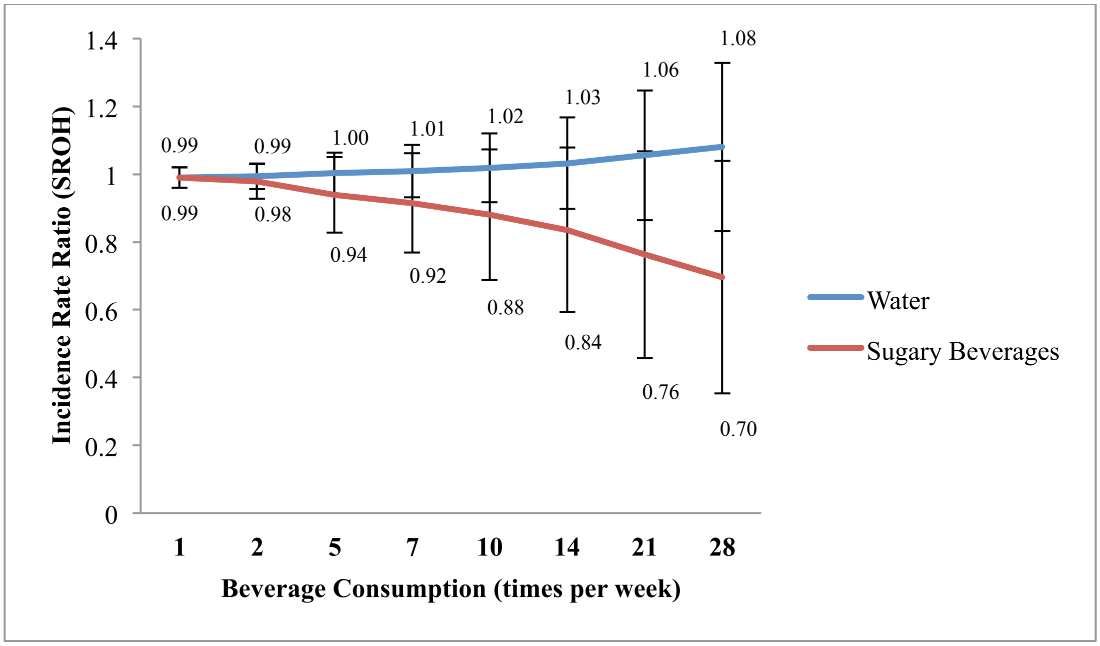
As displayed in Figure 38 below, sugary beverage consumption had a negative effect on self-rated oral health. As consumption of sugar-containing beverages increased, the average self-perceived oral health of CHMS participants decreased, from 4.08 (very good) in those that did not consume sugary beverages, to 3.18 (good) for respondents consuming 4 or more sugary beverages per day.

Figure 38. Effect of Sugary Beverage Consumption on Self-Rated Oral Health



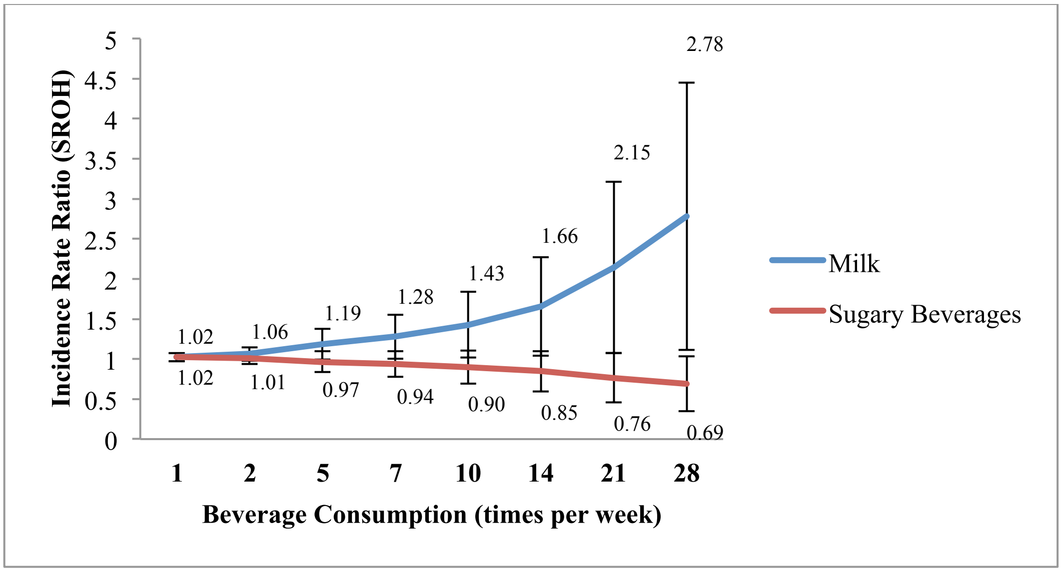
In examining the sugary beverage and water interaction, it was found that water has a slight protective effect over sugary beverage consumption for SROH. However, this effect was not significant so overall there appears to be no effect of the interaction between water and sugary beverage interaction in SROH. Each extra time water was consumed in a week raised the IRR by 0.0032 when sugary beverage consumption was held constant at 1 time per week. This effect is positive, but so minimal that to improve SROH score by one unit, an individual would have to consume water almost 45 more times per day. Sugary beverage consumption had a detrimental effect on SROH, lowering the IRR by 0.0106 for each increase in frequency of consumption. Thus, increasing sugary beverage consumption by 13.5 drinks per day would lower the SROH score by one unit. Figure 39 displays these effects.

Figure 39. Interaction between Water and Sugary Beverage Consumption



Milk had a significant protective effect over sugary beverage consumption for SROH. Investigation of the interaction term found that holding sugary beverage consumption constant, each extra time milk was consumed per week raised the IRR by 0.0386. Thus, milk confers a much greater protective benefit than water over sugary beverage consumption as it takes an increase of only 3.7 times drinking milk per day to improve SROH by one unit as opposed to almost 45 times for water (additionally, the milk and sugary beverage interaction was significant whereas the water and sugary beverage interaction was not). On the other hand, sugary beverage consumption lowered the IRR by 0.0149 when milk was held constant. Clinically, this translates to a unit decrease in self-rated oral health for every 9.6 times sugary beverages were consumed per day. Figure 40 below illustrates these results.

Figure 40. Interaction between Milk and Sugary Beverage Consumption



As illustrated in Table 14, income and visiting a dental professional were again associated with SROH. The same contrasts as in the main effects model were significant for visiting a dental professional, specifically emergency vs. once per year (IRR = 2.763; 95% CI = 1.353 – 5.641), emergency vs. more than once per year (IRR = 0.496; 95% CI = 1.865 – 6.552), less than once per year vs. once per year (IRR = 1.764; 95% CI = 1.142 – 2.724), and less than once per year vs. more than once per year (IRR = 2.232; 95% CI = 1.272 – 3.915). For income, the lowest income vs. highest income contrast was no longer significant, but being in the highest income group was associated with rating your oral health better than the middle (IRR = 1.953; 95% CI = 1.447 – 2.636) or upper middle (IRR = 1.480; 95% CI = 1.072 – 2.043) income groups. Additionally, sex was found to be significant in the sugary beverage model, with females having 1.215 times higher SROH and thus perceive their oral health better than men (95% CI = 1.003-1.471).

Table 14. Correlates of Self-Rated Oral Health, Sugary Beverage Index Model, Ordinal Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.003	0.994 – 1.012	0.530
Milk	**1.039**	**1.005 – 1.074**	**0.023**
Sugary Beverage Consumption Index	0.987	0.963 – 1.011	0.280
Diet Soft Drinks	1.006	0.958 – 1.057	0.805
Vegetable Juices	1.034	0.974 – 1.098	0.269
Milk and Sugary Beverage Interaction	**0.999**	**0.998 – 1.000**	**0.037**
Water and Sugary Beverage Interaction	1.000	1.000 – 1.001	0.084
Age			0.551
12-15 vs 16-19	0.802	0.529 – 1.215	0.297
12-15 vs 20-24	1.122	0.642 – 1.961	0.686
12-15 vs 25-30	0.972	0.578 – 1.633	0.914
16-19 vs 20-24	1.399	0.650 – 3.013	0.391
16-19 vs 25-30	1.212	0.789 – 1.860	0.380
20-24 vs 25-30	0.866	0.399 – 1.877	0.715
Sex	**1.215**	**1.003 – 1.471**	**0.046**
Education			0.980
< Post-Secondary vs Other Post-Secondary	0.733	0.420 – 1.279	0.274
< Post-Secondary vs Post-Secondary Grad	0.766	0.591 – 0.993	0.044
< Post-Secondary vs Not Stated	0.717	0.286 – 1.815	0.483
Other Post-Secondary vs Post-Secondary Grad	1.046	0.599 – 1.824	0.875
Other Post-Secondary vs Not Stated	0.979	0.334 – 2.867	0.969
Post-Secondary Grad vs Not Stated	0.936	0.358 – 2.447	0.893
Income			**<0.001**
Lowest income vs Middle income	1.130	0.542 – 2.357	0.744
Lowest income vs Upper middle income	1.492	0.638 – 3.487	0.356
Lowest income vs Highest income	2.208	0.931 – 5.236	0.072
Lowest income vs Not stated	1.471	0.486 – 4.447	0.494
Middle income vs Upper middle income	1.320	0.929 – 1.876	0.122
Middle income vs Highest income	**1.953**	**1.447 – 2.636**	**<0.001**
Middle income vs Not stated	1.301	0.730 – 2.319	0.372
Upper middle income vs Highest income	**1.480**	**1.072 – 2.043**	**0.017**
Upper middle income vs Not stated	0.986	0.613 – 1.585	0.953
Highest income vs Not stated	0.666	0.380 – 1.167	0.156
Smoking Habits			0.163
Current smoker vs Former smoker	0.869	0.366 – 2.062	0.750
Current smoker vs Never smoked	1.407	0.963 – 2.054	0.077
Former smoker vs Never smoked	1.619	0.823 – 3.182	0.163
Frequency of dental care			**<0.001**
Never vs Emergency	0.818	0.156 – 4.302	0.813
Never vs < Once per Year	1.282	0.382 – 4.306	0.688
Never vs Once per Year	2.261	0.521 – 9.803	0.276
Never vs > Once per Year	2.861	0.657 – 12.448	0.161
Emergency vs < Once per Year	1.566	0.597 – 4.108	0.362
Emergency vs Once per Year	**2.763**	**1.353 – 5.641**	**0.005**
Emergency vs > Once per Year	**0.496**	**1.865 – 6.552**	**<0.001**
< Once per Year vs Once per Year	**1.764**	**1.142 – 2.724**	**0.011**
< Once per Year vs > Once per Year	**2.232**	**1.272 – 3.915**	**0.005**
Once per year vs > Once per Year	1.265	0.923 – 1.735	0.144
Brushing Teeth	1.032	0.992 – 1.073	0.118
Flossing Teeth	1.2027	0.988 – 1.067	0.179
Dairy Consumption	1.013	0.981 – 1.047	0.432

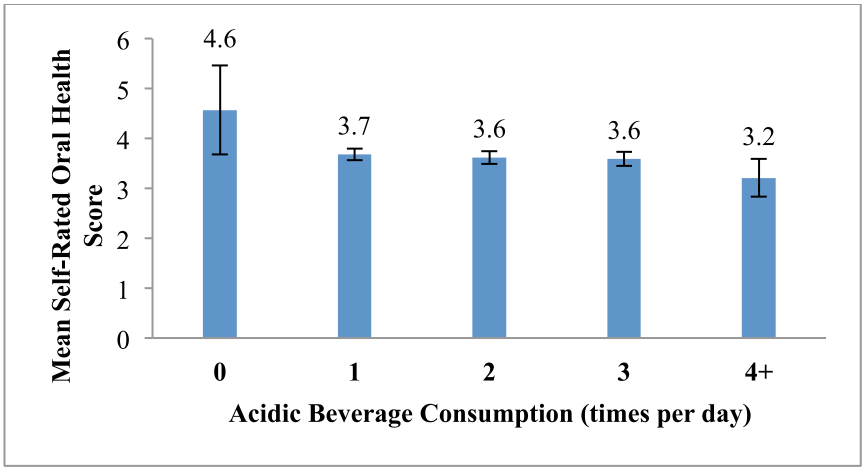
Fibre Consumption	1.011	0.997 – 1.025	0.112

Acidic Beverage Index Model – Self-Rated Oral Health

In the acidic beverage consumption model shown in Table 15 below, the significant predictor variables included milk consumption, the interaction between milk and acidic beverage consumption, sex, income and frequency of dental care. As in the sugary beverage model, milk again had a positive influence on SROH, increasing this score 1.045 times (95% CI = 1.012 – 1.080) for each extra time milk was consumed per week. The interaction between milk and acidic beverages (IRR = 0.999; 95% CI = 0.997 – 1.000) is further discussed below and displayed in Figure 43. Water consumption, acidic beverage consumption and the interaction between the two were not significant variables in this model.

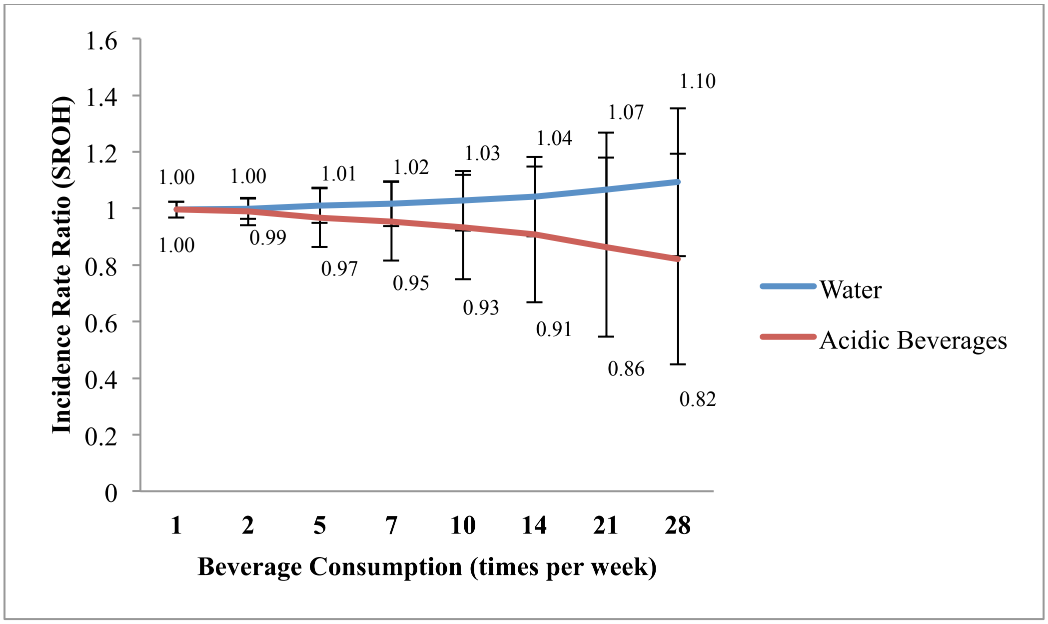
Although not significant, acidic beverage consumption had a negative effect on self-reported oral health. As weekly consumption of acidic beverages rose, average self-rated oral health scores became lower. Those participants who did not regularly consume acidic beverages had much higher scores than those who drank any amount of acidic beverages. The middle consumption groups (1, 2 or 3 times per day) had similar self-perceived oral health scores, although they decreased slightly as consumption increased. Those participants who drank acidic beverages 4 or more times per day had the lowest average self-rated oral health scores of any of the consumption groups.

Figure 41. Effect of Acidic Beverage Consumption on Self-Rated Oral Health



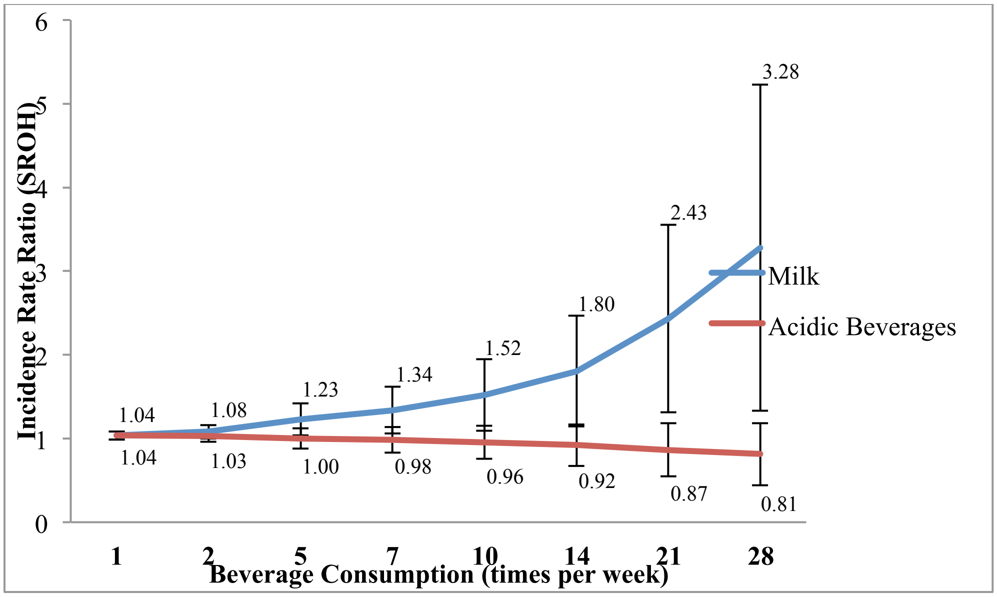
For the acidic beverage and water interaction for SROH, water was found to have a protective but insignificant effect over acidic beverage consumption. An increase in water consumption raised the IRR by 0.0034 when acidic beverage consumption was held constant, and the IRR decreased by 0.0072 for each extra acidic beverage per week when water consumption was held constant. This translates to an increase in one level of SROH for every 42 times water was consumed per day, and a decrease for every 19.8 times acidic beverages were consumed. This is illustrated in Figure 42 below.

Figure 42. Interaction between Water and Acidic Beverage Consumption



In the acidic beverage and milk interaction for SROH, milk was found to have a significant and relatively strong protective effect. Each increase in the number of times milk was consumed on a weekly basis raised the IRR for SROH by 0.0452 when acidic beverage consumption was held constant. In clinically significant terms, a patient would have to increase their milk consumption by 3.2 times per day to improve their SROH scale by one unit. Holding milk constant, acidic beverages lowered the IRR by 0.0092 for every extra time consumed per week, meaning one would have to consume acidic beverages an additional 15.5 times per day to decrease their SROH by one unit. The results of this analysis are illustrated in Figure 43.

Figure 43. Interaction between Milk and Acidic Beverage Consumption



Females were found to have 1.227 times (95% CI = 1.008 – 1.493) better SROH than males in the acidic beverage index model. In regards to income, the highest income group was found to have a significantly different effect on SROH than being in the middle income group or the upper middle income group, raising the SROH 1.946 times (95% CI = 1.452 – 2.607) and 1.476 times (95% CI = 1.073 – 2.031) respectively. Significant differences in SROH were also found between the frequencies of visiting a dental professional; those who visited a dental professional once per year had 2.805 times (95% CI = 1.398 = 5.628) better SROH than those who visited on an emergency basis and 1.741 times (95% CI = 1.123 – 2.699) higher SROH than those who saw an oral health care provider less than once per year. Compared to those who saw a dental professional more than once per year, respondents who visited their provider only for emergencies had 3.529 times (95% CI = 1.900 – 6.556) poorer SROH and those who visited less than once per year had 2.191 times (95% CI = 1.246 – 3.850) worse SROH.

Table 15. Correlates of Self-Rated Oral Health, Acidic Beverage Index Model, Ordinal Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.003	0.994 – 1.013	0.520
Milk	**1.045**	**1.012 – 1.080**	**0.008**
Acidic Beverage Consumption Index	0.993	0.971 – 1.014	0.498
Milk and Acidic Beverage Interaction	**0.999**	**0.997 – 1.000**	**0.004**
Water and Acidic Beverage Interaction	1.000	1.000 – 1.001	0.107
Age			0.522
12-15 vs 16-19	0.804	0.534 – 1.210	0.295
12-15 vs 20-24	1.114	0.631 – 1.967	0.709
12-15 vs 25-30	0.986	0.581 – 1.676	0.960
16-19 vs 20-24	1.387	0.637 – 3.019	0.410
16-19 vs 25-30	1.228	0.797 – 1.890	0.352
20-24 vs 25-30	0.885	0.392 – 2.000	0.769
Sex	**1.227**	**1.008 – 1.493**	**0.041**
Education			0.955
< Post-Secondary vs Other Post-Secondary	0.719	0.410 – 1.260	0.249
< Post-Secondary vs Post-Secondary Grad	0.771	0.586 – 1.014	0.062
< Post-Secondary vs Not Stated	0.702	0.277 – 1.778	0.456
Other Post-Secondary vs Post-Secondary Grad	1.072	0.618 – 1.861	0.804
Other Post-Secondary vs Not Stated	0.976	0.336 – 2.838	0.965
Post-Secondary Grad vs Not Stated	0.910	0.349 – 2.375	0.848
Income			**<0.001**
Lowest income vs Middle income	1.146	0.553 – 2.376	0.713
Lowest income vs Upper middle income	1.511	0.648 – 3.524	0.339
Lowest income vs Highest income	2.231	0.947 – 5.253	0.066
Lowest income vs Not stated	1.491	0.504 – 4.406	0.470
Middle income vs Upper middle income	1.319	0.920 – 1.889	0.132
Middle income vs Highest income	**1.946**	**1.452 – 2.607**	**<0.001**
Middle income vs Not stated	1.300	0.732 – 2.310	0.370
Upper middle income vs Highest income	**1.476**	**1.073 – 2.031**	**0.017**
Upper middle income vs Not stated	0.987	0.626 – 1.556	0.954
Highest income vs Not stated	0.668	0.389 – 1.149	0.145
Smoking Habits			0.149
Current smoker vs Former smoker	0.860	0.366 – 2.020	0.730
Current smoker vs Never smoked	1.409	0.976 – 2.034	0.067
Former smoker vs Never smoked	1.637	0.838 – 3.198	0.149
Frequency of dental care			**<0.001**
Never vs Emergency	0.816	0.157 – 4.240	0.809
Never vs < Once per Year	1.315	0.391 – 4.426	0.658
Never vs Once per Year	2.289	0.527 – 9.939	0.269
Never vs > Once per Year	2.881	0.658 – 12.609	0.160
Emergency vs < Once per Year	1.611	0.623 – 4.168	0.325
Emergency vs Once per Year	**2.805**	**1.398 – 5.628**	**0.004**
Emergency vs > Once per Year	**3.529**	**1.900 – 6.556**	**<0.001**
< Once per Year vs Once per Year	**1.741**	**1.123 – 2.699**	**0.013**
< Once per Year vs > Once per Year	**2.191**	**1.246 – 3.850**	**0.006**

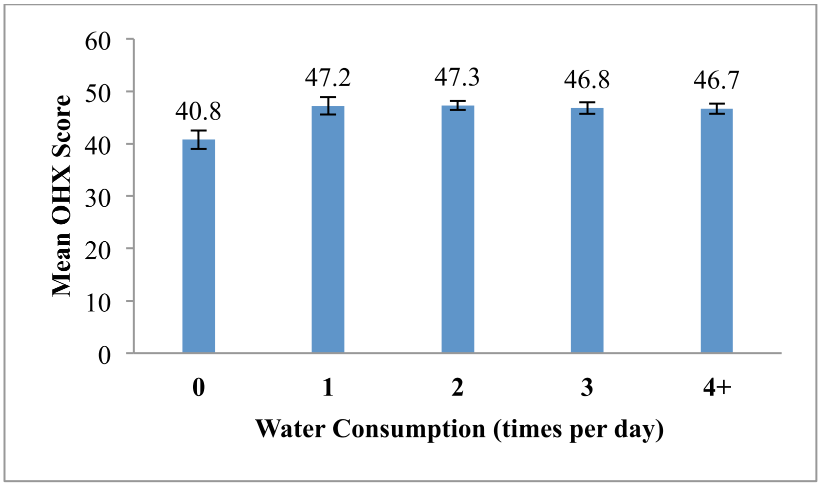
Once per year vs > Once per Year	1.258	0.924 – 1.714	0.145
Brushing Teeth	1.032	0.992 – 1.073	0.117
Flossing Teeth	1.028	0.989 – 1.068	0.159
Dairy Consumption	1.016	0.983 – 1.049	0.347
Fibre Consumption	1.011	0.997 – 1.024	0.120

Main Effects Model – Oral Health Index

The final set of models examined the effect of the predictor variables on the Oral Health Index (OHX). In the main effects model, regular soft drink consumption and age were the only significant variables. This is shown in Table 16 below. Regular soft drinks had a negative effect on OHX score, with each increase in number of times regular soft drinks were consumed per week gave an OHX 1.007 times lower (95% CI = 0.989 – 0.997). The beverage variables that were not significant in this model included water, milk, diet soft drinks, sports drinks, fruit juices, fruit-flavoured drinks, vegetable juices and alcohol.

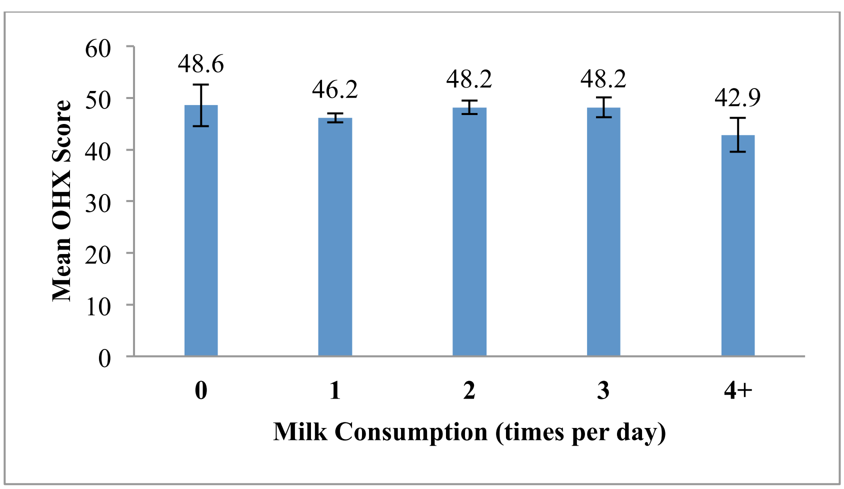
Based on the CHMS data, water consumption does not appear to have an effect on the OHX provided a participant consumed water at least once per day. However, those respondents who did not consume water on a daily basis had much lower average OHX scores than other participants. This is shown in Figure 44 below.

Figure 44. Effect of Water Consumption on Overall Oral Health



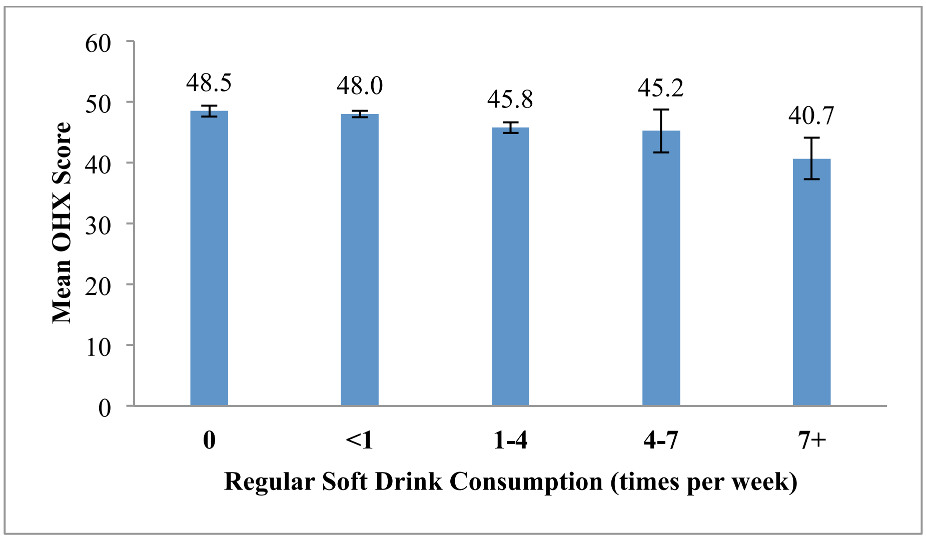
For the most part, milk consumption did not appear to affect OHX score. Although one group (1 time consuming milk per day) was slightly lower than the other three groups, average OHX scores were relatively similar for all participants who consumed milk less than 4 times per day. Those who did drink milk 4 or more times per day had much lower OHX scores than other consumption groups.

Figure 45. Effect of Milk Consumption on Overall Oral Health



Based on the CHMS data, a negative association existed between regular soft drink consumption and OHX score. Interestingly, similar average OHX scores were exhibited between the 0 and less than 1 times per week consumption groups, as well as between the 1-4 and 4-7 drinks per week groups. Those participants who consumed regular soft drinks 7 or more times per week had much lower average OHX scores than other consumption groups.

Figure 46. Effect of Regular Soft Drink Consumption on Overall Oral Health



Additionally, three of the six age contrast variables were significant; 12-15 year olds had OHX scores 1.076 times (95% CI = 0.891 – 0.957) higher than to 20-24 year olds and 1.074 times (95% CI = 0.887 – 0.967) higher than 25-30 year olds, and participants in the 20-24 age group had OHX scores 1.058 times (95% CI = 0.901 – 0.985) higher than 25-30 year olds.

Table 16. Correlates of Oral Health Index, Main Effects Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	1.000	0.999 – 1.001	0.974
Milk	1.000	0.999 – 1.001	0.912
Regular Soft Drinks	**0.993**	**0.989 – 0.997**	**0.001**
Diet Soft Drinks	1.000	0.997 – 1.004	0.821
Sports Drinks	1.004	0.998 – 1.009	0.211
Fruit Juices	1.000	0.998 – 1.001	0.579
Fruit-Flavoured Drinks	0.998	0.995 – 1.000	0.062
Vegetable Juices	1.000	0.996 – 1.005	0.879
Alcohol	1.000	0.997 – 1.002	0.857
Age			**0.002**
12-15 vs 16-19	0.984	0.962 – 1.006	0.159
12-15 vs 20-24	**0.924**	**0.891 – 0.957**	**<0.001**
12-15 vs 25-30	**0.926**	**0.887 – 0.967**	**0.001**
16-19 vs 20-24	1.016	0.969 – 1.066	0.504
16-19 vs 25-30	0.982	0.923 – 1.045	0.568
20-24 vs 25-30	**0.942**	**0.901 – 0.985**	**0.008**
Sex	0.989	0.968 – 1.010	0.295
Education			0.918
< Post-Secondary vs Other Post-Secondary	1.028	0.990 – 1.068	0.152
< Post-Secondary vs Post-Secondary Grad	1.022	0.991 – 1.054	0.161
< Post-Secondary vs Not Stated	1.026	0.972 – 1.084	0.354
Other Post-Secondary vs Post-Secondary Grad	0.976	0.880 – 1.082	0.643
Other Post-Secondary vs Not Stated	0.993	0.893 – 1.103	0.894
Post-Secondary Grad vs Not Stated	0.998	0.950 – 1.050	0.943
Income			0.184
Lowest income vs Middle income	1.059	0.998 – 1.124	0.058
Lowest income vs Upper middle income	1.063	0.992 – 1.138	0.083
Lowest income vs Highest income	1.082	1.014 – 1.154	0.018
Lowest income vs Not stated	1.077	1.007- 1.151	0.030
Middle income vs Upper middle income	0.991	0.945 – 1.040	0.717
Middle income vs Highest income	1.008	0.963 – 1.055	0.725
Middle income vs Not stated	1.019	0.976 – 1.063	0.389
Upper middle income vs Highest income	1.021	0.977 – 1.068	0.355
Upper middle income vs Not stated	1.017	0.978 – 1.057	0.410
Highest income vs Not stated	1.013	0.977 – 1.051	0.490
Smoking Habits			0.727
Current smoker vs Former smoker	1.039	0.965 – 1.119	0.306
Current smoker vs Never smoked	1.056	1.014 – 1.099	0.009
Former smoker vs Never smoked	1.045	0.980 – 1.113	0.178
Frequency of dental care			0.176
Never vs Emergency	1.026	0.915 – 1.150	0.664
Never vs < Once per Year	1.103	1.000 – 1.216	0.050
Never vs Once per Year	1.106	1.002 – 1.222	0.045
Never vs > Once per Year	1.103	0.996 – 1.221	0.060
Emergency vs < Once per Year	0.966	0.886 – 1.053	0.432

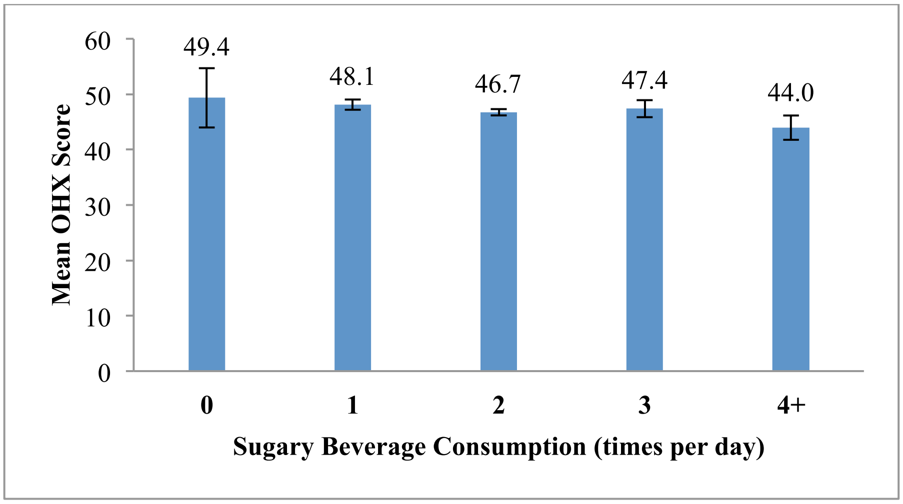
Emergency vs Once per Year	1.017	0.997 – 1.071	0.511
Emergency vs > Once per Year	1.010	0.990 – 1.030	0.346
< Once per Year vs Once per Year	1.079	1.002 – 1.161	0.044
< Once per Year vs > Once per Year	1.075	1.005 – 1.150	0.035
Once per year vs > Once per Year	1.000	0.956 – 1.046	0.998
Brushing Teeth	1.000	0.998 – 1.002	0.750
Flossing Teeth	1.000	0.998 – 1.003	0.958
Dairy Consumption	1.000	0.998 – 1.002	0.699
Fibre Consumption	1.001	1.000 – 1.002	0.057

Sugary Beverage Index Model – Oral Health Index

In the sugary beverage consumption model, milk consumption had a positive effect on OHX scores, raising it by 1.003 times for every increase in frequency of milk consumption per week. The milk and sugary beverage interaction was also significant (IRR = 1.000; 95% CI = 1.000 – 1.000). Water, sugary beverage, diet soft drink, and vegetable juice consumption were not significant predictors. The water and sugary beverage consumption interaction variable was also not significant in this model. These results are displayed in Table 17 below.

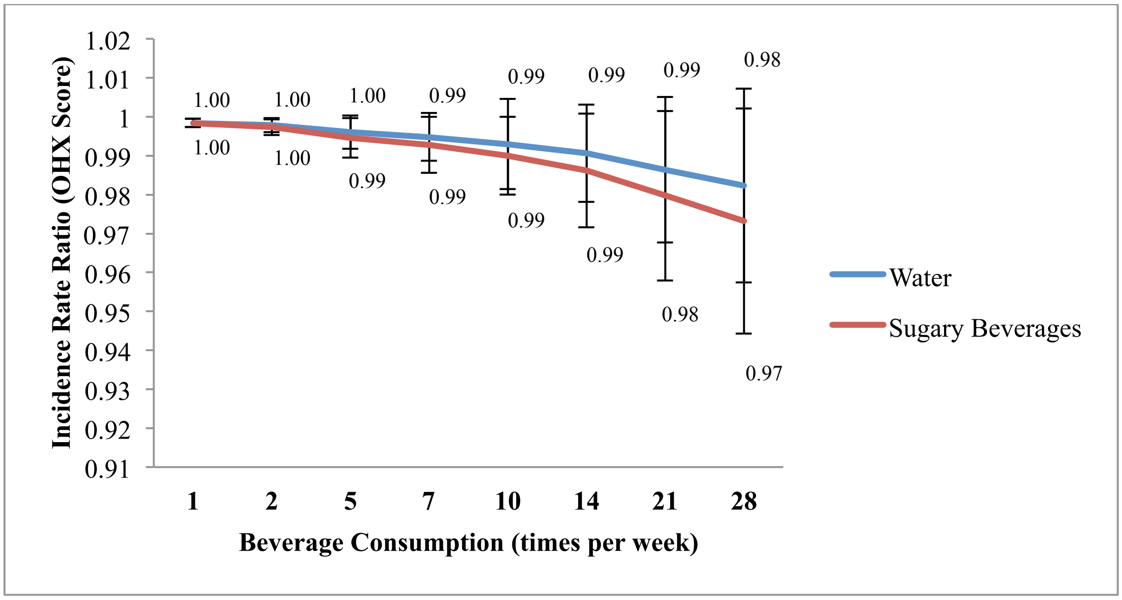
In general, increased consumption of sugar-containing beverages lowered mean OHX scores, although not significantly. There was one exception to this rule, that being 2 vs. 3 acidic beverages per day. Otherwise, as consumption of sugary beverages increased, average OHX scores decreased, with the largest difference in scores being between 3 sugary beverages per day and the largest consumption groups, 4 or more times consuming sugary-containing per day.

Figure 47. Effect of Sugary Beverage Consumption on Overall Oral Health



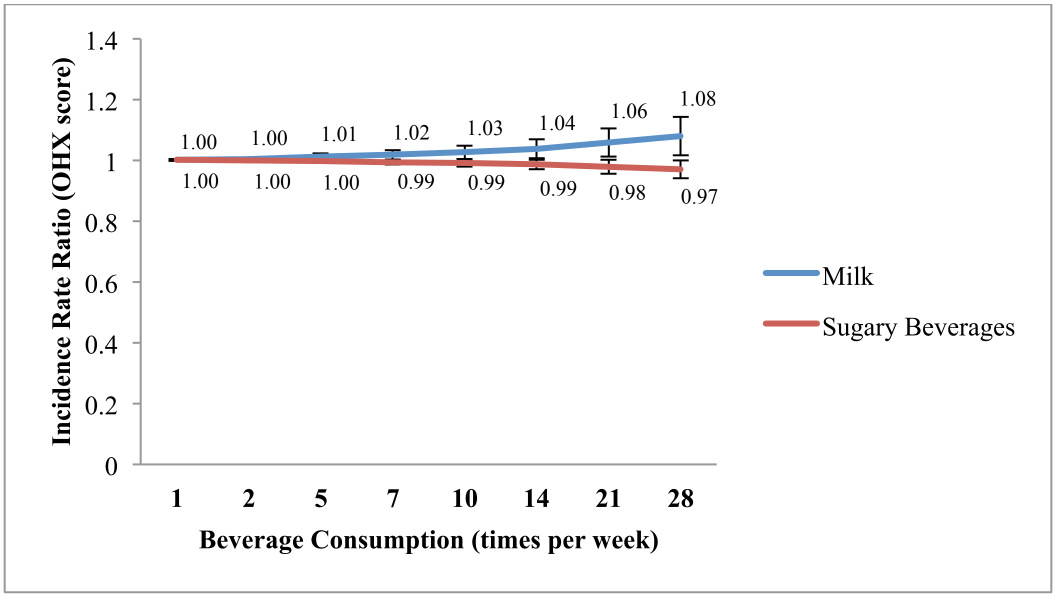
In the OHX Sugary Beverage model, both sugary beverages and water magnified the negative effect of each other when their interaction was examined; however, this interaction was not statistically significant. For each extra time water was consumed in a week, the IRR lowered by 0.0006, and each increase in sugary beverage consumption caused the IRR for OHX to decrease by 0.0011. These values correspond to decreases in IRR by 0.0429 and 0.0800 for each additional 10 times water or sugary beverages were consumed in a day, respectively. Figure 48 below further illustrates these effects.

Figure 48. Interaction between Water and Sugary Beverage Consumption



In this model, milk was found to have a significant protective effect when interacting with sugar-containing beverages. Holding sugary beverage consumption constant, each extra time milk was consumed in a week raised the IRR by 0.0028. If milk consumption was increased by 10 times per day, this would correspond to an IRR increased 1.2165 times. When milk consumption was held constant, an increase in sugary beverage consumption lowered the IRR by 0.0012. For each additional 10 times sugary beverages were consumed in a day, the IRR would be lowered by 0.0876. These findings are further demonstrated in Figure 49.

Figure 49. Interaction between Milk and Sugary Beverage Consumption



Significant differences were found between all age groups except between 12-15 and 16-19 year olds, and 16-19 and 25-30 year olds. Increasing fibre consumption by eating fibre one more time per week raised OHX by 1.001 times (95% CI = 1.000 – 1.002).

Table 17. Correlates of Oral Health Index, Sugary Beverage Index Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	0.999	0.998 – 1.000	0.194
Milk	**1.003**	**1.001 – 1.005**	**0.009**
Sugary Beverage Consumption Index	0.999	0.998 – 1.000	0.081
Diet Soft Drinks	1.001	0.997 – 1.005	0.599
Vegetable Juices	1.001	0.996 – 1.006	0.689
Milk and Sugary Beverage Interaction	**1.000**	**1.000 – 1.000**	**<0.001**
Water and Sugary Beverage Interaction	1.000	1.000 – 1.000	0.209
Age			**0.002**
12-15 vs 16-19	0.989	0.966 – 1.012	0.349
12-15 vs 20-24	**0.933**	**0.902 – 0.965**	**<0.001**
12-15 vs 25-30	**0.934**	**0.894 – 0.977**	**0.003**
16-19 vs 20-24	**1.062**	**1.016 – 1.110**	**0.008**
16-19 vs 25-30	0.997	0.951 – 1.045	0.897
20-24 vs 25-30	**0.945**	**0.904 – 0.988**	**0.012**
Sex	0.988	0.966 – 1.001	0.279

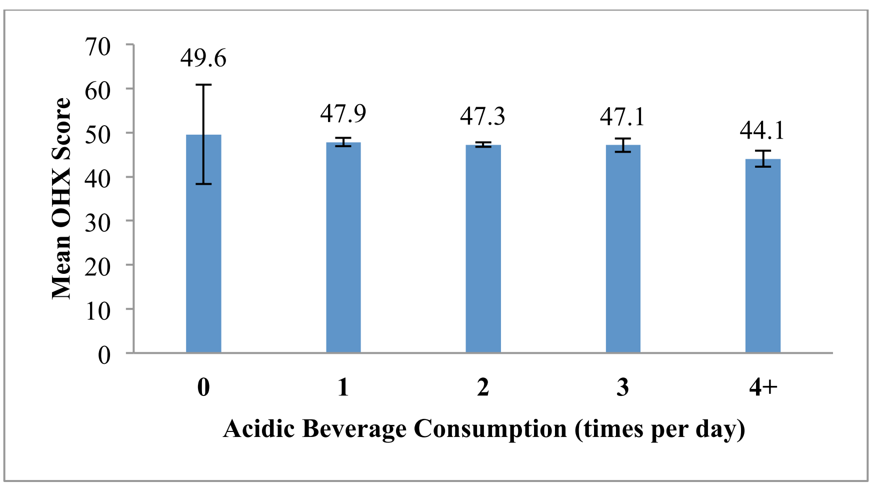
Education			0.888
< Post-Secondary vs Other Post-Secondary	1.027	0.990 – 1.065	0.161
< Post-Secondary vs Post-Secondary Grad	1.024	0.993 – 1.056	0.127
< Post-Secondary vs Not Stated	1.035	0.985 – 1.088	0.171
Other Post-Secondary vs Post-Secondary Grad	1.002	0.953 – 1.053	0.943
Other Post-Secondary vs Not Stated	0.996	0.949 – 1.045	0.869
Post-Secondary Grad vs Not Stated	1.008	0.963 – 1.056	0.725
Income			0.072
Lowest income vs Middle income	1.053	0.996 – 1.113	0.069
Lowest income vs Upper middle income	1.057	0.988 – 1.132	0.109
Lowest income vs Highest income	1.079	1.012 – 1.151	0.019
Lowest income vs Not stated	1.073	1.006 – 1.144	0.033
Middle income vs Upper middle income	0.984	0.946 – 1/023	0.410
Middle income vs Highest income	0.987	0.952 – 1.024	0.490
Middle income vs Not stated	1.005	0.964 – 1.046	0.825
Upper middle income vs Highest income	1.025	0.980 – 1.072	0.275
Upper middle income vs Not stated	1.019	0.981 – 1.058	0.329
Highest income vs Not stated	1.015	0.977 – 1.055	0.455
Smoking Habits			0.703
Current smoker vs Former smoker	1.042	0.974 – 1.113	0.232
Current smoker vs Never smoked	1.059	1.018 – 1.101	0.004
Former smoker vs Never smoked	0.984	0.902 – 1.075	0.727
Frequency of dental care			0.052
Never vs Emergency	1.012	0.900 – 1.137	0.847
Never vs < Once per Year	1.103	0.997 – 1.220	0.058
Never vs Once per Year	1.109	1.002 – 1.229	0.046
Never vs > Once per Year	1.104	0.994 – 1.226	0.066
Emergency vs < Once per Year	0.930	0.869 – 0.995	0.035
Emergency vs Once per Year	1.000	0.956 – 1.046	0.998
Emergency vs > Once per Year	1.003	0.989 – 1.018	0.665
< Once per Year vs Once per Year	1.097	1.022 – 1.177	0.011
< Once per Year vs > Once per Year	1.091	1.023 – 1.163	0.008
Once per year vs > Once per Year	1.001	0.954 – 1.050	0.970
Brushing Teeth	1.000	0.998 – 1.002	0.844
Flossing Teeth	1.000	0.997 – 1.002	0.869
Dairy Consumption	1.000	0.998 – 1.002	0.730
Fibre Consumption	**1.001**	**1.000 – 1.002**	**0.007**

Acidic Beverage Index Model – Oral Health Index

The same variables that were significant in the sugary beverage model were also significant in the acidic beverage model for OHX. Each unit increase in the number of times milk was consumed per week raised OHX score 1.003 times (95% CI = 1.001 – 1.006). The interaction between milk and acidic beverages (IRR = 1.000; 95% CI = 1.000 – 1.000) is further discussed in Figure 52 below. Water consumption, acidic beverage consumption and the interaction between the two were not significant in this model. The results of this model are shown in Table 18 below.

As displayed in Figure 50, acidic beverage consumption also had a negative albeit insignificant effect on average OHX score for CHMS participants. There was no exception to this trend, although the 3 middle consumption groups (1, 2 or 3 times consuming acidic beverages per day) displayed relatively similar mean OHX scores. OHX scores for those respondents that did not consume acidic drinks was much higher, and those who consumed acidic beverages 4 or more times per day had OHX scores that were low in comparison to other groups.

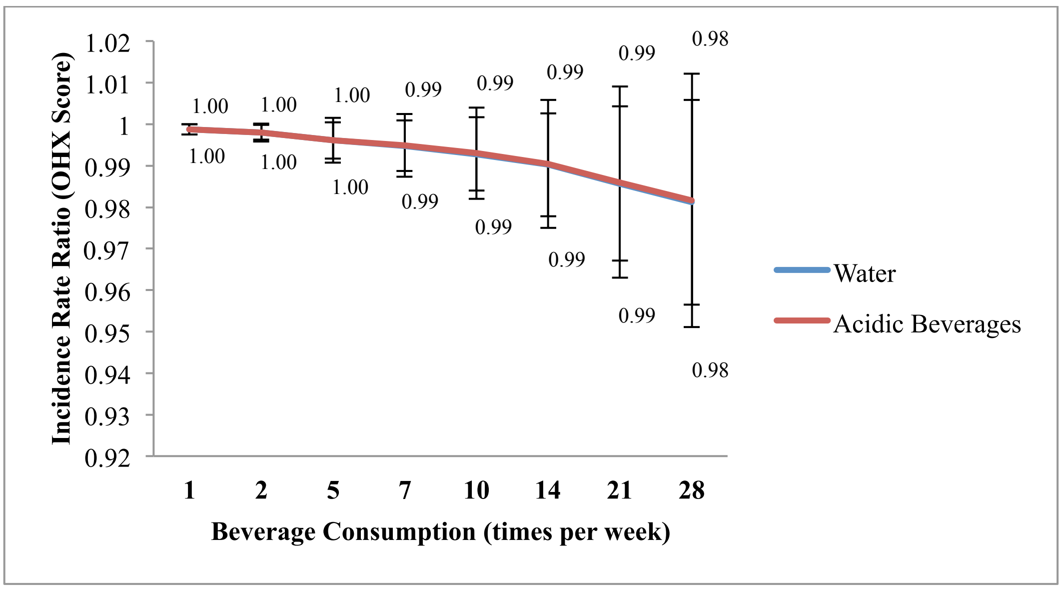
Figure 50. Effect of Acidic Beverage Consumption on Overall Oral Health



Both acidic beverages and water had a very similar, detrimental effect on OHX when examining the interaction variable, although this interaction was not significant.

An increase in consumption of both beverage variables lowered the IRR by about 0.0007 when the other beverage was held constant. In more clinically significant terms, if one were to increase their consumption of either water or acidic beverages by 10 times per day, the IRR would be lowered about 1.0502 times. Based on the data in Figure 51 below, water had a slightly stronger deleterious effect, and acidic beverage consumption had a larger confidence interval.

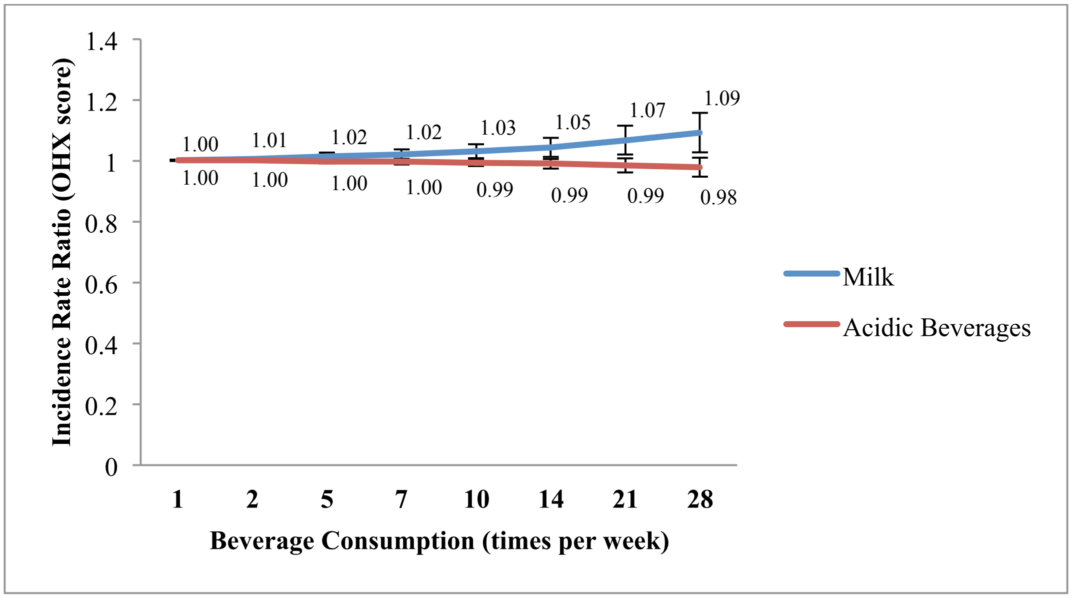
Figure 51. Interaction between Water and Acidic Beverage Consumption



In this model, the milk and acidic beverage interaction variable was found to be significant, with milk having a protective effect over acidic beverage consumption. As weekly milk consumption increased, the IRR was raised by 0.0032, holding acidic beverage consumption constant. This corresponds to an IRR increased by 0.2511 for each additional 10 times milk was consumed in a day. As the number of times acidic beverages were drank in a week increased, the IRR decreased by 0.0008, or decreased by

0.0576 for each additional 10 times acidic beverages were consumed in a day. The results are shown in the Figure 52.

Figure 52. Interaction between Milk and Acidic Beverage Consumption



All age groups comparisons were significant except for 12-15 vs. 16-19 year olds, and 16-19 year olds vs. 25-30 year olds. Fibre consumption again had a positive impact on OHX score, with each increase in frequency of fibre intake raising OHX scores 1.001 times (95% CI = 1.000 – 1.002).

Table 18. Correlates of Oral Health Index, Acidic Beverage Index Model, Poisson Regression (n=1534)

Variable	IRR	95% CI	p-value
Water	0.999	0.998 – 1.000	0.158
Milk	**1.003**	**1.001 – 1.006**	**0.003**
Acidic Beverage Consumption Index	0.999	0.998 – 1.000	0.253
Milk and Acidic Beverage Interaction	**1.000**	**1.000 – 1.000**	**<0.001**
Water and Acidic Beverage Interaction	1.000	1.000 – 1.000	0.181
Age			**0.002**
12-15 vs 16-19	0.990	0.966 – 1.013	0.386
12-15 vs 20-24	**0.933**	**0.902 – 0.965**	**<0.001**
12-15 vs 25-30	**0.936**	**0.897 – 0.976**	**0.002**

16-19 vs 20-24	**1.059**	**1.012 – 1.107**	**0.012**
16-19 vs 25-30	0.999	0.954 – 1.046	0.961
20-24 vs 25-30	**0.945**	**0.906 – 0.986**	**0.009**
Sex	0.989	0.967 – 1.011	0.324
Education			0.932
< Post-Secondary vs Other Post-Secondary	1.025	0.989 – 1.063	0.176
< Post-Secondary vs Post-Secondary Grad	1.024	0.993 – 1.056	0.130
< Post-Secondary vs Not Stated	1.033	0.982 – 1.085	0.203
Other Post-Secondary vs Post-Secondary Grad	0.992	0.947 – 1.033	0.627
Other Post-Secondary vs Not Stated	0.932	0.874 – 0.994	0.033
Post-Secondary Grad vs Not Stated	1.007	0.962 – 1.054	0.763
Income			0.091
Lowest income vs Middle income	1.055	0.997 – 1.116	0.063
Lowest income vs Upper middle income	1.058	0.990 – 1.132	0.096
Lowest income vs Highest income	1.081	1.015 – 1.152	0.016
Lowest income vs Not stated	1.075	1.008 – 1.147	0.028
Middle income vs Upper middle income	0.981	0.945 – 1.019	0.329
Middle income vs Highest income	0.985	0.948 – 1.024	0.455
Middle income vs Not stated	1.006	0.967 – 1.047	0.761
Upper middle income vs Highest income	1.025	0.979 – 1.072	0.293
Upper middle income vs Not stated	1.019	0.980 – 1.060	0.337
Highest income vs Not stated	1.016	0.977 – 1.056	0.428
Smoking Habits			0.698
Current smoker vs Former smoker	1.041	0.973 – 1.114	0.246
Current smoker vs Never smoked	1.058	1.019 – 1.099	0.003
Former smoker vs Never smoked	0.983	0.904 – 1.070	0.698
Frequency of dental care			0.058
Never vs Emergency	1.013	0.898 – 1.142	0.839
Never vs < Once per Year	1.105	0.998 – 1.223	0.054
Never vs Once per Year	1.110	1.002 – 1.230	0.045
Never vs > Once per Year	1.105	0.993 – 1.230	0.067
Emergency vs < Once per Year	0.917	0.860 – 0.977	0.008
Emergency vs Once per Year	0.999	0.953 – 1.048	0.970
Emergency vs > Once per Year	1.005	0.990 – 1.021	0.503
< Once per Year vs Once per Year	1.097	1.021 – 1.117	0.011
< Once per Year vs > Once per Year	1.091	1.023 – 1.164	0.008
Once per year vs > Once per Year	1.000	0.954-1.048	0.997
Brushing Teeth	1.000	0.998 – 1.002	0.873
Flossing Teeth	1.000	0.997 – 1.002	0.893
Dairy Consumption	1.000	0.998 – 1.002	0.908
Fibre Consumption	**1.001**	**1.000 – 1.002**	**0.006**

DISCUSSION

Although it was hypothesized that each of the beverage types and indices would affect oral health in either a beneficial or detrimental manner, many of the beverages were not associated with any of the various oral health outcomes. These variables included diet soft drinks, sports beverages, fruit juices, vegetable juice and alcohol. The acidic beverage consumption index was also not significant in all cases; however most of the interactions involving the indices were found to significantly contribute to oral health outcomes. Whereas other studies have found that most of these beverage types affect the teeth and oral cavity when their effects are examined in isolation, it appears from the current findings that consumption of many different beverage types does not have specific oral health outcomes when examined in the context of a whole person and the complexity of their diets and habits. In a way, this evidence could support an ecological fallacy in drawing hypotheses in this circumstance: liquid substances that may affect teeth and other oral structures at the biochemical level may not have a significant effect when the context of the whole person is considered.

Despite many of the predictor variables having no effect, some of the beverages were found to significantly contribute to oral health outcomes. It was hypothesized that water would have a positive effect on oral health. Although this was found to be the case, water was only significantly associated with one of the outcome measures, namely the main effects model for Self-Rated Oral Health. Since this was an outcome centered in self-perception, it is possible that many people believe that drinking a lot of water may have a positive impact on their oral health. This may be due to knowledge about the rinsing effects of water or the benefits of community water fluoridation. Alternatively, the relationship between water consumption and self-rated oral health could be confounded by having a health-conscious outlook, especially as other common health promoting behaviours, such as visiting a dental professional more often, were also significant in this model.

Fruit-flavoured beverage consumption was also found to have a limited effect, detrimentally impacting dental decay in the main effects model. This is likely due to the sugar content and acidic action of fruit-flavoured beverages affecting the tooth structure. Similarly, the sugary beverage consumption index, which was significant only for dental decay, likely affects oral health through the acid metabolism of sugars. Regular soft drinks, on the other hand, were found to be associated with all of the oral health outcomes, albeit the effect being small. This was consistent with the existing literature in which regular soft drink consumption often emerges as the only significant beverage predictor of oral health outcomes (Burt et al., 2006; Dugmore & Rock, 2004).

Milk was also found to be a common contributor to oral health outcomes. Milk emerged as significant in all of the consumption index models except for the sugary beverage consumption index for decay. Many of the interaction terms involving milk were also significant, except for the milk and sugary beverage interaction term in the sugary beverage index model for dental decay. When predictive on its own, milk always had a beneficial effect on oral health, as did it in 7 of the 8 interaction terms. These findings suggest that consuming milk more frequently is beneficial to oral health, although the specific reason why is not known; however, based on our data, we can begin to formulate some hypotheses. First, it does not appear that the effect milk is the same for all dairy products, as non-milk dairy consumption did not emerge in any of the models as a significant predictor. Thus, it is not likely that an inherent property of dairy products, such as calcium content, is responsible for the benefit to oral health; however, it is important to note that the effect of non-milk dairy products may have been mitigated by the high sugar content of ice cream, frozen yogurt and flavoured yogurt, and each dairy product should be considered individually when examining effects in future studies. One possible mechanism by which milk aids oral health is through its buffering capacity; this observation is strengthened by the fact that when considering the interaction between milk and sugary or acidic beverages, increased milk consumption tended to be protective over sugar or acid consumption. Finally, the effect of milk may be through remineralization of the tooth structure, as milk does contain calcium and phosphate, the two major constituents of hydroxyapatite, and may act topically as opposed to systemically in the case of other dairy products.

Although some of the beverage variables were significant, the magnitude of these effects was very small, meaning that although some of our results may be statistically significant, they are likely not clinically significant. This observation lends strength to the fact that oral health outcomes are multi-causative, and the reasons for an individual's oral health status must be explored in the context of an accumulation of life experiences and circumstances. This can also support the message that anything is acceptable in moderation, but consuming high amounts, especially of soft drinks, may have a detrimental impact to one's oral health.

In consideration of the small magnitude of effects and the multi-factorial causation of oral health or disease, other covariates are also important to examine. In dental decay, age, sex, flossing and fibre consumption were significant predictors. Most of the age contrasts were found to be significant, with older participants having more dental decay than younger respondents. This is consistent with current dental knowledge, as time is an essential factor in the caries development process. As time goes on, more opportunities are presented for acid attack on the tooth structure due to sugar metabolism by certain bacteria, and if this is not reversed, it can eventually lead to decay and cavitation within the enamel and dentin. Thus, age is associated with greater extent, number and severity of dental decay.

In terms of sex effects, it was found that females generally had less decay than males. This may be explained by females generally having better hygiene habits than males, especially during the adolescent age period; however, females are generally found to exhibit a higher prevalence of dental caries than men when rates are reported by sex (Lukacs & Largaespada, 2006). Reasons commonly given for this difference include an earlier time of eruption in females and thus longer exposure to the cariogenic oral environment, frequent snacking during food preparation as in most cultures females are the primary food preparers, and hormone fluctuations during pregnancy (Lukacs & Largaespada, 2006). These trends may not have held true in the sub-population, as the restricted age group suggests the majority of women may not have experienced a pregnancy or are not the primary food preparers, and the relative affluence of Canada may indicate that fewer females may be subscribing to the gender role of food preparation, or this chore may be more equitably shared (Lukacs & Largaespada, 2006).

Fibre consumption was found to positively affect the number of sound teeth in the mouth, a finding consistent with the literature, as discussed in the introductory section.

Finally, somewhat counter-intuitively, flossing was found to have a negative association with dental decay. Although more frequent flossing and better oral hygiene habits are generally thought to improve oral health, this was not the case here. This may be explained by the lack of temporal data in the CHMS, as it not possible to determine when the decay took place and when the patient started their current flossing habits. It is likely that these participants had been identified as high risk patients based on their extensive decay and were motivated to start flossing regularly. Further evidence that may help to test this hypothesis would be the location of the caries; if true, it is likely that interproximal as opposed to occlusal caries were prevented once the respondent starting flossing. Interestingly, although flossing may help to prevent decay, it is more often indicated for gum disease such as gingivitis and periodontitis, but flossing did not emerge as a predictor in these models. Future studies should therefore use temporal data in exploring the relationship between flossing and dental decay.

In the gingivitis models, very few variables were significant predictors of gingival outcomes. Age appeared to be the most consistent and significant covariate, with two of the age contrasts emerging in all three models. Specifically, those respondents in the 12-15 age group (the youngest group) were found to have better periodontal health than participants in the two highest age groups (20-24 and 25-30). This is not unexpected, as prevalence of gingivitis and other periodontal diseases increases with age (Eke, Dye, Wei, Thornton-Evans & Genco, 2012). This is grounded in the fact that increased age means increased exposure to the risk factors for periodontitis, an increased chance of developing a condition such as diabetes and heart disease that may promote gingival inflammation, and an increased exposure to stress and other hormones (Ababneh, Hwaij

& Khader, 2012; Eke et al., 2012; Loesche & Grossman, 2001; Rajhans, Kohad, Chaudhari & Mhaske, 2011). In addition to age, fibre consumption was also significant in the two index models. This finding is consistent with the published literature, which has found that fibre consumption, especially from fruit sources, can help to both prevent and slow the progression of periodontal disease (Merchant, Pitiphat, Franz & Joshipura, 2006; Schwartz, Kaye, Nunn, Spiro & Garcia, 2012).

In examining the significant covariates for self-rated oral health, income and frequency of visiting a dental professional consistently emerged. In terms of income, those in the highest income group rated their oral health as better than all other groups (lowest, middle and upper middle incomes). This is not surprising, as those of a higher SES are generally found to have better health for a variety of reasons including being more likely to have dental insurance or being better able to afford dental treatment in general, having better knowledge and education about the benefits of preventive dental behaviours, having an increased ability to purchase healthy foods that may benefit oral health, and placing a higher personal value on oral health, especially aesthetics (Donaldson et al., 2008; Hobdell et al., 2003). These thoughts are consistent with another significant covariate: frequency of visiting a dental professional. In general, those who visited a dental professional on at least a yearly basis had better oral health than those that visited less than once per year or only on an emergency basis. Interestingly, those who responded that they never visited a dental professional were not found to be significantly different than any of the other contrasts, possibly due to a confounding of reasons the participants responded to being a part of this group. Specifically, participants may never visit a dental professional for a variety of reasons: those who perceive they have good or excellent oral health likely never visit a dental professional as they view it as an unnecessary expense, whereas those with fair to poor self-rated oral health may not be able to afford dental care or do not understand its importance in achieving and maintaining good oral health (Afonso-Souza et al., 2007; Donaldson et al., 2008). Interestingly, income and frequency of visiting a dental professional were significant covariates only in the self-rated oral health, which suggests there may be a perception around the importance of finances, especially in relation to being able to afford dental care, that is not reflected in reality.

In addition to income and visiting a dental professional, sex was also significantly associated with SROH in the index models, with females perceiving themselves to have poorer oral health. Sex differences have been found in some aspects of oral health; for instance, women have a greater prevalence of dental caries, xerostomia due to Sjogren's Syndrome, or Temporo-Mandibular Joint pain (American Dental Association, 2006; Lukacs & Largaespada, 2006). Although there is a some evidence to suggest that females may experience poorer oral health overall, females were found to have less dental decay than males in this analysis, and no sex differences were found in our OHX model, suggesting that it is likely not a problem in this sample/population; however, it is important to remember that the OHX was not a comprehensive index of all possible oral and dental health conditions. In other self-rated measures of health, no clear and consistent sex differences were found, although there may be some association when age and sex are considered together, especially in older populations (Beniyamini, Blumstein, Lusky & Modan, 2003; Demirchyan, Petrosyan, & Thompson, 2012). However, in adolescent populations, it appears that girls tend to rate their health more poorly than boys, likely due to sex differences in self-esteem around this age; as the sample in our study was age-restricted to include adolescents and young adults, this may explain the sex differences observed (Jerden, Burell, Stenlund, Weinehall & Bergstrom, 2011; Vingilis, Wade & Seeley, 2002)

Similar to dental decay and periodontal disease, age was also a significant covariate in the Oral Health Index models, with increasing age generally being associated with poorer OHX scores. This is to be expected as many components of oral health are affected by an accumulation of life experiences and oral health tends to worsen with age (Hugoson et al., 2005; Steele et al., 2004). Dental decay and periodontal disease are two such oral health conditions that follow this trend, and are also large components of the OHX, and thus it is not surprising that age is a significant covariate in the OHX models. However, although age was taken into account in all models, it is important to note that age may have skewed the results in some models, as most oral health conditions do worsen with cumulative exposures and experiences, and thus age. In the sugary and acidic index models, fibre consumption also emerged as a covariate. As discussed above, fibre consumption, like age, was also significant in the decay and gingivitis models, and thus is not surprising that it also plays a role in the composite measure of oral health.

In addition, a few of the covariates were not significant in any model, namely brushing teeth, (non-milk) dairy consumption, education and smoking. The fact that brushing teeth and smoking were not significant is particularly surprising, as dental professionals commonly advise patients about these two habits (CDA, 2012b; CDA, 2014). The value of toothbrushing is commonly accepted and has been generally been found to improve prevalence of both caries and periodontal disease; however, the frequency of toothbrushing, technique employed and type of toothbrush used all play a role in the impact of toothbrushing and the wide variability in these factors may have contributed to the lack of significance in this investigation (Claydon, 2008; Davies, Davies & Ellwood, 2003). Additionally, much of the preventive value of toothbrushing is attached to the use of fluoride toothpaste when brushing; since the type of toothpaste used was not taken into consideration in the CHMS, this may also have affected results (Claydon, 2008; Davies, Davies & Ellwood, 2003). The lack of significance of toothbrushing may also be attributable to a lack of variability within the CHMS population, with most participants brushing their teeth at least once per day, and this lack of variability may have obscured any effects tooth brushing does have on oral health. There could also be a threshold effect after which the number of times one brushes their teeth does not have an additional impact. Interestingly, there is also evidence to suggest that toothbrushing may actually cause damage to the dentition and soft tissues in terms of abrasion, sensitivity and periodontal recession (Addy, 2010; Claydon, 2008).

Smoking has been widely identified as a risk factor for poor oral health. Current smokers are more likely to have fewer teeth, more dental decay on both crown and root surfaces, a greater severity and extent of periodontal disease, higher prevalence of mucosal disorders, decreased functional ability of the oral structures, and overall exhibit a greater need for dental care (Locker, 1992; Locker & Millar, 2007; Preber, Kant & Bergstrom, 1980). The incidence of oral cancer is also significantly higher in smokers (Blot et al., 1988; Mashberg, Boffetta, Winkelman, & Garfinkel, 2006). The risk for poor oral health outcomes is higher in former smokers as compared to non-smokers; however, over time the risk of poor oral health decreases in former smokers as compared to current smokers (Locker & Millar, 2007). Chewing tobacco has also been found to contribute to poorer oral health, especially through incidence of oral squamous cell carcinoma and other oral cancers (Critchley & Unal, 2002). Future analyses should also consider the impact of smokeless as well as smoking tobacco for these reasons, although at this time it does not present an extensive public health concern due to the low prevalence of smokeless tobacco use in Canada (Reid, Hammond, Rynard, & Burkhalter, 2014). Considering the strength of the body of evidence advocating that tobacco consumption is harmful to oral health, it is surprising that smoking status did not seem to have a significant effect on any of the outcomes. This may be due to underreporting in line with social desirability bias, or a lack of variability as the majority of participants had never smoked. The age restriction used in the study may also have had an effect, as the length of time smoking has the largest impact on oral health and these times were likely to be significantly lower in this study as compared to much of the body of research. The categorical nature of this variable may also have skewed the results; future investigations should consider the effect of the number of cigarettes smoked per day and the length of time the participant has been a smoker.

As discussed above, the effect of dairy consumption on oral health may have been negated by combining non-milk dairy products, especially considering the relatively high sugar content of ice cream and how this may affect oral health. In addition, although the non-milk dairy products recorded tend to be those most highly consumed, other dairy product consumption, such as cheese, sour cream and butter, was not considered and may have had an effect. The different types of yogurt that were consumed may also have an effect; some yogurts and dairy products contain probiotics which may be beneficial to oral health that may not be present in other products due to processing differences (Caglar, Kargul & Tanboga, 2005).

Unexpectedly, education was also not significant in any models. The role of education on oral health status has been well documented, with the potential mechanism of its effect being exerted through higher SES and therefore access to dental care, and a higher dental IQ (Hollister & Weintraub, 1993; Paulander, Axelsson & Lindhe, 2003). There are several possible reasons that education was not significant in this investigation. First of all, there was not much variability in education, with over 75% of the sample falling in the "post-secondary graduate" category. The inclusion of the "not stated" category may also have skewed results. Additionally, income was significant in at least one of the models, and the effect of education may have been obscured with income as a proxy for SES; however, an education and income interaction variable was considered in the investigatory phase of this study and did not seem to have much effect on oral health outcomes. The effect of education or other significant variables may also have acted as a proxy for the effects of other variables, especially considering the high number of covariates included in this analysis.

There were several limitations to this study affecting its generalizability and the ability to draw certain conclusions. First and foremost, the lack of temporal data in the CHMS and the cross-sectional design of this study limit the conclusions that can be drawn. This limitation has already been mentioned a number of times, and further investigations of this topic should use temporal data.

Time is also a limitation of the study in the context of patterns of consumption of the beverage. By choosing to report beverage consumption habits in aggregate measures of times per week or year, results were not as precise as say diet diaries or monitoring would have been, and this may have impacted the accuracy of results. This information was also based on participant recall, and this method may have lead to bias and inaccuracies in results.

Furthermore, no information was captured on the habits that surrounded beverage consumption such as at what time in the day the beverage(s) was consumed, whether it was consumed with a meal or on its own, how long it took to drink the beverage, or what habits participants employed after consuming the beverage, such as brushing their teeth or rinsing their mouth with water. In relation to the interaction terms, these results may have been impacted by whether or not they were consumed in close proximity, as the time between drinks could have affected the buffering capacity or multiplicatory effect of the beverages. These are important considerations as research has shown that patterns surrounding beverage consumption can greatly affect the impact the beverage has on oral health. For instance, beverages consumed with food tend to have lesser impact on oral health than those consumed alone, due to a faster clearance rate, increased salivary output, and buffering capacity (Scardina & Messina, 2012). The faster a beverage is consumed, the less impact it has on the teeth and oral cavity as time is an essential factor in the caries process, as well as other oral diseases (Scardina & Messina, 2012). By clearing from the mouth at a faster rate, there length of the acid attack is shorter and less demineralization of the tooth structure will occur (Scardina & Messina, 2012). The length of action and acid attack can also be minimized by brushing the teeth or rinsing with water following sugary or acidic beverage consumption; however brushing the teeth immediately following consumption during the acid attack may contribute to erosion via mechanical action (Scardina & Messina, 2012).

The use of an unvalidated food frequency questionnaire for both food and beverage consumption is another serious limitation of the CHMS. The challenges and limitations of food-frequency questionnaires have been well documented, and include recall and social desirability biases, a lack of information regarding serving size (especially in the case of the CHMS), as well as general inaccuracies in reporting (Schaefer, et al., 2000). The CHMS is no exception to these limitations, especially as the questionnaire was not a validated scale, including in reliability. This may have resulted in inaccurate reporting, which could have in turn affected the accuracy of our results. Furthermore, the use of food and beverage frequencies for reporting may have resulted in a “time anchor” effect, which appears to have happened judging by the relatively common consumption of beverages in multiples of seven times per week. In this way, study participants may have used convenient approximations of frequency of consumption for reporting, as opposed to more accurate values.

Beyond the limitations in data collection from the CHMS, some of the indices used in this analysis may also have affected the accuracy of results. The fibre index created for this study was basically a measure of frequency of grains and fruit and vegetable intake, and did not take into consideration some fibre sources such as nuts and legumes. Reporting in terms of frequency may also have lead to inaccuracies in our index. As some fibre sources were not included, it is likely these inaccuracies resulted in underestimations. Since increased fibre consumption was found to have a positive association with many of the outcome measures, this underestimation likely does not affect the conclusions drawn; however the magnitude of effect may be larger than indicated, and results should be used with these limitations in mind. Additionally, the sugary and acidic beverage indices differed by the addition of two drinks (vegetable juices and diet soft drinks) in the acidic beverage index, so some of the effects and results could have been confounded by this overlap. As regular soft drink consumption was significant and had a detrimental effect in all of the main effects models, the significance of the indices could be driven by the relatively strong effect of regular soft drinks itself, and the sugar content or acidity of the beverage may not be as important as the results indicate.

Another major limitation of the study was the inability to use fluoridation data, due to the lack of a reliable and complete source of this information and the inability to integrate it with the existing data identifiers. Fluoridation data is especially of importance considering the current dental political climate in which many communities are opting to have fluoride removed from their public water supplies. This lack of data may also have confounded results, as significant differences between consumption effects of fluoridated versus unfluoridated water may exist, and may have skewed or obscured results in this analysis. Future research would be greatly strengthened and more applicable if this information could be included. Further beverage details would also be beneficial for milk, as many different types of milk are regularly consumed, including 1%, 2%, skim, homogenized, flavoured, powdered, soy and almond, among others. It is possible differences in the type of milk consumed may affect oral health, although this area has not yet been examined in detail.

In addition, although the OHX was based on the validated measure by Burke and Wilson (1995), it was modified slightly to better fit our study and the available measures. Specifically, the wear, occlusion and denture assessments were not included as there was not direct correspondence to sections in the CHMS, and this may have affected the accuracy of the OHX as an index measure of oral health.

Due to the large number of models investigated in this study, the risk of one of the significant associations being solely due to chance is greatly increased, and may have contributed to inaccuracies in the data. It may be argued that a lower p-value of $p<0.01$ should have been used; however, this would have had minimal impact on the results as most of the significant variables continue to be significant at this lower cut-off point. This change would have made no changes in the periodontal health models, and would have affected only one age contrast in the sugary and acidic index models for OHX. This change would have had a greater effect on the dental decay and SROH models, eliminating fruit-flavoured beverages in the main effects model, and the milk, milk and sugary- or acidic-beverage interaction and one age contrast in the dental decay index models. For SROH, water would have narrowly missed the cut-off ($p<0.011$), and some contrasts for income and frequency of dental care would no longer have been significant. Sex and one contrast for each income and frequency of dental care would have been affected in the SROH index models, as well milk and the milk and sugary-beverage interaction variable in the sugary index model. Although there would have been some changes, it appears as if the general trends and conclusions drawn from the investigation would be similar; namely that soft drink consumption consistently demonstrates a detrimental effect on oral health and milk consumption may confer a protective benefit.

Although the CMHS was representative of 97% of Canadians, individuals living on reserves, and in penitentiaries and other government institutions were not included, and thus results are not generalizable to these populations. Those from extremely remote locations may also be underrepresented as only participants that lived within a 100km radius of the MEC were sampled. Otherwise, the sampling frame, representativeness and generalizability of the study are strengths of this investigation.

Other strengths associated with using the CHMS include its large sample size, which helped ensure we had adequate power for this study. Thanks to the design of both the CHMS and this study, there was no missing information, other than the "not stated" groups for income and education; this helped to simplify the analysis and minimized the effect of non-response bias. Another benefit of the CHMS is the standardization of both the household interview and clinical assessment. Although there may be some inter-rater bias as multiple individuals were used to carry out these investigations, they were consistent in the questions asked and how they were asked, the equipment available and technique used.

Much of the value in this study is rooted in the number of covariates included. As oral health conditions tend to be multifactorial in etiology, controlling for as many potential confounders as possible was essential to the success and accuracy of this investigation. Thanks to the comprehensive and detailed design of the CHMS, we were able to include many factors that have been shown to affect oral health. The extensive number of measures included in the CHMS also made it possible to investigate a wide variety of oral health outcomes in order to achieve a more complete picture of the impact beverage consumption has on various aspects oral health, as well as overall.

CONCLUSIONS

Overall, a picture of the trends surrounding beverage consumption and oral health outcomes has emerged from this investigation, and can contribute to public health recommendations in order to improve the oral health of Canadian citizens. Soft drinks have consistently arisen from this and other research as being detrimental to oral health, and thus their consumption should be limited. On the other hand, milk emerged from many of the analyses as being beneficial to oral health; with this in mind, it would be recommended for individuals and the population as a whole to replace soft drink consumption with milk in order to improve population oral health. However, it is important to keep in mind that the etiology of oral diseases is multi-causative, and many factors play a part in determining one's oral health.

In general, these results are consistent with similar previous research. As discussed in the introductory section, regular soft drink consumption consistently emerges from analysis as having a significant, detrimental impact on many areas of oral health, as was the case in this investigation. Milk has been found to have a beneficial or neutral effect on oral health, a finding that was again reflected in this analysis. Although in the context of diet the results are similar to the published literature, this was not the case when investigating the effects of singular beverages. This suggests that the effects of beverages which may be evident at a biochemical level do not necessarily have a significant effect on oral health at the individual level. Further and more detailed examination of the effect of interactions in diet is needed to better address this discrepancy.

The added value of this investigation was the examination of beverage interaction effects. In our investigation, water did not significantly interact with sugary or acidic beverages, but milk had a significant interaction with the sugary- or acidic-beverage index in all but one of the cases investigated. In general, milk was found to have a protective effect over sugary or acidic beverage consumption, and intake of these sugary and acidic beverages had a detrimental impact when consumption was increased and milk consumption was held constant. In order to further investigate this phenomenon, future research should take into consideration the context and volume of consumption of the beverages, as well as understand at a biochemical level how this interaction may be affecting oral health. As discussed above, the sugary and acidic beverage indices were very similar and their significant effects could have been driven by the relatively strong effect of regular soft drink consumption; however, whatever the driving force, our results suggest that milk consumption can help to mitigate the detrimental oral effects of sugary or acidic beverage consumption.

Future research is needed to examine the association between beverage consumption and oral health more closely. Subsequent investigations should employ a longitudinal design to address the causative factors surrounding the associations between oral health, beverage consumption and other relevant factors. This longitudinal design should also address the context of consumption, including timing and frequency. Future research would also benefit from a more complete list of beverages, including coffee and tea, as well as information on fluoridation and its impact. Additionally, it would be beneficial to determine whether there were any differences in type of milk consumed (skim, 1%, 2%, homogenized, soy, almond, etc.). Until this research can be undergone and the knowledge base expanded, it may be best to subscribe to the adage "everything is okay so long as it's in moderation".

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Appendix A – CHMS Questions

Sociodemographic Variables:
What is [respondent name]'s age? (AWC_Q04)

Is [respondent's name] male or female?
Male, female. (SEX_Q01)

What is the highest degree, certificate or diploma [Respondent's Name] has obtained?
No post-secondary degree, certificate or diploma; trade certificate or diploma from a vocational school or apprenticeship training; Non-university certificate or diploma from a community college, CEGEP, school of nursing, etc.; Certificate below bachelor's level; Bachelor's degree; University degree or certificate above bachelor's degree. (ED_Q04)

What is your best estimate of the total income, before taxes and deductions, of all household members from all sources in the past 12 months? (INC_Q21)

Oral Health Variables:
In general, would you say the health of your mouth is:
Excellent, very good, good, fair, poor. (OHM_Q11)

How satisfied are you with the appearance of your teeth and/or dentures?
Very satisfied, satisfied, neither satisfied nor dissatisfied, dissatisfied, very dissatisfied. (OHM_Q12)

(In the past 12 months,) How often have you avoided eating particular foods because of problems with your month?
Often, Sometimes, Rarely, Never. (OHM_Q22)

In the past 12 months, how often have you had any other persistent or on-going pain anywhere in your mouth?
Often, Sometimes, Rarely, Never. (OHM_Q23)

Record the mucosal status of the respondent. Mark all that apply:

1. *No mucosal abnormalities*
2. *Angular cheilitis*
3. *Mucosal white patches*
4. *Denture stomatitis*
5. *Denture induced hyperplasia (epulis)*
6. *Glossitis*
7. *Sinus or fistula*
8. *Aphthous ulcer*
9. *Traumatic or unspecified ulcer*
10. *Other – Specify*

(OHE_N14)

Beverage Variables:
How often do you usually drink regular soft drinks? (WSD_B11)

How often do you usually drink diet soft drinks (WSD_B12)

How often do you usually drinks sport drinks, such as Gatorade or Powerade? (WSD_B13)

How often do you usually drink fruit juices (100% pure fruit juices either from concentrate or not from concentrate)? (WSD_B14)

How often do you usually drink fruit-flavoured drinks (such as Sunny Delight, fruit punch or Kool Aid)? (WSD_B15)

How often do you usually drink vegetable juices (WSD_B16)

How often do you usually drink water? (WSD_B21)

How often do you drink milk or enriched milk substitutes or use them on cereal? (MDC_B11)

During the past 12 months have you had a drink of beer, wine, liquor or any other alcoholic beverage?

Yes, No (ALC_Q11)

During the past 12 months, how often did you drink alcoholic beverages?

Less than once a month, once a month, 2 to 3 times a month, once a week, 2 to 3 times a week, 4 to 6 times a week, every day (ALC_Q12)

Other Variables:

How often do you usually eat hot or cold cereal? (GFV_B11)

How often do you usually eat brown bread, including bagels, rolls, pita bread or tortillas? (GFV_B12)

How often do you usually eat white bread, including bagels, rolls, pita bread or tortillas? (GFV_B13)

How often do you usually eat any kind of pasta (including spaghetti, noodles, macaroni & cheese or pasta salad)? (GFV_B14)

How often do you usually eat any kind of rice? (GFV_B15)

How often do you usually eat fruit (fresh, frozen or canned)? (GFV_B17)

How often do you usually eat tomatoes or tomato sauce, including salsa, tomato soup and spaghetti sauce but excluding tomato paste, ketchup or pizza sauce? (GFV_B18)

How often do you usually eat lettuce or green leafy salad, with or without other vegetables? (GFV_B19)

How often do you usually eat spinach, mustard greens or collards excluding kale? (GFV_B20)

How often do you usually eat other potatoes including baked, boiled, mashed or in potato salad, but excluding sweet potatoes? (GFV_B22)

How often do you usually eat all other types of vegetables, excluding those already mentioned? (GFV_B23)

How often do you usually eat cottage cheese? (MDC_B13)

How often do you usually eat yogurt, excluding frozen yogurt? (MDC_B14)

How often do you usually eat ice cream or frozen yogurt? (MDC_B15)

In your lifetime, have you smoked a total of 100 or more cigarettes (about 4 packs)? (SMK_Q11)

At the present time, do you smoke cigarettes daily, occasionally or not at all?
Daily, Occasionally, Not at all (SMK_Q12)

How often do you usually brush your teeth and/or dentures? (OHM_Q31)

How often do you usually floss your teeth? (OHM_Q32)

Do you usually see a dental professional?
More than once a year for check-ups or treatment, about once a year for check-ups for treatment, less than once a year for check-ups or treatment, only for emergency care, never. (OHM_Q33)

Appendix B – CHMS Derived Variables

Sociodemographic Variables:

Highest level of education – household, 4 levels (highest level of education acquired by any member of the household) (EDUDH04 – based on ED_Q04)

Less than secondary school graduation, secondary school graduation but no post-secondary education, some post-secondary education, post-secondary degree/diploma, missing information

Total household income – 5 categories (INCDDIA5)

Not enough information, lowest income, lower middle income, middle income, upper middle income, and highest income groupings

Oral Health Variables:

Gingivitis score (OHEDGS12 – OHEDGS44)

0 – No inflammation, 1 – Mild inflammation, 2 – Moderate inflammation, 3 – Severe inflammation, 4 – Tooth missing

Number of permanent crowns recorded as 1 (sound – never decayed or restored) (OHEDAC01) *0-28*

Number of permanent crowns recorded as 2 (sound – crown sealed, never decayed or restored) (OHEDAC02) *0-28*

Number of deciduous teeth recorded as 1 (sound – never decayed or restored) (OHEDDT01) *0-28*

Number of deciduous teeth recorded as 2 (sound – crown sealed, never decayed or restored) (OHEDDT02) *0-28*

Beverage Variables:
Drinks milk – times per year (MDCD11Y)

Drinks regular soft drinks – times per year (WSDD11Y)

Drinks diet soft drinks – times per year (WSDD12Y)

Drinks sport drinks – times per year (WSDD13Y)

Drinks fruit juices – times per year (WSDD14Y)

Drinks fruit flavoured drinks – times per year (WSDD15Y)

Drinks vegetable juices – times per year (WSDD16Y)

Drinks water – times per year (WSDD21Y)

Alcohol – weekly consumption (ALCDWKY)

Nutrition Variables:
Number of times teeth brushed per year (OHMD31Y)

Number of times teeth flossed per year (OHMD32Y)

Smoking – Type of Smoker (SMKDSTY)

Current daily smoker, occasional smoker (former daily smoker), occasional smoker (never a daily smoker or has smoked less than 100 cigarettes in lifetime), non-smoker (former daily smoker), non-smoker (former occasional smoker, at least 100 cigarettes in lifetime), never smoked (at least 100 cigarettes), missing information, population exclusions

Fibre Consumption – Eats hot or cold cereal – times per year (GFVD11Y)

Fibre Consumption – Eats brown bread, including bagels, rolls, pita bread, or tortillas – times per year (GFVD12Y)

Fibre Consumption – Eats white bread, including bagels, rolls, pita bread or tortillas – times per year (GFVD13Y)

Fibre Consumption – Eats any kind of pasta – times per year (GFVD14Y)

Fibre Consumption – Eats any kind of rice – times per year (GFVD15Y)

Fibre Consumption – Eats fruit – times per year (GFVD17Y)

Fibre Consumption – Eats lettuce or green leafy salad – times per year (GFVD19Y)

Fibre Consumption – Eats spinach, mustard greens, or collards – times per year (GFVD20Y)

Fibre Consumption – Eats other potatoes – times per year (GFVD22Y)

Fibre Consumption – Eats all other types of vegetables – times per year (GFVD23Y)

Dairy Consumption – Eats cottage cheese – times per year (MDCD13Y)

Dairy Consumption – Eats yogurt – times per year (MDCD14Y)

Dairy Consumption – Eats ice cream or frozen yogurt – times per year (MDCD15Y)