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# GIRLS' EARLY BEVERAGE PATTERNS: LONG-TERM IMPACT ON DIETARY INTAKE AND ADIPOSITY

A Dissertation in

Nutrition

by

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## ABSTRACT

Data on the persistence of early beverage patterns throughout childhood and adolescence are limited. Furthermore, little is known about whether these patterns influence dietary intake and measures of adiposity in childhood and adolescents are limited. The purpose of the present research is to describe changes in girls' beverage intake and to assess whether early beverage intake patterns persisted and predicted dietary intake and measures of adiposity from 5 to 15 years. Participants were part of a longitudinal study of non-Hispanic white girls, predominantly middle class, (n=170) living in central Pennsylvania, assessed biennially from 5 to 15 y. At each assessment, intake of beverage (milk, 100% fruit juice, and sweetened beverages: fruit drinks, sodas, and tea/coffee), and dietary intake were assessed using three, 24-hour recalls. Percent body fat and waist circumference were measured. Height and weight were measured and used to calculate body mass index. A series of mixed modeling analyses were used to describe changes in beverage intake and the impact of early beverage intake on girls' dietary intake and measures of adiposity over time. Results revealed that although total beverage intake servings did not change from 5 to 15 y, major shifts occurred in the contribution of servings of various types of beverages. Milk and fruit juice declined, while soda and tea/coffee increased and fruit drinks remained unchanged. Early difference in soda intake predicted later soda intake and differences in beverage related food groups and nutrients. In addition, higher intake of sweetened beverage at 5 y, but not milk or fruit juice, was associated with greater adiposity and weight status in childhood and adolescence. This association was independent of energy intake at study entry and concurrent age sweetened beverage intake. In sum, these results suggest that prevention

efforts should include a focus on promoting healthy beverage patterns to reduce children's risk of lower diet quality and higher adiposity. Such prevention efforts need to begin during early childhood, and should focus on reducing availability of sweetened beverages, and substituting healthy alternatives, such as milk, water, and limit fruit juice, within recommended levels by the American Academy of Pediatrics.

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# Chapter 1

# GENERAL INTRODUCTION

Beverage patterns of US children and adolescents have changed dramatically over the past 2 decades. Specifically, data from national dietary surveys (1-4) indicate that consumption of sweetened beverages (i.e. fruit drinks, sodas, and tea/coffee), particularly soda, has increased while consumption of milk has significantly decreased. These trends in beverage patterns are of concern because adverse nutritional and health effects have been linked with these changes (1, 2, 5-7). Studies have reported that sweetened beverage consumption are positively associated with energy intake and inversely associated with overall diet quality among children and adolescents (1, 2, 5, 7). Changes in beverage consumption may also be contributing to the obesity epidemic among children and adolescents (6, 7). Given the apparent centrality of beverage intake and its possible implication on children's diet quality and weight status, additional research is needed to characterize children's early beverage choices and their impact on diet quality, adiposity, and weight status.

*Secular Trends and Age Differences in Beverage Consumption*

Secular trends have shown marked increases in sweetened beverage consumption patterns accompanied by a decrease in milk intake over the past two decades among children and adolescents. The mean intake of sweetened beverages, such as sodas and fruit drinks, almost doubled, and the percent of children and adolescents consuming these beverages had also increased considerably (3, 8-11). Although increases in mean intakes of other beverages such as fruit juice, coffee, and tea have been noted, these changes were comparatively small (8, 10, 12). The largest increase has occurred for soda, the majority of which is sugar sweetened, rather than artificially sweetened (11). In this case, increases have been noted in both the proportion of children who consumed sodas, as well as in the amounts consumed. French et al (9) documented that school-aged children's (6-17 years) consumption has risen, with the average daily intake more than doubling (5 to 12-oz) between 1977-1978 and 1994-1998. The prevalence of consumption increased by 48% during the same period of time, and among consumers, average consumption increased by 50% (from 14 to 21 oz/d). The biggest increase between surveys was observed among adolescents, particularly among males age 14-17 years (9, 11, 13).

Paralleling the rise in sweetened beverage consumption has been a decline in milk consumption. Between the late 1970's and mid 1990's, mean milk intake decreased 24% among boys and 32% among girls 6 to 11 years old, and by one third among both males and females 12 to 19 years old (11). The decrease was accompanied by a drop in the proportion of individuals drinking milk, particularly among adolescents (12-19 years). Forshee and colleagues (14) compared beverage intake from the Continuing Survey of Food Intake by Individuals (CFSII) 1994-96 and National Health and Nutrition Examination Survey (NHANES) 1999-2002 and found a decrease in mean milk intake among children 6-11 y between both surveys, however, it remained unchanged among adolescents 12-19 y.

Cross-sectional data consistently document that beverage intake patterns also differ with age. For example, CSFII 1994-96 and 1998 (3, 10, 15) data suggests that milk is the beverage served to young children, but with increasing age milk intake decreases and intake of sweetened beverages, particularly sodas, increases. The same data shows that at age 5, the mean intake of sodas and fruit drinks exceeded that of 100% fruit juice (3). By age 13, adolescents drank more sodas than milk, 100% fruit juice, or fruit drinks (3). The changes in beverage consumption with increasing age occurred not only in the amounts consumed but also in the proportion of consumers.

In fact, recent nationally representative data (NHANES 1999-2004) (12) show that the prevalence of sweetened beverage consumption increased from 70% to 84% between children aged 2-5 and 12-19 years. This increase was mainly due to a steep increase in the proportion of soda consumers (1). In contrast, the same data (12) show a sharp decrease (34%) in the prevalence of milk consumption over the same age period. The proportion of children consuming 100% fruit juice decreases about 20%, whereas the proportion of children consuming tea increases about 7% with increasing age (12).

Although the cross-sectional data suggest there are secular trends and age differences in beverage consumption patterns, it cannot be concluded that there are changes with age. There is a need for longitudinal data that follows the same group of individuals over time to describe developmental trends in beverage patterns.

*Soda Intake and Diet Quality*

A growing body of literature indicates that beverage patterns characterized by high levels of soda intake may have a negative effect on children's and adolescents diet quality (1-3, 10, 16-18). Studies using nationally representative data (CSFII) (1, 10), have found that children who consumed more servings of soda consumed fewer servings of milk and fruit juice, and had lower mean intakes of nutrients related to milk and fruit juice. Numerous cross-sectional studies based on nationally representative samples (i.e. NHANES and CSFII) (1-3, 10, 18) have reported that higher soda consumption was negatively related to achieving recommended intakes of many essential nutrients including calcium, phosphorous, riboflavin, folate, magnesium, vitamin A, B12, and C, and positively associated with energy and carbohydrates, particularly added sugars, intake. Sweetened beverages, particularly regular sodas, are the largest source of added sugars in the diet of children and adolescents (19, 20). In part these unfavorable consequences might be the result of displacement of more nutritious beverages, such as milk and fruit juice (1, 3, 10, 18, 21). Nutrients provided by milk and fruit juice are not easily available from other food groups and thus may not be consumed at all when the tradeoff of these beverages occurs in the diet. Soda consumption associated with decreased milk intake and other more healthy beverages may be an important risk factor for poor nutrition. However, most of the evidence is cross-sectional and longitudinal observational studies investigating the impact of early soda consumption on dietary intake throughout childhood and adolescence are lacking.

*Association between Sweetened beverage Intake and Obesity*

Dramatic increases in sweetened beverage intake have occurred during the same time period in which we have witnessed dramatic increases in the prevalence of overweight among children and adolescents (22). Since the 1970's, the prevalence of overweight has more than quadrupled among 6-11y and more than tripled among 12-19y children and adolescents. Epidemiological data (NHANES 2003-2004) reveal that ~37%

of children ( 6-11y) and ~34% of adolescents (12-19 y) are overweight and obese, respectively (22). Obesity tracks over time; that is, obese children tend to become obese adults (23, 24). For instance, data from the Bogalusa Heart Study (24) showed that childhood levels of both BMI and triceps skinfold were associated with adult levels of BMI and adiposity, as assessed 18 years later. Furthermore, childhood obesity is an important predictor of adult metabolic syndrome, type II diabetes and cardiovascular disease (23, 25).

The basics of energy balance are well understood: weight gain results when energy intake consistently exceeds energy expenditure (26). However, less clear are the causes of the imbalance. There is substantial agreement that childhood overweight is a multi-factorial disease that results from an interaction between a number of genetic and socio-environmental influences (27-29). The dramatic increases in overweight underscore the importance of identifying environmental determinants that may ultimately explain these changes in childhood body weight. In part, obesity may be a result because of the poor food choices children and their parents are making. Crawford and colleagues (30) examined the evidence of various dietary factors that might relate to weight and adiposity in children. The authors concluded that only one high risk dietary practice emerged as being linked to overweight in children: intake of sweetened beverages (i.e. fruit drinks and sodas).

The percent of total energy consumed from sweetened beverages more than doubled among children from 4.8% to 10.3% during 1977 and 2001 (8). A recent review found that in the majority of the studies sweetened beverage intake was linked to weight status and obesity among children and adolescents (6). Although the mechanism by which sweetened beverage intake is associated with weight status is not completely understood the association has been attributed to multiple factors (32). The simplest mechanism to explain whether sweetened beverage consumption leads to obesity is energy balance; that is, increased sweetened beverage intake could contribute to increased caloric intake, thereby bending energy balance toward increased adiposity. It is also possible that liquid calories may not trigger physiological satiety mechanisms, as do solid calories, thereby providing a mechanism leading to higher caloric intake (32). Another plausible explanation relates to the metabolic effects of the primary sweetener, high-fructose corn syrup, used to sweeten fruit drinks and sodas. The consumption of high-fructose corn syrup has increased 1,000% in the past 3 decades. High-fructose corn syrup is metabolized differently than other simple sugars; it stimulates less insulin secretion and leptin production, and increases fat synthesis (32).

The majority of the studies addressing the association between sweetened beverage intake and weight status are cross-sectional in nature and in these studies beverage consumption as well as weight status were measured at only one point in time and cannot address causality (6). For example, overweight persons may abstain from consuming sweetened beverages or consume diet soda as part of a weight loss strategy, which can result in a spuriously negative association (6). Furthermore, studies controlled for different confounding variables and operationalized body weight in a number of different ways. Several prospective studies (5, 31-34) among children and adolescents suggest that higher intakes of sweetened beverages were associated with weight. These studies (5, 31-34) estimate adiposity using as body mass index (BMI), thus, there is a need for other long-term studies that measure adiposity using dual-energy X-ray absorptiometry, which provide a precise measurement of adiposity (35). Ludwig and colleagues (5), in a 19 months prospective study of children aged 11 and 12 y, found that for each additional daily serving of sweetened beverage both BMI and the odds ratio of becoming overweight increased by 60%. Berkey and colleagues (31), in a 3-year study found that among children 9 to 14 y, increasing daily sweetened beverage intake by ≥2 servings from the previous year was associated with a 0.1 increase in BMI. Additionally, Striegel Moore et al. (32), in a 10 year prospective study among 2000 9 year- old girls found that for every 100 gr of soda consumed BMI increased by 0.1 units. Only one of these studies (32) measured the longitudinal association between sweetened beverage intake and weight for a long period of time (10 years); however, the sample size of this study was very small (n=30). Thus, there is a need for prospective studies that follow girls for a longer period of time. Finally, findings from these studies are not conclusive with respect to how much intake has an influence on weight. Understanding the association between sweetened beverage intake and weight status and adiposity, in childhood and adolescence is a viable starting point for targeted prevention efforts. Particularly, there is a need for specific recommendations to limit children's sweetened beverage intake.

*Stability of Beverage Intake*

Limited research suggests that early intake patterns tend to influence intake patterns later in life (36-50). Menella and colleagues (36, 37) demonstrated that exposure to food flavors (i.e. carrots) via amniotic fluid in utero or via breast milk after birth increased infants' intake and rate of eating of those foods later on, suggesting the importance of early experience. Furthermore, a 5-year longitudinal study by Skinner and colleagues suggested that food preferences formed during toddler years predicted later preferences (48). Foods liked from 2 to 4 years were highly predictive of preferences at 8 years. Consistent with these findings (43-47) girls' milk intake during middle childhood is predictive of milk intake during adolescence and young adulthood. For example, Fisher and colleagues (45) found that differences in patterns of milk and sweetened beverage intakes that distinguished girls who met and did not meet calcium recommendations at age 5 were maintained from the end of the preschool period throughout middle childhood. Retrospective studies (43, 44, 46) indicate that although milk and calcium intake decline during childhood and adolescence, the development of dietary habits that include frequent milk intake during childhood tend to track over time, and to set the course of milk and calcium intake during adulthood. In addition, Kvaavik et al. (50) found that soda intake tracked from adolescence into early adulthood and from early adulthood into late adulthood. Taken together, these studies reveal that early patterns of dietary intake persist and predict later intake. However, few studies have focused on the stability of beverage intake within individuals over time. Additionally, the impact of early beverage intake patterns on long-term dietary intake and measures of adiposity in childhood and adolescence is not well understood.

*Proposed Research*

In sum, children's beverage patterns have changed dramatically between 1977 and 2001 (8). Sweetened beverage intake, particularly soda intake, has increased sharply, accompanied by a decrease in milk intake. These changes have occurred at a time when obesity prevalence in children has risen dramatically (22). However, most of the studies within this field use cross-sectional data. The longitudinal design of this investigation will allow us to evaluate developmental stability and change in beverage intake in childhood and adolescence and its relation to diet quality and measures of adiposity. Further, there is evidence that early food and beverage patterns of intake are likely to carry over to later in life (36-50). Another line of evidence suggests that weight status and adiposity tracks from childhood into adulthood (23, 24). Given the different lines of evidence, the overall goal for this research is to assess whether: 1) early beverage patterns of intake persist throughout childhood and adolescence, and 2) early patterns of beverage intake affect girls' dietary intake, adiposity, and weight status in childhood and adolescence.

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# Chapter 2

## GIRLS' EARLY BEVERAGE PATTERNS PREDICT DIETARY INTAKE ACROSS CHILDHOOD AND ADOLESCENCE

## ABSTRACT

**Background:** Data are limited on persistence of early beverage patterns throughout childhood and adolescence and whether these patterns influence long-term dietary intake are limited.

**Objective**: To describe changes in beverage intake during childhood and assess differences in beverage and dietary intake from 5 to 15 y among girls who were either consuming or not consuming soda at study entry.

**Design/ subjects:** Participants were part of a longitudinal study of non-Hispanic white girls, predominantly middle class, (n=170) living in central Pennsylvania, assessed biennially from 5 to 15 y.

**Statistical analyses:** At each assessment, intake of beverage (milk, fruit juice, fruit drinks, sodas, and tea/coffee), food groups, macronutrients, micronutrients was assessed using three, 24-hour recalls. Analyses of longitudinal changes and the interaction between beverage type and age were conducted using a mixed modeling approach. Girls were categorized as either soda consumers or non-consumers at 5 y. A mixed modeling approach was used to assess longitudinal differences and patterns of change in beverage and dietary intake between soda consumption groups.

**Results:** Total beverage servings intake remained stable from 5 to 15 y; however, servings of milk and fruit juice declined, while servings of soda and tea/coffee increased and fruit drinks remained unchanged. Girls consuming soda at 5 y differed from non-consumers; in addition to higher soda intake, lower milk intake, higher intake of added sugars, lower dairy-related nutrients, and were less likely to meet dairy-related nutrient recommendations from 5 to 15 y, than soda non-consumers.

**Conclusions:** These findings provide new longitudinal evidence showing that milk and fruit juice intake decline during childhood parallel to increases in soda and tea/coffee. This research provides a more complex picture regarding the persistence of early beverage patterns and their effects food group and nutrient intake from childhood and adolescence.

## INTRODUCTION

Data from national dietary surveys (1-4) indicate that consumption of sweetened beverages, particularly soda, has increased dramatically over the past two decades among US children and adolescents. During the same period of time, children's consumption of milk has significantly decreased. In addition to these secular trends, longitudinal studies (5-7) suggest that as children get older, declines in milk and fruit juice intake are accompanied by increases in intake of sweetened beverages.

A growing body of literature indicates that soda intake has increased more than any other beverage intake over the past decades and that beverage patterns characterized by high levels of soda intake have negative effects on child and adolescent diet quality (1, 2, 8-10). In fact, some authors have argued that soda intake may displace more nutritious beverages and nutrients associated with these beverages. For example, Harnack et al. (1) , in analyzing Continuing Survey of Food Intakes by Individuals data (CSFII 1994-1996), found that children who consumed more servings of soda consumed fewer servings of milk and fruit juice, and had lower mean intakes of nutrients related to milk and fruit juice. However, despite the evidence for secular increases in soda intake and the possible impact on children's diets, most studies are cross-sectional, and there are few longitudinal studies that address this issue.

The limited longitudinal research suggests that early patterns of food and beverage intake persist and influence preferences and patterns of intake later in life (5, 11-24). For example, retrospective studies (18-20) indicate that although milk and calcium intake decline during childhood and adolescence, the development of dietary habits that include frequent milk intake during childhood and adolescence appears to set the course of milk and calcium intake during adulthood. Similarly, another longitudinal study (24) showed that soda tracked from adolescence into early adulthood and from early adulthood into later adulthood. Despite the apparent centrality of early beverage patterns, the stability of beverage patterns during childhood and adolescence and their impact on dietary intake are not well understood. In this research, we assess whether 1) beverage patterns characterized by high levels of soda intake and lower levels of milk intake start early in childhood and persist throughout childhood and adolescence, and 2) whether beverage patterns influence children's dietary intake.

Recent research on beverage intake and health has focused on either milk intake or sweetened beverage intake (24-33). However, milk and sweetened beverage intake tend to be negatively correlated (5, 8, 34-37), such that focusing on one type of beverage intake fails to take into account that the dietary impact of consuming one type of beverage may result not only from choosing that beverage, but also from the absence of the impact of the alternatives not chosen. Therefore, rather than focusing on the effects of one beverage, the present study assesses the relative impact of several beverage categories on girls' dietary intake.

The objectives of the present study were to describe changes from 5 to 15 y in beverage intake (milk, fruit juice, fruit drinks, soda, tea/coffee) and assess whether beverage intake at age 5 y influenced beverage and dietary intake during childhood and adolescence. Based on previous research (1, 2, 5-7, 38, 39), we hypothesized that milk and fruit juice intake would decrease from 5 to 15 y while intakes of fruit drinks, soda, and tea/coffee would increase. We also hypothesized that these early differences in soda intake at 5 y would be associated with differences in other beverages (especially milk), food group, and nutrient intake over time. Specifically, we hypothesized that those girls consuming soda at age 5: 1) would consume fewer servings of milk and more fruit drinks, soda, and tea/coffee from 5 to 15 y; and; 2) would show differences in beverage related food group and nutrient intake, and would be less likely to meet beverage-related food group and nutrient recommendations from 5 to 15 years, compared with girls not consuming soda at 5 y.

## METHODS

### *Participants*

Participants were part of a longitudinal study of the health and development of young girls living in central Pennsylvania. At study entry, participants included 197 5-year-old girls and their parents; families were reassessed every 2 years (ages 7, 9, 11, 13 and 15 years). The final assessment included 167 families. Attrition was primarily due to family relocation outside of the study area. Only girls with complete dietary intake data at 4 of 6 times of measurement were included in this study, resulting in a final sample of 166 girls.

Families were recruited for participation in the study using flyers and newspaper advertisements. In addition, families with age-eligible female children within a 5-county radius received mailings and follow-up phone calls (Metromail Inc.). Eligibility criteria for girls' participation at the time of recruitment included living with both biological parents, the absence of severe food allergies or chronic medical problems affecting food intake, and the absence of dietary restrictions involving animal products; families were not recruited based on weight status or concerns about weight.

Families were predominantly non-Hispanic, White, and the average income for the sample ranged between $50 000 and $75 000, representing the demographics of the area surrounding the study site (Census 2000). Parents were relatively well educated, with fathers having a mean ± SD of 14.9 ± 2.7 years of education and mothers having 14.8 ± 2.3 years. Parents were on average slightly overweight at the first time of measurement with a mean body mass index score (BMI) of 26.4 ± 6.05 for mothers, and 28.0 ± 4.35 for fathers. Mean BMI of girls at entry was 15.8 ± 1.4, and 18% and 5% were at risk for overweight and overweight, respectively classified as at risk of overweight if their BMI percentile was ≥85 and overweight if their BMI was ≥95 (40). The Pennsylvania State University Institutional Review Board approved all study procedures, and parents provided consent for their family's participation before the study began.

*Measures*

*Dietary Intake.* Three 24-hour recall interviews were conducted at the Dietary Assessment Center at the Pennsylvania State University at each occasion by trained staff using the computer-assisted Nutrition Data System for Research (NDS-R) software (Database Version 4.01_30, Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). The NDS-R software itself provides a structured, guided controlled platform where questions, and probes and the process of conducting the 24-hour recall are standard. The NDS-R time-related database updates analytic data while maintaining nutrient profiles true to the bastion used for data collection. The NDS-R is updated annually. Interviewers were required to complete 40 hours of intensive training and were subject to reliability tests. To assess reliability, a nutritionist administers three standard dietary recalls in a mock telephone interview to all newly trained interviewers. Reliability among interviewers for calculating nutrient intakes was based on an interclass correlation of 0.95 or higher (41). Girls provided three 24-hour recalls within a 2-to 3-week period, including 2 weekdays and 1 weekend day. These dates were randomly selected and recalls were conducted from June through October. At ages 5, 7, and 9 mothers in the presence of their daughters were the primary reporter of the girls' intake. At ages 11, 13, and 15, girls were the primary reporters with mothers participating in the interview as needed. Participants were mailed a poster depicting 2-dimensional representations of food portions (2D Food Portion Visual, Nutrition Counseling Enterprises, Framingham, MA) as a visual aid for estimating amounts of food eaten. Nutrient data were averaged across 3 days to obtain an estimate of energy and nutrient intakes. Nutrient intake estimates were based on foods consumed and do not include intakes from supplements.

Food group and beverage data were averaged across three days to obtain an estimate of the number of servings reported consumed based on the 2005 Dietary Guidelines for Americans (42) and US Department of Agriculture Food Guide Pyramid Guidelines (43). Mixed dishes were disaggregated into the corresponding components, and the sum of the gram weights of the components was used to calculate the number of servings for each food group.

Beverage output files were used to calculate average 3-day beverage consumption into 5 intake categories: (1) milk; (2) fruit juice; (3) fruit drinks; (4) soda; (5) tea/coffee. Milk included whole and reduced fat milk and was quantified as that consumed as a beverage. Fruit juice was defined as 100% fruit juice. At 5 y, artificially sweetened fruit drinks, soda, and tea/coffee were a small fraction of girls' beverage consumption (see

**Appendix A**), so sugar and artificially sweetened fruit drinks, sodas, tea/coffee were summed into composite variables referred to as fruit drinks, sodas, tea/coffee. Fruit drinks included any sweetened or artificially sweetened fruit flavored drinks (natural or artificial), drinks that contained less than 100% fruit juice. Sodas included carbonated sweetened or artificially sweetened, caffeinated or uncaffeinated colas. Tea/coffee included sweetened or artificially sweetened, caffeinated or uncaffeinated; girls' intake of water was not assessed. Consumption in each category was expressed in servings.

The percent of energy consumed from fat, carbohydrate and protein were compared to the Acceptable Macronutrient Distribution Ranges (AMDR) for these macronutrients (44) (See **Appendix B** ). For vitamin calcium, potassium, vitamin D, and fiber mean intakes were compared with Adequate Intake recommendations (44-46). Magnesium, phosphorous, and iron mean intakes were compared with the Recommended Daily Allowances (45, 47). Girls' food group intakes were compared to MyPyramid recommendations (48) (see **Appendix C**).

*Statistical Analyses*

Data were analyzed using the SAS software (version 9.1, 2001, SAS Institute, Cary NC) (49). Descriptive information was generated for all variables of interest. Each outcome variable was assessed for normality. In all analyses P values $<0.05$ were considered significant. Change was defined as the linear decrease or increase in the variable of interest from girls 5 to 15 y.

*Analyses first aim:* The first aim was to describe changes in beverage intake for the total sample across 5 to 15 y. To describe changes in girls' beverage intake, the interaction between beverage type and age, and the relative contribution of servings of various types of beverages to total beverage intake across 5 to 15 y, a mixed modeling approach (PROC MIXED, SAS) was used. Specifically, a random coefficient model was used to assess change over 10 years for continuous variables. Mixed modeling is a useful tool for analyzing the linear relationship over time, and a major advantage of the Proc Mixed procedure is its ability to retain cases with one or more missing data points (50).

To assess the prevalence of various types of beverage consumed from 5 to 15 y, a generalized linear model approach (PROC GENMOD, SAS) was used. Proportion of consumers at 5 y was compared against proportion of consumers at 7, 9, 11, 13, and 15 y. A generalized linear model is a mixed model approach and is specifically useful when dealing with binary data in a within-subjects design.

*Analyses second aim:* The second aim was to assess differences in beverage and dietary intake from 5 to 15 y between girls who were either not consuming or consuming soda at study entry. Drinking or not drinking soda at 5 y was used to classify girls as soda consumers and non-consumers (no soda consumed across 3 day average).

Differences in beverage, food group, and nutrient intake at each point in time between soda consumption groups were assessed using repeated measures analyses employing a mixed modeling approach (PROC MIXED, SAS). Another advantage of the Proc Mixed procedure is it allows the researcher to more adequately define the covariance structure that may exist between measurements that are made on an individual subject over time. Different covariance structures were investigated. Models were examined using the following covariance patterns: unstructured, compound symmetry, and auto regressive (1). The compound symmetry structure consistently gave model results with the lowest Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. Thus, this type of covariance structure was specified in the analysis procedure.

Next, change in beverage, food group, and nutrient intake were examined across 5 to 15 y for the soda consumption groups using a mixed modeling, random coefficient approach (PROC MIXED, SAS). Given that soda group membership was defined at 5 y, we only examined change in soda intake between the 2 groups from 7 to 15 y, excluding age 5. The main effect of group membership, the main effect of age, and the interaction between group membership and age were of interest. A significant group membership main effect indicates that on average, girls in one group had higher scores on the outcome variable as they get older than girls in the opposing group. A significant age effect indicates that on average, girls in both groups have an increase or decrease on the outcome variable as they get older. A significant interaction effect provides evidence for a differential pattern of change for girls consuming or not consuming soda.

Repeated measures type analyses (PROC GENMOD, SAS), was used to asses: (1) whether girls who were consuming soda at 5 y were less likely to meet food group and nutrient recommendations over time, compared with girls not consuming soda at age 5; and (2) whether the proportion of girls meeting recommendations declined from 5 to 15 y for both soda consumption groups.

# RESULTS

*Beverage intake*

**Table 2.1** displays age-related trends in girls' mean beverage intake for each beverage subcategory independently for the total sample and consumers, along with the percentage of participants consuming various types of beverages from 5 to 15 y. Total beverage intake remained relatively stable from 5 to 15 y. However, mean milk and juice intake decreased significantly from 5 to 15 y, with mean intakes of 1.4 ± 1.1 and 0.9 ± 1.1 servings/d at 5 y, and mean intakes of 0.9 ± 0.8 and 0.6 ± 1.1servings/d at 15 y, respectively. In contrast, intake of soda increased significantly from 5 to 15 y, from 0.3 ± 0.4 at 5 y, to 0.7 ± 0.8 servings/d at 15 y. Similarly, mean tea/coffee intake increased from 0.1 ± 0.3 to 0.4 ± 0.6 servings/d from 5 to 15 y. Intake of fruit drinks did not vary with age.

**Table 2.1** also shows the patterns of change in the percentage of consumers of each beverage across time. Ninety percent of the sample was consuming milk as a beverage at 5 y; however, the proportion of consumers declined significantly to 59% by 15 y, revealing that the decrease in milk intake for the total sample was in part due to a 30% decrease in the proportion of girls who were consuming any milk as a beverage from 5 to 15 y. With respect to fruit juice, 70% of the sample was consuming fruit juice at 5 y; however, compared to 5 y the proportion of fruit juice consumers declined significantly at each time of assessment, so that by 15 y only 48% of the girls consumed fruit juice. Therefore, the decline in fruit juice noted for the total sample was mainly due to the decline in the proportion of consumers and not due to changes in the amount consumed by consumers. In addition, compared to 5 y, the proportion of girls consuming fruit drinks decreased significantly by 20% at 15 y. Surprisingly, except for a significant increase at 11 and 13 y, the proportion of girls consuming soda remained relatively stable over the study period indicating that the sharp increase in soda intake for the total sample was mostly due to a doubling in the amount of soda consumed by those consuming soda; mean intakes doubled from 0.5 $\pm$ 0.4 servings/d to 1.0 $\pm$ 0.7 servings/d from 5 to 15 y, respectively. The proportion of girls consuming tea/coffee increased significantly by about 20%, from 24% to 42% from 5 to 15 y.

**Figure 2.1** presents the relative contribution of servings of each beverage to total beverage intake. At 5 y, milk constituted ~ 40% of all beverages consumed, while fruit juice represented close to 25%, and fruit drinks, soda, and tea/coffee constituted ~35% of girls' intake. By 15 y, milk and fruit juice only constituted 28.5% and 17.5%, respectively, while fruit drinks, soda, tea/coffee represented 54% of girls' beverage intake. There was a decrease in the contribution of milk (~30%) and fruit juice (~31%) to total beverage intake from 5 to 15 y. This decrease was accompanied by an increase in the relative contribution of soda (124%) and tea/coffee (3.4%). The contribution of fruit drinks did not change significantly over time.

To determine whether the patterns of change with age of beverage consumption differed for different beverages, a mixed modeling approach was used to assess beverage type by age interactions. Results revealed different patterns of change for girls' milk, fruit juice, soda, fruit drinks, and tea/coffee from 5 to 15 y ($F=32.57$, $p<0.0001$). Compared to milk, fruit juice remained stable over time, while fruit drinks, soda and tea/coffee intakes increased from age 5 to 15 among the total sample.

*Percentage of Energy Intake from Beverages*

For the total sample, the percentage of 24-h energy intake consumed from all beverages decreased from 26% to 21% ($p<0.0001$), from 5 to 15 y (see **Appendix D**). The decrease was mainly due to a significant decrease in the percentage of energy obtained from milk (10.7% to 6.4%; $p<0.0001$). The overall percentage of energy obtained from sweetened beverages (i.e. fruit drinks, sodas, tea/coffee) remained fairly stable (10.3% to 11.6%) from 5 to 15 years; however, the percentage of energy obtained from fruit drinks decreased (4.8% to 3.1%; $p<0.001$), and an increase in the percentage of energy obtained from sodas (3.2% to 4.2%; $p<0.001$) and tea/coffee (0.7% to 1.6%; $p<0.001$). In contrast, the percentage of energy obtained from fruit juice (4.8% to 3.1%; $p<0.001$) decreased significantly over the entire study period.

*Identification of Soda Consumers and Non-Consumers at 5 y*

Sixty percent (n=102) of girls were categorized as soda consumers at 5 y, with mean soda intake of $0.5 \pm 0.4$ servings per day; the other 40% (n=68) were categorized as non-consumers of soda (no soda consumed across three 24-h recalls). No differences were seen between girls categorized as either soda consumers or non-consumers at 5 y in parental income and education at study entry, maternal duration of breastfeeding, and girls reported birth weight. However, at study entry BMI for mothers ($p<0.01$) and fathers ($p<0.05$) of girls consuming soda at 5 y was significantly higher than for mothers and fathers of girls not consuming soda at 5 y (see **Appendix E**).

*Soda Consumers and Non-Consumers at 5 y: Differences in Beverage Intake Patterns from 5 to 15 y*

**Table 2.2** presents differences at each time of assessment and changes from 5 to 15 y in mean beverage intake for girls classified as soda consumers or non-consumers at 5 y. Results revealed no significant differences in girls' total beverage intake between soda consumers and non-consumers, and no significant change in total beverage intake from 5 to 15 y. However, for girls' milk intake, a significant interaction of group by time was noted:. Although both groups showed declines in milk intake from 5 to 15 y, greater declines were noted for soda non-consumers, due to their significantly higher milk intake at 5 y. From 5 to 15 y, the soda non-consumer group's milk intake declined from 1.6 to 0.9 servings; for the SC group, milk intake declined from 1.2 to 0.9 servings. The initial differences between the groups in milk intake did not persist to age 15. With respect to changes in soda intake over time, because differences in soda intake at 5 y between groups were based on the categorization criteria, we examined change in soda intake between groups from 7 to 15 y, excluding 5 y. No interaction was noted for soda intake; a significant main effect for group membership was noted, indicating that soda consumers at 5 y continued to have higher intakes of soda from 7 to 15 y, and a main effect of age was also noted, with both soda consumers and non-consumers groups increasing soda intake over time. Main effect for age were also detected for girls' , fruit juice, and tea/coffee intakes, with fruit juice intakes decreasing for both groups, and tea/coffee intakes increasing from 5 to 15y. No differences in girls' fruit drinks were noted between groups, as well as no change from 5 to 15 y. When the data were analyzed using the percentage of consumers rather than number of servings as the dependent variable, similar patterns were noted (data not shown).

*Soda Consumers and Non-Consumers at 5 y: Differences in Food Group Intake from 5 to 15y*

**Table 2.3** presents differences at each time of assessment and changes from 5 to 15 y in mean food group intake for girls classified as soda consumers and non-consumers at 5 y. No group by age interactions were noted. The only significant difference between groups was in fruit intake, with soda consumers having lower fruit intakes. Several age effects were noted; a significant decline in fruit intake was observed for both groups over the study period. In addition, a significant decline with age was noted for girls' dairy intake among both groups. In contrast, while increases with age were noted for soda consumers and non-consumers in vegetable and meat intake from 5 to 15 y; No significant differences were found between groups for grain intake, as well as no change in intake from 5 to 15 y.

*Soda Consumers and Non-Consumers at 5 y: Differences in Nutrient intake from 5 to 15y*

Differences at each time of assessment and changes from 5 to 15 y in mean nutrient intake for girls classified as soda consumers or non-consumers at 5 y are presented in **Tables 2.4**. There was a significant interaction effect between group membership and age for girls' percentage of energy from added sugars, showing a greater decrease in intake over the study period for soda consumers. This interaction was due to group differences at age 5y: girls' who consumed soda at 5 y had significantly higher intakes of added sugars at 5 y. A main effect of group membership was noted for other nutrients that are impacted by beverage intake: percentage of energy from protein, fiber, and dairy related nutrients (i.e. calcium, vitamin D, magnesium, potassium, and phosphorous); indicating that soda consumers had lower intakes of these nutrients from 5 to 15 y. Further, an age effect was noted for girls' vitamin D and potassium intakes, showing a significant decline in vitamin D and potassium intakes for both groups from 5 to 15 y. Intakes of calcium, magnesium, and phosphorous did not change significantly over time. Other changes noted in mean nutrient intake from 5 to 15 y are presented in **Table 2.4**.

*Soda Consumers and Non-Consumers at 5 y: Proportion Meeting Food Group and Nutrient Recommendations from 5 to 15 y*

Differences at each time of assessment and changes from 5 to 15 y in the proportion of girls meeting food group and nutrient recommendations are presented in **Table 2.5**. Girls who were soda consumers were less likely to meet the recommended number of servings from grains and dairy from 5 to 15 y. However, for both groups a larger proportion of girls failed to meet recommendations at 15 y. Similarly, a significant decline in the proportion of girls' meeting vegetable and fruit recommendations was noted for both groups.

A significant interaction between group membership and age was noted for girls' vitamin D intake, indicating that the decline in the proportion of girls meeting vitamin D recommendations over time was smaller among soda consumers. However, soda consumers were less likely to meet vitamin D recommendations at 5 y and over time than soda non-consumers. A significant main effect for group membership was noted only in the proportion of girls' meeting recommendations for dairy related nutrients. Girls who were soda consumers were less likely to meet recommendations for calcium, magnesium, and phosphorous recommendations from 5 to 15 y. Further, an age effect was detected for girls' energy, calcium, magnesium, phosphorous, and iron, showing a decrease in the proportion of girls meeting recommendations for these nutrients for both groups.

## DISCUSSION

This prospective analysis was conducted to describe changes in beverage intake patterns across childhood and adolescence in a sample of non-Hispanic white girls. Our findings extend previous cross-sectional studies (51-53), indicating that from 5 to 15 y, the contribution of servings of milk and fruit juice declined with age, while soda and tea/coffee increased. Fruit drink intake remained relatively unchanged. Results also provided evidence that early differences in soda consumption persist over time. The early differences in soda consumption at 5 y predicted differences in milk, beverage-related food groups, and nutrient intake. Relative to girls who were not consuming soda at 5 y, soda consumers had in addition to higher soda intake, lower milk intake, higher intake of added sugars, lower dairy-related nutrients, and were less likely to meet dairy-related nutrient recommendations from 5 to 15 y. Although girls who were not consuming soda at 5 y consumed more milk than soda consumers 5 y, these differences did not persist over time. This research suggests that early differences in beverage intake patterns characterized by higher soda and lower milk intake tend to persist over time and are associated with girls' dietary intake across childhood and adolescence.

Previous research has shown that early dietary intake patterns can influence intake patterns later in life (5, 11-24), and limited research has focused on either the stability of milk or soda intake from adolescence into adulthood (18-20). Focusing on one type of beverage intake fails to take into account the possible impact of consuming one beverage on intake of other beverages, which may result not only from choosing that beverage, but also from the absence of the alternatives not chosen. In this study, early differences in soda intake were predictive of later soda and milk intake, and of differences in beverage-related nutrients, particularly added sugar and dairy-related nutrients. Although soda intake increased for both groups over the study period, soda intake was consistently higher, both in the mean amount and proportion of consumers, among girls who were already consuming soda at 5 y. In addition, relative to girls not consuming soda at 5y, soda consumers drank fewer servings of milk from 5 to 15 y. Differences in milk intake between groups were mainly due to differences in the proportion of girls consuming milk. Although there was a decline in the proportion of milk consumers for both groups, soda consumers were less likely to be milk consumers from 5 to 15 y (data not shown). Thus, these data suggest the importance of limiting soda intake among young children under 5 y. Data from the FITS study show that ~11% of toddlers between 15 and 24 months of age were already consuming sodas (55). At study entry, when girls were 5 y, 60% of our sample were already soda consumers. While there is little systematic evidence on the development of soda consumption, it is likely that the soda consumers began drinking soda prior to 5 y, findings revealed that these established patterns persisted over time.

In this study we examined differences in family demographics and parental weight status between groups of soda consumption. These two groups only differed in parental weight status at study entry, with parents of girls classified as soda consumers having higher BMIs at study entry. However, no differences between soda consumption groups were noted in girls' weight status from 5 to 15 y (see **Appendix F**). There is other evidence (54) that family environments characterized by higher parental weight status also are obesigenic, characterized by poorer diet quality and fewer opportunities for an active lifestyle, which may include differences in beverage availability. In this context parents may have made more soda and less milk available during early childhood, and thus developing a beverage intake pattern that would persist throughout childhood and adolescence and in turn affecting girls diet quality. Future research is needed to further assess characteristics of the family environment that are associated with the development of beverage intake patterns. Identification of these factors may highlight modifiable behaviors that can be the focus of these intervention efforts.

Early differences in beverage intake predicted long-term differences in beverage-related food groups and nutrients between soda consumption groups. Soda consumers had lower milk intake over the study period, which was associated with a diet lower in milk-related nutrients. Thus, these results suggest that drinking soda is a marker for a less healthy diet quality. This study extends previous cross-sectional findings (1, 2, 8, 9), revealing that soda consumers had significantly lower intakes of calcium, vitamin D, phosphorous, magnesium, and potassium over the study period. Albeit in consistent with previous research (6, 55, 56) both groups showed a decline in overall diet quality over the study period; soda consumers were less likely to meet recommendations for dairy and dairy related nutrients recommendations. Furthermore, reflective of differences in soda intake between groups, soda consumers showed higher intakes of added sugars from 5 to

15 y. Cross-sectional data indicate that sodas constitute the largest source of added sugars in the diet of American children and adolescents (57, 58).

The fact that early differences in beverage intake predicted long-term differences in beverage-related food groups and nutrients between soda consumption groups is of concern, because a diet poor in diet quality may have serious health implications. Soda intake has been proposed as a risk factor for obesity (59). Other studies found a positive association between soda intake and dental caries (60), increased risk of bone fracture (31, 32), type II diabetes (61), and various components of the metabolic syndrome (62). In the present study, differences in dairy-related nutrients, including calcium, vitamin D, phosphorous, magnesium, and potassium were also noted; adequate intake of these nutrients are important for optimal health and growth (6, 20, 63). Calcium intake has been found to be suboptimal in a notable proportion of US children (especially adolescent girls) and may place girls at risk for developing osteoporosis (4).

Several limitations of our study should be considered. First the sample is a homogeneous one; girls were non-Hispanic white, and our findings cannot be generalized to other racial or ethnic populations or to boys. For example, studies show that African-American children tend to consume less milk, and more fruit drinks (64). It would be advantageous to examine children's beverage intake patterns and the impact on dietary intake among more diverse populations. Second, at the beginning of the study, 5 to 9 y, mothers were the primary reporters of girls' dietary intake, with presence of their daughters. However, from 11 to 15 y, girls were the primary reporters with mothers participating in the interview as needed. This could be a potential source of reporting bias; results revealed that changes in girls' beverage intake occurred at the same time that reporting in 24-h recall changes from mothers to daughters. Third, we collected three, 24-h dietary recall at each assessment point, which may have led to misclassifying girls as "soda non-consumers" who consumed soda rarely enough that it was not reported on those days. Furthermore, reporting bias research suggests that unhealthy foods, such as soda, are more likely to be under-reported (65). Both of these factors would have reduced the likelihood of seeing differences between soda consumers and non-consumers; despite this, systematic differences in beverage-related food group and nutrient intake were noted. Fourth, this study does not provide data on girls' water intake. Thus, we could not determine how water intake relates to the consumption patterns of other beverages. As indicated in a study in adults (66) it is possible that water intake might have a positive impact on children's diet. Fifth, while we provide evidence for a differential pattern of beverage intake for soda consumption groups, indicating that soda consumers had higher soda and lower milk intake from 5 to 15 y, our results do not signify causality. Finally, the longitudinal data allowed us: 1) to follow the same cohort of girls over time and provided essential data on changes in beverage intake across childhood and adolescence; 2) and to identify girls who were soda consumers and non-consumers at 5y and to assess the impact on their beverage and nutritional intake over time. However, we could not assess the extent to which the observed changes in beverage intake patterns are attributable to developmental changes or secular trends.

Despite these limitations, our study has several strengths. First, the longitudinal data set offers advantages over previous cross-sectional research by allowing us to examine change in beverage intake patterns within individuals across childhood and adolescence and its impact on indicators of diet quality. We assessed developmental stability and change in beverage intake across childhood and adolescence, which is a developmental period where major social, environmental, and biological changes occur which may persist throughout life. Second, this study focused not just at one type of beverage intake, but rather patterns of beverage intake and their impact on indicators of diet quality. Milk and soda intake tend to be negatively correlated (5, 8, 34-37), such that focusing on one type of beverage intake fails to take into account the impact of consuming other type of beverage, which may result not only from choosing that beverage, but also from the absence of the alternatives not chosen. Third, beverage intake was assessed by 24-h dietary recalls repeatedly over 10 y across childhood and adolescence. Lastly, the data set gave us the opportunity to include additional measures of the family environment that are associated to girls' beverage and dietary intake.

In sum, this study suggests that early patterns of beverage intake can have persistent effects during childhood and adolescence. Patterns characterized by higher soda and lower milk intake at an early age can have a negative impact on girls' beverage-related food groups and nutrient intake during childhood and adolescence. Additional evidence from our study suggests that nutritious beverages, such as milk, are negatively related to fruit drinks, soda, tea/coffee, during childhood and early adolescence. This is of concern given that a less nutritious diet may have serious health implications. Our findings suggest that prevention efforts should include a focus on promoting healthy beverage patterns early in childhood, as these patterns were relatively well established by age 5, to reduce children's risk of lower diet quality. Such prevention efforts should focus on preventing and limiting the early introduction of soda and other sweetened beverages and instead promoting the intake of water, reduced fat milk, while limiting fruit juice, within recommended levels by the American Academy of Pediatrics (67). The emergence of a group of soda consumers by 5 y suggests developing tailored strategies for promoting healthy beverage patterns among those who are becoming consumers should continue to be a major focus of interventions. Specifically, the development of beverage intake patterns that include frequent milk, water, and fruit juice intake is likely to lead to diets that could in turn reduce the risk of chronic diseases, including osteoporosis, obesity, hypertension, and cancer.

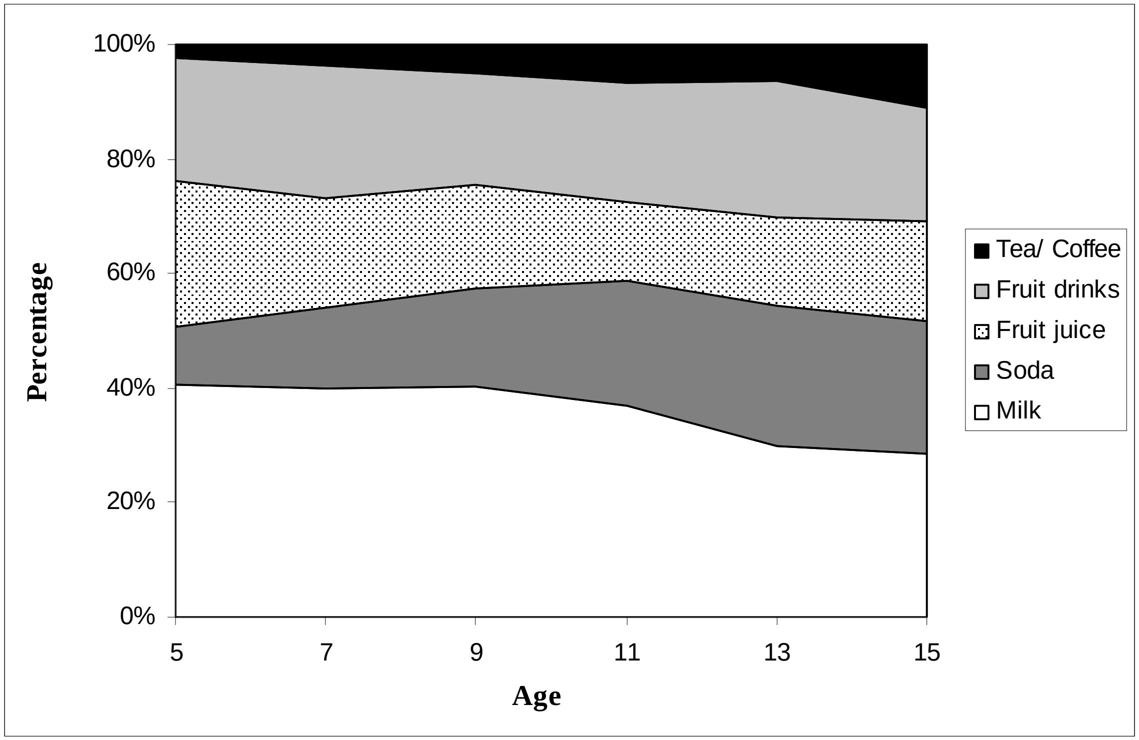
**Table 2.1** Mean servings per day of each beverage, for the total sample, and for the percentage of the total sample who are consuming each beverage, consumers, from 5 to 15 y (N=170)

| Beverages[1] | | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | Change | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F value | p-value |
| Total Beverage | Total sample (Servings/d) | 3.4 ± 1.7[2] | 3.3 ± 1.4 | 3.3 ± 1.4 | 3.8 ± 1.8 | 3.6 ± 1.8 | 3.1 ± 1.7 | 0.00 | ns |
| Total milk | Total Sample (Servings/d) | 1.4 ± 1.1[3] | 1.3 ± 0.9 | 1.2 ± 0.8 | 1.4 ± 1.1 | 1.0 ± 0.9 | 0.9 ± 0.8 | 32.85 | <0.01 |
| | % Consumers | 90 | 89 | 85 | 78** | 70*** | 59*** | | |
| | Consumers (Servings/d) | 1.5 ± 1.1 | 1.4 ± 0.8 | 1.4 ± 0.8 | 1.7 ± 1.0 | 1.5 ± 0.7 | 1.4 ± 0.5 | 0.09 | ns |
| Whole milk | Total Sample (Servings/d) | 0.3 ± 0.7 | 0.2 ± 0.5 | 0.2 ± 0.4 | 0.4 ± 0.8 | 0.1 ± 0.3 | 0.1 ± 0.3 | 23.84 | <0.01 |
| | % Consumers | 28 | 23 | 20* | 20* | 5*** | 6*** | | |
| | Consumers (Servings/d) | 1.1 ± 0.9 | 1.1 ± 0.5 | 1.0 ± 0.4 | 1.8 ± 1.0 | 1.4 ± 0.6 | 1.2 ± 0.7 | 4.39 | <0.05 |
| Reduced fat milk | Total Sample (Servings/d) | 1.0 ± 0.9 | 1.0 ± 0.8 | 1.0 ± 0.8 | 1.0 ± 0.9 | 1.0 ± 0.9 | 0.8 ± 0.8 | 10.07 | <0.01 |
| | % Consumers | 79 | 82 | 78 | 72 | 66** | 55*** | | |
| | Consumers (Servings/d) | 1.3 ± 0.8 | 1.3 ± 0.7 | 1.2 ± 0.7 | 1.4 ± 0.7 | 1.4 ± 0.7 | 1.4 ± 0.6 | 4.31 | <0.05 |
| Fruit juice | Total Sample (Servings/d) | 0.9 ± 1.1 | 0.7 ± 0.9 | 0.7 ± 0.9 | 0.6 ± 1.0 | 0.6 ± 0.9 | 0.6 ± 0.9 | 13.47 | <0.01 |
| | % Consumers | 70 | 61* | 61* | 49*** | 49*** | 48*** | 70 | |
| | Consumers (Servings/d) | 1.3 ± 1.0 | 1.2 ± 0.9 | 1.1 ± 0.8 | 1.2 ± 1.1 | 1.2 ± 1.0 | 1.2 ± 1.0 | 0.26 | ns |

| Beverages[1] | | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | Change | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | F value | p-value |
| Fruit drinks | Total Sample (Servings/d) | 0.7 ± 0.8 | 0.7 ± 0.7 | 0.6 ± 0.6 | 0.8 ± 0.7 | 0.8 ± 0.9 | 0.5 ± 0.7 | 1.31 | ns |
| | % Consumers | 81 | 81 | 73 | 81 | 74 | 61*** | | |
| | Consumers (Servings/d) | 0.9 ± 0.7 | 0.9 ± 0.6 | 0.9 ± 0.6 | 0.9 ± 0.7 | 1.1 ± 0.9 | 0.9 ± 0.6 | 1.22 | ns |
| Soda | Total Sample (Servings/d) | 0.3 ± 0.4 | 0.4 ± 0.5 | 0.6 ± 0.6 | 0.8 ± 0.9 | 0.9 ± 0.9 | 0.7 ± 0.8 | 77.93 | <0.01 |
| | % Consumers | 60 | 62 | 68 | 77** | 72** | 64 | | |
| | Consumers (Servings/d) | 0.5 ± 0.4 | 0.7 ± 0.4 | 0.9 ± 0.6 | 1.1 ± 0.8 | 1.2 ± 0.8 | 1.0 ± 0.7 | 71.13 | <0.01 |
| Tea/coffee | Total Sample (Servings/d) | 0.1 ± 0.3 | 0.2 ± 0.4 | 0.2 ± 0.4 | 0.3 ± 0.6 | 0.3 ± 0.9 | 0.4 ± 0.6 | 40.31 | <0.01 |
| | % Consumers | 24 | 25 | 29 | 34* | 29 | 42*** | | |
| | Consumers (Servings/d) | 0.4 ± 0.5 | 0.6 ± 0.6 | 0.7 ± 0.5 | 0.9 ± 0.8 | 1.0 ± 1.0 | 0.9 ± 0.6 | 17.39 | <0.01 |

[1] 1 serving of milk = 1 cup equivalent (8 oz) (48),1 serving of fruit juice = 8 oz; 1 serving of fruit drinks, soda or tea/coffee = 8 oz.
[2] mean ± SD (all such values);
[3] Proportion of consumers at 5 y were compared against proportion of consumers at 7, 9, 11, 13, and 15 y; Significant at *p<0.05, **p<0.01, ***p<0.0001

**Figure 2.1** Relative contribution of servings of beverage subcategories to total beverage intake from 5 to 15 y (N=170)[1]




[1]Water intake was not assessed

**Table 2.2** Mean beverage intake for girls who were soda consumers (SC) and non consumers (SNC) at 5 y, from 5 to 15 y [1]

| Beverage (servings/d) | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | p-value | |
| Total Beverage | SNC | 3.4 ± 1.9 [2,3] | 3.3 ± 1.5 | 3.2 ± 1.5 | 3.8 ± 1.9 | 3.7 ± 1.6 | 3.0 ± 1.8 | ns | ns | ns |
| | SC | 3.4 ± 1.5 | 3.4 ± 1.3 | 3.4 ± 1.3 | 3.9 ± 1.7 | 3.6 ± 1.9 | 3.1 ± 1.6 | | | |
| Milk | SNC | 1.6 ± 1.1** | 1.4 ± 0.9 | 1.3 ± 0.9 | 1.5 ± 1.1 | 1.1 ± 0.9 | 0.9 ± 0.9 | <0.01 | <0.01 | <0.05 |
| | SC | 1.2 ± 1.1 | 1.2 ± 0.9 | 1.1 ± 0.8 | 1.3 ± 1.1 | 1.0 ± 0.9 | 0.9 ± 0.9 | | | |
| Fruit juice | SNC | 1.0 ± 1.3 | 0.8 ± 1.1 | 0.7 ± 0.8 | 0.6 ± 1.0 | 0.7 ± 1.1 | 0.8 ± 1.1* | ns | <0.01 | ns |
| | SC | 0.8 ± 0.9 | 0.7 ± 0.8 | 0.7 ± 0.9 | 0.6 ± 0.9 | 0.6 ± 0.8 | 0.5 ± 0.8 | | | |
| Fruit drinks | SNC | 0.7 ± 0.8 | 0.7 ± 0.6 | 0.6 ± 0.7 | 0.8 ± 0.8 | 0.8 ± 0.8 | 0.6± 0.5 | ns | ns | ns |
| | SC | 0.7 ± 0.7 | 0.8 ± 0.7 | 0.6 ± 0.6 | 0.7 ± 0.7 | 0.8 ± 0.9 | 0.6± 0.7 | | | |
| Soda | SNC | 0.0 ± 0.0 [4] | 0.3 ± 0.4** | 0.4 ± 0.4** | 0.5 ± 0.7*** | 0.7 ± 1.0* | 0.5 ± 0.7** | <0.01 | <0.01 | ns |
| | SC | 0.5 ± 0.4 | 0.6 ± 0.5 | 0.7 ± 0.7 | 1.0 ± 0.9 | 0.9 ± 0.8 | 0.8 ± 0.8 | | | |
| Tea/coffee | SNC | 0.1 ± 0.3 [4] | 0.1 ± 0.4 | 0.2 ± 0.5 | 0.3 ± 0.7 | 0.3 ± 0.7 | 0.3 ± 0.5 | ns | <0.01 | ns |
| | SC | 0.1 ± 0.3 | 0.2 ± 0.4 | 0.2 ± 0.4 | 0.3 ± 0.6 | 0.3 ± 0.7 | 0.4 ± 0.7 | | | |

[1] Soda consumers (n=102) and non consumers (n=68) defined at 5 y
[2] mean (SD) (all such values)
[3] Mean variable and mean within age significantly different at *p<0.05
[4] Differences in soda intake at 5 y between groups are based on the categorization criteria, thus change in soda intake was tested from 7 to 15 y, excluding 5 y.

**Table 2.3** Mean food group servings per day for girls who soda consumers (SC) and non consumers (SNC) at 5 y, from 5 to 15 y [1]

| Food groups (servings/day)[2] | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | p-value | | |
| Grain | SNC | 5.5 ± 1.9 [3] | 6.0 ± 1.6 | 6.8 ± 1.6 | 6.6 ± 1.7* | 6.0 ± 1.9 | 5.9 ± 2.0 | ns | ns | ns |
| | SC | 5.2 ± 1.6 | 5.9 ± 1.7 | 6.3 ± 1.7 | 6.0 ± 2.1 | 5.9 ± 2.1 | 5.6 ± 1.9 | | | |
| Vegetable | SNC | 1.5 ± 1.1 | 1.8 ± 1.2 | 2.0 ± 0.9 | 2.0 ± 1.2 | 1.7 ± 1.1 | 1.8 ± 1.3 | ns | <0.05 | ns |
| | SC | 1.5 ± 1.1 | 1.7 ± 0.7 | 1.9 ± 1.1 | 2.0 ± 1.2 | 1.8 ± 1.0 | 1.7 ± 1.1 | | | |
| Fruit | SNC | 2.1 ± 1.7* | 2.0 ± 1.9* | 1.7 ± 1.3 | 1.5 ± 1.7 | 1.3 ± 1.1 | 1.6 ± 1.8* | <0.05 | <0.01 | ns |
| | SC | 1.6 ± 1.3 | 1.4 ± 1.1 | 1.4 ± 1.2 | 1.2 ± 1.1 | 1.1 ± 1.1 | 1.1 ± 1.3 | | | |
| Dairy | SNC | 2.7 ± 1.1 | 3.0 ± 1.2* | 2.9 ± 1.7 | 2.9 ± 1.3 | 2.8 ± 1.4 | 2.4 ± 1.2 | ns | <0.01 | ns |
| | SC | 2.3 ± 1.2 | 2.6 ± 1.1 | 2.6 ± 1.1 | 2.7 ± 1.2 | 2.5 ± 1.4 | 2.0 ± 1.2 | | | |
| Meat | SNC | 2.9 ± 1.4 | 3.1 ± 1.5 | 3.5 ± 1.4 | 3.5 ± 1.6 | 3.4 ± 1.5 | 3.5 ± 2.0 | ns | <0.01 | ns |
| | SC | 2.9 ± 1.3 | 3.1 ± 1.4 | 3.4 ± 1.6 | 3.4 ± 1.7 | 3.5 ± 1.9 | 3.6 ± 2.1 | | | |

[1] Soda consumers (n=102) and non consumers (n=68) defined at 5 y
[2]For food group recommendations refer to Mypyramid (48).
[3]Mean variable and mean within an age significantly different at *p<0.05

**Table 2.4**. Mean energy, macronutrient, and micronutrient intakes for girls who soda consumers (SC) and non consumers (SNC) at 5 y, from 5 to 15 y [1]

| Nutrient [2] | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | p-value | |
| Energy (Kcal/d) [5] | SNC | 1564 ± 369 [3,4] | 1757 ± 419 | 1892 ± 352 | 1860 ± 437 | 1676 ± 452 | 1615 ± 417 | ns | ns | ns |
| | SC | 1509 ± 309 | 1675 ± 273 | 1781 ± 323 | 1803 ± 439 | 1703 ± 479 | 1561 ± 416 | | | |
| Carbohydrates (% energy) | SNC | 57.2 ± 5.7 | 56.8 ± 5.3 | 55.5 ± 5.9 | 55.2 ± 5.3 | 54.4 ± 6.2 | 52.3 ± 6.0 | ns | <0.01 | ns |
| | SC | 57.2 ± 6.0 | 57.4 ± 5.5 | 56.1 ± 5.7 | 55.3 ± 6.4 | 53.7 ± 6.7 | 53.0 ± 7.8 | | | |
| Protein (% energy) | SNC | 14.3 ± 2.5 | 13.7 ± 2.3 | 13.8 ± 2.4 | 14.3 ± 2.6 | 15.1 ± 3.5 | 15.2 ± 2.7 | <0.05 | <0.01 | ns |
| | SC | 13.5 ± 2.5 | 13.1 ± 2.2 | 13.6 ± 2.5 | 13.6 ± 2.7 | 14.7 ± 3.1 | 15.3 ± 3.5 | | | |
| Fat (% energy) | SNC | 30.2 ± 4.6 | 31.1 ± 4.6 | 32.3 ± 4.5 | 31.8 ± 4.6 | 31.9 ± 5.3 | 33.9 ± 5.2 | ns | <0.01 | ns |
| | SC | 30.7 ± 5.1 | 31.0 ± 4.9 | 31.7 ± 4.6 | 32.6 ± 4.9 | 32.9 ± 5.4 | 33.1 ± 6.4 | | | |
| Saturated fat (% energy) | SNC | 11.3 ± 2.5 | 11.6 ± 2.6 | 11.8 ± 2.5 | 12.0 ± 2.3 | 12.3 ± 2.7 | 12.9 ± 2.8* | ns | <0.01 | ns |
| | SC | 11.4 ± 2.5 | 11.4 ± 2.1 | 11.8 ± 2.1 | 12.0 ± 2.3 | 12.2 ± 2.5 | 12.0 ± 2.9 | | | |
| Added sugar (% energy) [6] | SNC | 17.8 ± 5.8** | 19.6 ± 6.3 | 18.7 ± 6.7* | 18.9 ± 6.4** | 18.4 ± 6.8 | 16.6 ± 5.3 | <0.01 | <0.01 | <0.05 |
| | SC | 21.1 ± 6.3 | 21.2 ± 6.1 | 20.7 ± 6.2 | 21.8 ± 7.0 | 18.7 ± 6.9 | 17.7 ± 7.4 | | | |
| Fiber (g) | SNC | 11.7 ± 4.3* | 12.7 ± 6.5* | 13.8 ± 4.0** | 13.3 ± 4.6* | 11.5 ± 4.0 | 11.9 ± 5.0 | <0.01 | ns | ns |
| | SC | 10.1 ± 3.5 | 11.0 ± 2.7 | 12.1 ± 3.7 | 11.8 ± 4.1 | 11.2 ± 4.2 | 10.7 ± 4.7 | | | |
| Calcium (mg) | SNC | 903 ± 311 [3,4]** | 913 ± 317* | 981 ± 313* | 989± 402* | 924 ± 370 | 856 ± 389 | <0.01 | ns | ns |
| | SC | 765 ± 340 | 803 ± 272 | 858 ± 287 | 859 ± 376 | 857 ± 345 | 765 ± 330 | | | |
| Vitamin D (μg) | SNC | 5.8 ± 2.5** | 5.3 ± 2.3 | 5.5 ± 2.7* | 5.6 ± 3.5* | 5.1 ± 2.7 | 4.5 ± 3.0 | <0.01 | ns | ns |
| | SC | 4.4 ± 2.6 | 4.6 ± 2.3 | 4.6 ± 2.6 | 4.6 ± 2.6 | 4.8 ± 2.7 | 3.9 ± 2.7 | | | |

| Nutrient [2] | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | p-value | |
| Magnesium (mg) | SNC | 204 ± 64** | 212 ± 65* | 224 ± 48* | 219 ± 66* | 201 ± 61 | 200 ± 71 | <0.01 | <0.01 | ns |
| | SC | 175 ± 47 | 188 ± 43 | 201 ± 49 | 196 ± 57 | 193 ± 64 | 185 ± 72 | | | |
| Phosphorous (mg) | SNC | 1051± 310* | 1102± 295* | 1165 ± 279* | 1144 ± 343* | 1090± 337 | 1024 ± 332 | <0.01 | ns | ns |
| | SC | 929 ± 287 | 981 ± 243 | 1048 ± 283 | 1031 ± 307 | 1059 ± 327 | 980 ± 343 | | | |
| Iron (mg) | SNC | 10.9 ± 3.8 | 12.1 ± 4.0 | 13.4 ± 4.6* | 13.2 ± 4.7 | 11.7 ± 3.6 | 12.5 ± 4.2 | <0.01 | ns | ns |
| | SC | 10.4 ± 3.6 | 11.3 ± 3.6 | 12.1 ± 3.3 | 12.2 ± 4.8 | 12.7 ± 4.9 | 12.2 ± 4.8 | | | |
| Potassium (mg) | SNC | 2063 ± 637** | 2129 ± 652* | 2230 ± 514* | 2170± 703* | 1938 ± 627 | 1907 ± 730 | ns | <0.01 | ns |
| | SC | 1771 ± 527 | 1910 ± 460 | 2003 ± 530 | 1963 ± 535 | 1881 ± 648 | 1751 ± 619 | | | |

[1] Soda consumers (n=102) and non consumers (n=68) defined at 5 y
[2] For nutrient recommendations refer to the Dietary Reference Intakes (DRIs) (44-47).
[3] Mean (SD) (all such values);
[4] Mean variable and mean within an age significantly different at *p<0.05; **p<0.01
[5] A range of Energy Estimate Requirements (EER) was created for girls 4-8 yr and 9-18 yr. Girls' mean age, weight and height and physical activity (PA) coefficients (Sedentary, low active, active and very active) were used to create the ranges. The range of values in EER reflects possible differences in the physical activity coefficients of participants (44). For girls aged 4-8 the range of EER was 1233-2140 kcal/d, and for girls aged 9-18 t the range of EER was 1500-2700.
[6] Added sugars include sugars added in the processing or preparation of foods and beverages (48).

**Table 2.5** Proportion of girls meeting food group and nutrient intake recommendations for girls who soda consumers (SC) and non consumers (SNC) at 5 y, from 5 to 15 y [1]

| | | % Meeting Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age<br>p-value | group*age |
| Grains | SNC | 84[3] | 88 | 88 | 79* | 66 | 44 | <0.01 | <0.01 | ns |
| | SC | 75 | 87 | 79 | 65 | 61 | 32 | | | |
| Vegetable | SNC | 7 | 15 | 4 | 10 | 2 | 3 | ns | <0.01 | ns |
| | SC | 7 | 5 | 5 | 5 | 5 | 0 | | | |
| Fruit | SNC | 43 | 35 | 12 | 10 | 15 | 21* | ns | <0.01 | ns |
| | SC | 34 | 31 | 11 | 11 | 9 | 8 | | | |
| Dairy | SNC | 71 | 81* | 40 | 40 | 35 | 27 | <0.05 | <0.01 | ns |
| | SC | 58 | 66 | 32 | 32 | 34 | 20 | | | |
| Meat | SNC | 40 | 50 | 59 | 63 | 53 | 50 | ns | ns | ns |
| | SC | 40 | 51 | 53 | 54 | 50 | 60 | | | |
| Energy [2] | SNC | 74[3] | 82 | 87 | 78 | 62 | 56 | ns | p<0.01 | ns |
| (kcal/d) | SC | 74 | 89 | 78 | 69 | 58 | 52 | | | |
| Carbohydrate | SNC | 88 | 90 | 91 | 91 | 82 | 82 | ns | ns | ns |
| (% energy) | SC | 90 | 92 | 91 | 92 | 82 | 78 | | | |
| Protein | SNC | 99 | 94 | 94 | 97 | 90 | 96 | ns | ns | ns |

| % Meeting Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
| | | | | | | | | | p-value | |
| (% energy) | SC | 93 | 91 | 94 | 94 | 95 | 93 | | | |
| Fat | SNC | 72 | 69 | 71 | 63 | 59 | 62 | ns | ns | ns |
| (% energy) | SC | 69 | 73 | 72 | 69 | 54 | 56 | | | |
| Saturated fat | SNC | 28 | 24 | 25 | 19 | 27 | 21 | ns | ns | ns |
| (% energy) | SC | 28 | 25 | 22 | 18 | 21 | 29 | | | |
| Fiber | SNC | 2 | 2 | 0 | 2 | 0 | 3 | ns | ns | ns |
| (g) | SC | 0 | 0 | 1 | 1 | 0 | 3 | | | |
| Calcium | SNC | 63** | 62 | 15* | 21* | 16 | 15 | <0.01 | <0.01 | ns |
| (mg) | SC | 42 | 48 | 5 | 10 | 10 | 8 | | | |
| Vitamin D | SNC | 57** | 54* | 57** | 46 | 50 | 29 | <0.01 | <0.01 | <0.01 |
| (µg) | SC | 32 | 36 | 34 | 38 | 43 | 29 | | | |
| Magnesium | SNC | 94* | 97 | 29 | 29* | 22 | 24 | <0.05 | <0.01 | ns |
| (mg) | SC | 80 | 94 | 22 | 17 | 20 | 19 | | | |
| Phosphorous | SNC | 100 | 97 | 37 | 28 | 31 | 24 | <0.05 | <0.01 | ns |
| (mg) | SC | 98 | 99 | 22 | 23 | 25 | 19 | | | |
| Iron | SNC | 53 | 65 | 94 | 94 | 85 | 25 | ns | <0.01 | ns |

| % Meeting Recommendations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | group | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age<br>p-value | group*age |
| (mg) | SC | 47 | 60 | 89 | 86 | 85 | 19 | | | |
| Potassium | SNC | 0 | 2 | 0 | 0 | 0 | 0 | ns | ns | ns |
| (mg) | SC | 0 | 0 | 1 | 0 | 0 | 0 | | | |

[1] Soda consumers (n=102) and non consumers (N=68) defined at 5 y
[2] Meeting recommendations were calculated in terms of meeting the lower value of the range recommended for each food group (48) and nutrient (44-47).
[3] Proportion within an age significantly different at $^{*}p<0.05$

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# Chapter 3

# GIRLS' EARLY BEVERAGE INTAKE PREDICTS LONG-TERM ADIPOSITY AND WEIGHT STATUS IN CHILDHOOD AND ADOLESCENCE

**ABSTRACT**

**Background:** Increased consumption of sweetened beverage has been linked to higher energy intake, adiposity, and weight status in children and adolescents.

**Objective:** To assess whether early beverage intake at 5 y predicted energy intake, adiposity, and weight status across childhood and adolescence.

**Design/ subjects:** Participants were part of a longitudinal study of non-Hispanic white girls, predominantly middle class (n=170), living in central Pennsylvania, assessed biennially from 5 to 15 y.

**Statistical analyses:** At each assessment, intake of beverages (milk, fruit juice, and sweetened beverages) and energy intake were assessed using three, 24-hour recalls. Percent body fat was measured. Trained nurses measured waist circumference. Height and weight were measured and used to calculate BMI. Linear and multiple regression analyses were used to predict girls' adiposity. At 5 y, girls' were categorized as consuming <1, ≥1 and <2, or ≥2 servings of sweetened beverages. A mixed modeling approach was used to assess longitudinal differences and patterns of change in sweetened beverage and energy intake, adiposity, and weight status by frequency of sweetened beverage intake.

**Results:** Sweetened beverage, but not milk or fruit juice, at 5 y was positively associated with adiposity at each measurement point from 5 to 15 y. No significant differences in total dietary energy intake were noted by frequency of sweetened beverage intake at 5 y. Greater consumption of sweetened beverage at 5 y (≥2 servings/d) was associated with higher percent body fat, waist circumference, and weight status from 5 to 15 y.

**Conclusion:** These findings provide new longitudinal evidence that early intake of

sweetened beverage intake influences adiposity and weight status across childhood and adolescence.

## INTRODUCTION

The prevalence of overweight and obesity in children has been growing at an alarming rate for the past three decades (1). Recent statistics from the National Health and Nutrition Examination Survey (NHANES) 2003-2004 showed that ~37% of children ( 6-11y) and ~34% of adolescents (12-19 y) are at risk of overweight or overweight (1). Evidence also indicates that weight status and adiposity tracks from childhood into adulthood (2-5). Thus, obesity during childhood is an important predictor of adult obesity (2, 6).

Various environmental and social factors relating to diet and physical activity have been identified that could contribute to obesity (7). One such factor that has recently received significant attention is consumption of sweetened beverages (8). Concomitant with the increase of overweight and obesity, national survey data indicates that consumption of sweetened beverages has increased considerably while milk intake decreased among children and adolescents (9). Sweetened beverages provide little or no nutritional value beyond energy and represent the leading source of added sugars in children's diet (10-13). A recent review found that in the majority of the studies higher sweetened beverage intake was linked to increased weight status and obesity among children and adolescents possibly by increasing overall energy intake. However, the majority of the studies were cross-sectional in nature, and therefore measure sweetened beverage intake and weight at only one point in time and cannot address whether higher sweetened beverage intake causes higher weight (8). Several prospective studies found that higher sweetened beverage intake was associated with higher weight status (13-17). For example, Ludwig and colleagues (14), in a 19 months prospective study of children aged 11 and 12 years, found that the odds ratio of becoming overweight increased 60% for each serving of sweetened beverages consumed daily. However, these studies (13-17) measured adiposity as body mass index (BMI), thus, there is a need for other long-term studies that measure adiposity using dual-energy X-ray absorptiometry, which provide a precise measurement of adiposity (18).

With respect to links between intake of other beverages with obesity, 100% fruit juice has also been associated with increased energy intake and weight status among preschool children in some studies (19, 20) but not others (21-26). Negative associations between milk intake and weight status in children have been noted in some studies (27-29) but others have failed to confirm this relation between milk and weight status (30-32).

Limited research suggests that early food and beverage consumption patterns persist and influence preferences and patterns of intake later in life (33-47). In addition, retrospective studies (40, 41, 43) indicate that although milk and calcium intake decline during childhood and adolescence, the development of dietary habits that include frequent milk intake during childhood tend to track over time, and set the course of milk and calcium intake during adulthood. In addition, Kvaavik et al. (47) found that soda intake tracked from adolescence into early adulthood and from early adulthood into late adulthood. However, few studies have focused on the stability of beverage intake within individuals over time. Additionally, the impact of early beverage intake patterns on long-term measures of adiposity in childhood and adolescence is not well understood.

The overall objective of this study was to assess whether early beverage intake predicted adiposity, measured as percent body fat and waist circumference, and weight status, measured as BMI-for-age percentiles and risk of being overweight ($\geq$85 BMI-for age-percentile), from 5 to 15 y. Given that there is evidence that sweetened beverage intake is associated with higher weight status and adiposity (6), we hypothesized that sweetened beverage at 5 y, modeled as a continuous variable, but not milk or fruit juice would be a significant and positive predictor of girls' adiposity in childhood and adolescence. We also hypothesized that higher levels of sweetened beverage intake at 5 y would predict higher 24-h energy intake, adiposity, and weight status, from 5 to 15 y, based on frequency of sweetened beverage intake at 5 y.

## METHODS

*Participants*

Participants were part of a longitudinal study of the health and development of young girls living in central Pennsylvania. Participants included 197 5-year-old girls and their parents; families were reassessed every 2 years (ages 7, 9, 11, 13 and 15 years). The final assessment included 167 families. Attrition was primarily due to family relocation outside of the study area. Only girls with complete dietary and body weight intake data at 4 of 6 times of measurement were included in this study, resulting in a final sample of 166 girls.

Families were recruited for participation in the study using flyers and newspaper advertisements. In addition, families with age-eligible female children within a 5-county radius received mailings and follow-up phone calls (Metromail Inc.). Eligibility criteria for girls' participation at the time of recruitment included living with both biological parents, the absence of severe food allergies or chronic medical problems affecting food intake, and the absence of dietary restrictions involving animal products; families were not recruited based on weight status or concerns about weight.

Families were predominantly non-Hispanic, White, and the average income for the sample ranged between $50 000 and $75 000, representing the demographics of the area surrounding the study site (Census 2000). Parents were relatively well educated, with fathers having a mean ± SD of 14.9 ± 2.7 years of education and mothers having 14.8 ± 2.3 years. Parents were on average slightly overweight at the first time of measurement with a mean body mass index score (BMI) of 26.4 ± 6.05 for mothers, and 28.0 ± 4.35 for fathers. The Pennsylvania State University Institutional Review Board approved all study procedures, and parents provided consent for their family's participation before the study began.

*Measures*

*Height, Weight, and Weight Status.* Height and weight measurements were taken in the laboratory and were used to calculate BMI [weight (kilograms)/height (meters squared)]. Age- and sex-specific BMI percentiles were also calculated and used to determine the prevalence of overweight in girls in this sample. Using the Centers for Disease Control and prevention growth charts and girls were classified as overweight if their BMI percentile was ≥85 (48).

*Adiposity.* Girls' percentage of body fat was calculated at ages 5, 7, 9, 11, 13, and 15 y. Triceps and subscapular skinfold measurements were collected when girls were 5, 7, 9, and 11 years, and  dual-energy X-Ray absorptiometry (DXA) scans were administered at

9, 11, 13, and 15 years. To most accurately estimate girls' percent body fat at ages 5 and 7 years, regression equations were created to describe the relationship between skinfold and DXA measurements at ages 9 and 11 (when collection of these two measures overlapped). Based on previous research by Slaughter and colleagues (49), the equation created regressed DXA data on the sum and squared sum of triceps and sub-scapular skinfold measurements. The equation derived from this regression model was applied to the age 5 and 7 years skinfold data to calculate estimates of percent body fat at these assessment points. The final equation: Body fat percent=1.46205*(sum of skinfolds) - 0.0136*((sum of skinfolds)$^2$) had an $R^2$ = 0.991 and an SEE =0.005. This equation was then applied to the skinfold measurement data at ages 5 and 7, and estimates of body fatness were calculated.

Trained nurses measured girls' waist circumference at ages 7, 9, 11, 13, and 15 years.

*Dietary intake.* Three 24-hour recall interviews were conducted by the Dietary Assessment Center at the Pennsylvania State University at each occasion by trained staff using the computer-assisted Nutrition Data System for Research (NDS-R) software (Database Version 4.01_30, Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). The NDS-R software itself provides a structured, guided controlled platform where questions, and probes are standard and the process of conducting the 24-hour recall is standard. The NDS-R time-related database updates analytic data while maintaining nutrient profiles true to the bastion used for data collection. The NDS-R is updated annually. Furthermore, interviewers were required to complete 40 hours of intensive training and are subject to reliability tests. To assess reliability, a nutritionist administers three standard dietary recalls in a mock telephone interview to all newly trained interviewers. Reliability among interviewers for calculating nutrient intakes was based on an interclass correlation of 0.95 or higher (50). At ages 5,7,9,11,13, and 15 y, girls provided three 24-h recalls within a 2-to 3-week period, including two randomly selected weekdays and one weekend day. Recalls were conducted from June through October. At ages 5, 7 and 9 mothers in the presence of their daughters were the primary reporter of girls' intake. At ages 11, 13 and 15, girls were the primary reporters with mothers participating in the interview as needed. Participants were mailed a poster depicting 2-dimensional representations of food portions (2D Food Portion Visual, Nutrition Counseling Enterprises, Framingham, MA) as a visual aid for estimating amounts of food eaten. Nutrient data were averaged across 3 days to obtain an estimate of 24-h energy, macronutrients (percent of energy), saturated fat (percent of energy), and added sugars (percent of energy). Nutrient intakes estimates were based on foods consumed and do not include intakes from supplements.

Beverage data were averaged across 3 days to obtain an estimate of the number of servings reported consumed based on the 2005 Dietary Guidelines for Americans (51) and US Department of Agriculture Food Guide Pyramid Guidelines (52). Beverage data were grouped into 3 intake categories: (1) milk; (2) fruit juice; (3) sweetened beverage. Milk included whole and reduced fat milk and was quantified as that consumed as a beverage. Fruit juice was defined as containing 100% fruit juice. At 5 y, artificially sweetened beverages were a small fraction of girls' beverage consumption (see **Appendix A**), so sugar and artificially sweetened beverages were summed into a composite variable referred to as sweetened beverages. Sweetened beverage included: 1) any sweetened or artificially sweetened fruit flavored drinks (natural or artificial), drinks that contained less than 100% fruit juice; 2) sodas which included carbonated sweetened or artificially sweetened, caffeinated or uncaffeinated colas; and 3) tea/coffee which included sweetened or artificially sweetened, caffeinated or uncaffeinated. Girls' intake of water was not assessed. Consumption in each category was expressed in servings.

*Statistical Analyses*

Data were analyzed using the SAS software (version 9.1, 2001, SAS Institute, Cary NC) (53). Descriptive information was generated for all variables of interest. Each outcome variable was assessed for normality. In all analyses a P values <0.05 were considered significant. Change was defined as the linear decrease or increase in the variable of interest from girls 5 to 15 y.

To examine girls' change in adiposity and weight status a mixed modeling approach (PROC MIXED, SAS) was used. Specifically, a random coefficient model was used to assess change from 5 to 15 y for continuous variables. Mixed modeling is a useful tool for analyzing the linear relationship over time, and a major advantage of the Proc Mixed procedure is its ability to retain cases with one or more missing data points (54).

*Analyses for Aim 1:* The first aim was to assess whether milk, fruit juice or sweetened beverage intake (i.e fruit drinks, sodas, and tea/coffee) at 5 y, modeled as continuous variables, predicted girls' adiposity from 5 to 15 y. Spearman rank-order correlations were used to assess stability for milk, fruit juice, and sweetened beverages between measurement occasions from 5 to 15 y. Stability is defined as consistency of girls' beverage intake between 2 measurement occasions, represented by the correlation coefficient between values at two times across individuals (55). A series of simple regression analyses were conducted to determine whether girls' intake of milk, fruit juice, and sweetened beverage at 5y were independent predictors of girls' adiposity measured as percent body fat at 5, 7, 9, 11, 13, and 15 y. The contribution of each predictor variable was determined by examining the standardized parameter estimate.

Multiple regression was used to determine whether sweetened beverage intake at 5 y predicted percent body fat over time, after controlling for potential covariates. Covariates included in the model included: sweetened beverage intake measured at the same point in time that adiposity, 24-h energy intake at 5 y, parental education, family income, and maternal BMI at study entry. These adjustments provide evidence about whether the relationship between higher sweetened beverage intake and higher adiposity is altered in the presence of these variables. Analyses were controlled for sweetened beverage intake at the same age adiposity was measured to test whether early intake of sweetened beverage was a stronger predictor of adiposity than concurrent intake. In addition, we controlled for initial 24-h energy intake to test whether sweetened beverage intake predicted adiposity even in the presence of energy intake. Parental education and family income at study entry were included as a covariate given previous research outlining links between parental education, family income and children's dietary intake and weight status (56-59). Finally, given that maternal BMI is associated with daughters' weight status and adiposity we adjusted for maternal BMI at study entry (60).

*Analyses for Aim 2:* The second aim was to assess whether higher levels of sweetened beverage intake at 5 y would predict greater 24-h energy intake, adiposity, and weight status from 5 to 15 y. To this end, girls were categorized by frequency of sweetened beverage intake at 5 y. Specifically, girls were classified as drinking <1, ≥1 and <2, or ≥2 servings of sweetened beverages per day at 5 y.

Differences in percent body fat, waist circumference, and BMI-for-age percentiles at each point in time among groups were assessed using repeated measures using a mixed modeling approach (PROC MIXED, SAS). Another advantage of the Proc Mixed procedure is it allows for a more adequate definition of the covariance structure that may exist between measurements that are made on an individual subject over time. Different covariance structures were investigated. Models were examined using the following covariance patterns: unstructured, compound symmetry, and autoregressive (1). The compound symmetry structure consistently gave model results with the lowest Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. Thus, this type of covariance structure was specified in the analysis procedure.

Repeated measures type analyses (PROC GENMOD, SAS), appropriate when dealing with binary data, were used to asses (1) whether girls who consumed ≥ 2 servings of sweetened beverage at 5 y were more likely to be overweight (≥85 BMI-for age-percentile) compared with girls at lower levels of intake; and (2) whether the proportion of girls being overweight increased from 5 to 15 y.

Further, change for sweetened beverage and 24-hour energy intake, percent body fat, waist circumference, and BMI-for-age percentiles were assessed from 5 to 15 y for girls drinking <1 serving/day, ≥1 to <2 servings/day, and ≥ 2 servings per day of sweetened beverage. To this end we used a mixed modeling, random coefficient approach (PROC MIXED, SAS), with a Tukey correction for post hoc comparisons. Given that sweetened beverage group membership was defined at 5 y, we only examined change for sweetened beverage intake among groups from 7 to 15 y, excluding 5 y. The main effect of group membership, the main effect of age, and the interaction between group membership and age were of interest. A significant group membership main effect indicates that on average, girls in one group had higher scores on the outcome variable as they get older than girls in the opposing groups. A significant age main effect indicates that on average, girls in the 3 groups had an increase or decrease on the outcome variable as they get older. A significant interaction effect provides evidence for a differential pattern of change for girls' drinking <1 serving/day, ≥1 to <2 servings/day, and ≥ 2 servings per day of sweetened beverage at 5 y.

## RESULTS

*Adiposity and Weight Status*

Descriptive information on girls' percent body fat, waist circumference, and waist status are presented in **Table 3.1**. Weight status measured as BMI-for-age percentiles was stable over the period studied, with stability estimates ranging from r=0.60 (p<0.0001) to r=0.92 (p<0.0001) (see **Appendix G**). However, both the percentage of body fat and the percentage of girls classified as overweight increased significantly from 5 to 15 y.

*Association among Beverages and Stability of Beverage Intake over Time*

Relationships among girls' milk, fruit juice and sweetened beverage intake at 5 y were assessed. The association of milk with fruit juice (r = -0.12, ns) and sweetened beverage (r = -0.06, ns) were not significant, whereas fruit juice and sweetened beverage intake were negatively associated (r = -0.16, p<0.05). **Table 3.2** illustrates girls' beverage stability between measurement occasions from 5 to 15y. For milk and sweetened beverage intake, stability was moderate but stability declined from 5 to 15y. In contrast, fruit juice showed low stability over the study period.

*Beverage Intake at 5 y Predicting Adiposity from 5 to 15y*

Results of the simple regressions conducted to assess milk, fruit juice, and sweetened beverage at 5 y as independent predictors of girls' adiposity at each age from 5 to 15 y appear in **Table 3.3**. These findings indicate that only sweetened beverage intake was a significant predictor of girls' adiposity at each age from 5 to 15 y. Sweetened beverage intake at 5 y explained 11%, 9%, 9%, 5%, 3%, and 4% of the variance in girls' percent body fat at each time point assessed between 5 to 15 y, respectively.

The association between sweetened beverage intake at 5 y and adiposity from 5 to 15 y was also assessed after controlling for potential covariates (**Table 3.3**). After controlling for sweetened beverage intake at the same age adiposity was measured, higher sweetened beverage intake at 5 y continued to predict higher percent body fat at each time point assessed between 5 to 15 y. Similarly, when controlling for 24-h energy intake at 5 y, sweetened beverage intake at 5 y remained significantly and positively associated with girls' adiposity at each time point assessed between 5 to 15 y. Adjusting for 24-h energy intake at the same time point that sweetened beverage was measured did not alter the results (data not shown). Further, we assessed whether sweetened beverage intake at 5 y was associated with higher adiposity after accounting for parental education at study entry. Results showed that higher sweetened beverage intake at 5 y remained a predictor of higher percent body fat at 5, 7, and 9 y after taking parental education into account; however, at 11, 13, and 15y the association was no longer significant. When maternal BMI at study entry was added as a covariate, sweetened beverage intake at 5 y continued to predict girls' adiposity at each time point assessed, between 5 to 11y. However, at 13 and 15 y the association was no longer significant. Lastly, early sweetened beverage intake continued to predict higher adiposity from 5 to 15 y, after family income at study entry was taken into account.

*Girls Consuming <1, ≥1 and <2 or ≥2 Servings of Sweetened Beverage at 5y*

Given that sweetened beverage intake at 5 y, and not milk or fruit juice, was associated with adiposity, the second aim of this study focused on girls' sweetened beverage intake. To assess whether higher levels of sweetened beverage intake at 5 y were associated with greater adiposity and weight status from 5 to 15 y, girls were categorized by daily frequency of sweetened beverage intake at 5 y. Sweetened beverage intake was averaged across 3 days. Fifty six percent (n=96), 28% (n=48), and 15% (n=26) of girls were categorized as consuming <1, ≥1 and <2 or ≥2 servings/day of sweetened beverage at 5y, with mean intakes of consumption of 0.5 ± 0.3 servings/d, 1.4 ± 0.3 servings/d, 3.0 ± 0.8 servings/d, respectively.

*Girls Consuming <1, ≥1 and <2 or ≥2 Servings of Sweetened Beverage at 5y: Differences in Sweetened Beverage Intake from 5 to 15 y*

Patterns of change in mean sweetened beverage intake from 5 to 15 y by frequency of sweetened beverage intake at 5y were examined (**Figure 3.1**). Given that differences in sweetened beverage intake at 5 y among groups were based on the categorization criteria for sweetened beverage consumption at 5 y, we examined changes in sweetened beverage intake among groups from 7 to 15 y, excluding age 5. Once age 5 data are excluded from the analyses, the interaction of group by age is not significant. However, a significant main effect for group membership was noted (F= 22.70, p<0.0001). Post hoc Tukey test revealed that girls drinking ≥2 servings of sweetened beverage at 5 y had significantly higher intakes from 7 to 15 y than girls drinking <1 serving of sweetened beverage at 5 y. However, no differences were noted over time between girls drinking ≥2 servings or ≥1 and <2 servings of sweetened beverage at 5 y. Additionally, a significant main effect for age (F= 16.80, p<0.0001) was noted for girls' sweetened beverage intake from 7 to 15 y, showing an overall increase in sweetened beverage intake. Intakes of total beverage, milk, and fruit juice at each time point of assessment and patterns of change from 5 to 15 y by frequency of sweetened beverage intake at 5 y are presented in the appendix (see **Appendix H**).

*Girls Consuming <1, ≥1 and <2 or ≥2 Servings of Sweetened Beverage at 5y: Differences in Energy Intake from 5 to 15 y*

Patterns of change 24-h energy intake by frequency of sweetened beverage intake at 5y were examined (**Figure 3.2**). Neither the main effect for group membership or age nor the interaction between group membership and age were significant for girls' 24-h energy intake. Mean intakes of macronutrients, saturated fat, added sugars, and food groups from girls 5 to 15 y, by frequency of sweetened beverage intake at 5 y are presented in **Appendix I**.

Given that sweetened beverage group membership was defined at 5 y, the pattern of change in the percentage of energy from sweetened beverage intake was examined from 7 to 15 y (**Figure 3.3**). Neither the main effect of age nor the interaction between group membership and age were significant; only a significant main effect for group membership was noted for percentage of energy from sweetened beverages (F= 22.58, p<0.0001); indicating that girls drinking ≥2 servings of sweetened beverage at 5 y had significantly higher intakes of percentage of energy from sweetened beverages (least-squares means =14.7) from 7 to 15 y than girls drinking ≥1 and <2 (least-squares means =12.5) or <1 daily (least-squares means= 9.1) serving of sweetened beverage at 5 y.

*Girls Consuming <1, ≥1 and <2 or ≥2 Servings of Sweetened Beverages at 5y: Differences in Adiposity and Weight Status from 5- to 15 y*

Differences at each time of assessment (**Table 3.4**) and patterns of change in mean percent body fat, waist circumference, BMI-for-age percentiles, and percent of girls classified as overweight for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5y were assessed. The interaction of group membership and age was not significant for any of the outcome measures, indicating that we did not detect differences in change in adiposity measures over time. A significant main effect for group membership was noted for girls percent body fat (F=7.07, p<0.001), waist circumference (F=3.75, p<0.05), and BMI-percentile (F=5.71, p<0.01); Post hoc Tukey test revealed that girls drinking ≥2 servings of sweetened beverage at 5 y had higher scores on percent body fat, and BMI-for-age percentiles from 5 to 15y, compared with girls at lower levels of sweetened beverage intake (**Figures 3.3, 3.4, and 3.5**). Similarly, a main effect for group membership was detected for the percentage of girls classified as overweight (Z=2.85, p<0.01); girls consuming ≥2 servings of sweetened beverage at 5 y were more likely to be overweight from 5 to 15 y, compared to girls at lower levels of intake (**Table 3.4**). A main effect for age was detected for girls' percent body fat (F=261.85, p<0.0001) and waist circumference (F=995.61 p<0.0001), indicating a general increase in adiposity over time among the 3 groups.

*Girls Consuming <1, ≥1 and <2 or ≥2 Servings of Sweetened Beverage at 5y: Family Demographics and Parental Weight Status*

Parents of girls in the group drinking ≥2 daily servings of sweetened beverage reported lower income at study entry compared to parents of girls drinking <1 serving of sweetened beverage at 5y (p<0.05). In addition, parents of girls in the groups ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y reported significantly lower education levels compared to parents of girls drinking <1 serving of sweetened beverage at 5 y (p<0.0001). No significant differences were seen among groups for daughters' birth weight and maternal breastfeeding. At study entry, BMI for mothers and fathers of the girls drinking ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y was significantly higher than for mothers of girls drinking <1 serving of sweetened beverage at 5 y (p<0.05) (see **Appendix J**).

## DISCUSSION

The main findings of this study were that while neither milk nor fruit juice intake were related to girls' adiposity or weight status, servings of sweetened beverage consumed at 5 y predicted girls adiposity and overweight from 5 to 15y. Girls consuming more servings of sweetened beverage at 5 y, had significantly higher adiposity during childhood and adolescence. In addition, differences in sweetened beverage intake already present at 5 y persisted across childhood and adolescence, and predicted differences in adiposity and weight status in childhood and adolescence. Drinking $\geq$2 servings of sweetened beverage at 5 y was associated with higher percent body fat, waist circumference, and BMI-for- age percentiles from 5 to 15 y. Further, girls' drinking $\geq$2 servings of sweetened beverage at 5 y were more likely to be overweight than girls at lower levels of intake. However, higher levels of sweetened beverage intake at 5 y were not associated with higher 24-h energy intake from 5 to 15 y.

In support of our first hypothesis, early sweetened beverage intake but not milk or fruit juice, predicted higher adiposity during childhood and adolescence. Results from this longitudinal study provide more definitive evidence than previous cross-sectional (61-64) research of the relation between sweetened beverage intake and some measure of adiposity, and concur with findings from other longitudinal studies (14-17, 65, 66) in children and adolescents. However, in contrast to other studies (14, 16, 66, 67) we did not find evidence that differences in girls' sweetened beverage intake at 5 y was predictive of differences in change in adiposity over the study period. Our failure to note associations between the consumption of fruit juice or milk and adiposity is consistent with previous studies that have indicated that fruit juice and milk intake are not related to adiposity (25, 27, 30, 68-72).

In this study, we observed that higher intake of sweetened beverages at 5 y predicted higher adiposity from 5 to 15 y, even after adjusting for sweetened beverage intake at the same time that adiposity was measured. The fact that controlling for concurrent age intake did not attenuate the ability of early sweetened beverage intake to predict adiposity later on suggests the possibility that early sweetened beverage intake may be particularly important in shaping individual differences in adiposity. In fact, previous work with this sample revealed that (73) that early childhood sweetened beverage intake was the only dietary factor associated with differences in metabolic syndrome risk in adolescence. However, it is also possible that increasing under-reporting bias with age might have masked the association between girls' concurrent age sweetened beverage intake and adiposity. There is evidence that the presence of bias in self-reported dietary data can mask the association between diet and health outcomes (74).

It appears that as children get older they are more likely to under-report energy intake (75-77). Previous investigators have contended that foods that are high in added sugars, such as sodas, are selectively under-reported (75, 78). Our data indicates that under-reporting for energy intake increased with age (see **Appendix K**), possibly attenuating the likelihood that concurrent sweetened beverage intake would be predictive of girls' adiposity.

In support of our second hypothesis, higher levels of sweetened beverage were associated with higher adiposity and weight status. In our sample, girls who consumed $\geq$2 sweetened beverage servings per day at 5 y had greater adiposity and weight status. Further, girls drinking $\geq$2 sweetened beverage servings at 5 y were more likely to be overweight than girls classified at lower levels of intake. Our results are in line with other studies that indicate that higher intakes of sweetened beverages are associated with higher BMI (13-16, 79). However, Welsh et al. (15) in a 1 year retrospective study among children aged 2 to 3 years found a threshold effect with the daily intake of 1 or more sweetened beverages. Further, Ludwig et al. (14) in a prospective study of children aged 11 and 12 years, found that the odds of becoming overweight increased 60% for each serving of sweetened beverages consumed daily. Thus, findings are still not conclusive with respect to how much sweetened beverage intake has an influence on weight status and adiposity. An advantage of our study is that in addition to measuring BMI, we also measured waist circumference and percent body fat by DXA. Further, we measured weight status and adiposity biennially across 10 years.

Despite significant differences in adiposity and weight status among sweetened beverage groups, no differences in 24-h energy intake were noted. It is possible that total dietary energy differences among sweetened beverage groups may have not been detected due to greater tendencies toward under-reporting bias at later ages (75-77). Although, no differences were noted in 24-h energy intake, the percentage of energy from sweetened beverages differed among groups. Girls drinking $\geq$2 servings of sweetened beverage at 5 y had significantly higher percent of energy from sweetened beverages over the study period. Nationally representative data (NHANES 1999-2004) (80) indicates that girls aged 2-5 y, 6-11 y and 12-19 y, consume 10%, 11%, and 16% of total daily energy from sweetened beverages, respectively. In this sample girls who consumed $\geq$2 servings of sweetened beverages per day at 5 y, consumed about twice of total energy of sweetened beverages (20.3%) at 5 y. However, by 15 y sweetened beverages represented a similar percent of total daily energy intake (16.2%). Sweetened beverages may contribute energy (81, 82) to the diet but offer little other nutritional value relative to other beverages, such as milk and 100% fruit juice, (11, 83).

The mechanism by which sweetened beverages affects obesity and other metabolic disorders is not yet fully understood or accepted. Several studies have provided evidence that the association is mediated by the additional energy provided by higher levels of sweetened beverage consumption, leading to positive energy balance and increased adiposity. This may be due to incomplete compensation in subsequent meals for the “liquid calories” consumed, relative energy consumed in solid form (14, 84-86). However, in agreement with other studies (14, 17) we found that the association between sweetened beverage and adiposity remained significant after controlling for initial energy intake at 5 y, indicating that sweetened beverage intake continued to predict adiposity over and above the effects of energy intake. Another plausible explanation for the association between sweetened beverages and weight status and adiposity relates to the metabolic effects of the primary sweetener, high-fructose corn syrup, used to sweeten fruit drinks and sodas. The consumption of high-fructose corn syrup has increased 1,000% in the past 3 decades. On average, in the United States, the high-fructose corn syrup added to beverages contains about 55% of fructose, which is metabolized differently than glucose. Fructose is metabolized mainly in the liver and converted to fatty acids. In addition, fructose stimulates less insulin secretion and leptin production than glucose increasing the likelihood of weight gain (87, 88).

Results from this study revealed that the association between sweetened beverage intake and adiposity in girls was attenuated as girls got older by the inclusion of maternal BMI and parental education in the model. It is well established that maternal weight status is one of the strongest predictors of childhood adiposity (89, 90). In our sample pubertal onset occurred, on average around 9 to 10 y (91), which is the time where mothers' BMI has a greater predicting effect on girls' adiposity, indicating that after puberty mothers' and daughters' BMI starts to resemble (92). In addition, this study provided evidence that girls who consumed more servings of sweetened beverage at 5 y were living in families with lower level of parental education, lower SES, and higher parental BMIs at study entry. Thus, suggesting that girls drinking more sweetened beverage servings per day at 5 y were raised in a different familial environment than girls drinking fewer servings of sweetened beverages at 5 y. Evidence on family resemblances in adiposity indicate that overweight parents tend to have overweight children. Although familial similarity in weight status is partially attributable to genetics (93), characteristics of parents and family environments also have a substantial influence on childhood weight status (94, 95). Previous work with this sample revealed that (94) certain families display a pattern of dietary and activity that is likely to promote the development of obesity among children, beyond that explained by genetic susceptibility. These findings suggest that beverage availability may differ among these families and that early differences in sweetened beverage intake may reflect differences in parental beverage intake. However, differences in girls' adiposity from 5 to 15 y by frequency of sweetened beverage consumption were attenuated but persisted after taking into account family characteristics and maternal BMI, suggesting that differences in background did not account for differences in adiposity among groups.

Sweetened beverage groups differed in familial SES, as girls consuming ≥2 serving of sweetened beverage per day were raised in families with lower incomes at study entry. This finding is consistent with evidence that the lower cost of sweetened beverages is implicated in the increasing prevalence of obesity, especially among those with lower incomes, to higher weight status (96). The cost of fruit juice and milk is higher than the cost of sweetened beverages, thus representing a clear barrier for the family to choose healthy alternatives. In this context, it is probable that parents of girls drinking ≥2 servings of sweetened beverage at 5 y chose to purchase a less expensive, but also a less healthy, beverage for their family. Future research is needed to further assess characteristics of the family environment that are associated with the development of beverage intake patterns and higher adiposity. Identification of these factors may highlight modifiable behaviors that can be the focus of these intervention efforts.

Several limitations of out study should be considered. First, this study includes a sample relatively small and homogenous in both race/ethnicity and gender. Because we examined a sample of predominantly non-Hispanic white girls our findings cannot be generalized to other racial/ethnic populations or to boys. Furthermore, the relatively small sample size may have limited power to detect effects, for example the failure to note differences in 24-h energy intake across sweetened beverage groups. Second, this study does not provide data on girls' water intake. Thus, we could not determine how water intake relates to weight status and adiposity. Third, given the observational nature of this study, we cannot infer that the observed associations are causal; however, our data implicate sweetened beverage intake in the development of obesity, and provides new evidence for the persistent effects of early sweetened beverage intake on later beverage intake and on adiposity and risk for overweight, more so than could be indicated from cross-sectional studies. We attempted to include covariates that might influence adiposity in childhood in our models, and the pattern of effects noted for these covariates suggest that sweetened beverage intake may be a marker of other lifestyle differences that affect adiposity. For example, in this study we did not control for physical activity, which is known to be negatively associated with adiposity and weight status (97). Lastly, these data were self reported; thus, there is potential for reporting bias.

Nevertheless, this prospective design provided several strengths. First, we utilized utilize a longitudinal dataset to examine girls' early beverage patterns to predict measures of adiposity and weight status during childhood and adolescence. This association was examined across childhood and adolescence, which is a developmental period where major social, environmental, and biological changes occur which may persist throughout life. Second, this study focused not just at one type of beverage intake, but rather intake of different beverages and their impact on measures of adiposity (14, 62, 68, 72). Third, the prospective design of this study offers advantages over previous cross-sectional research by assessing beverage intake by 24-h dietary recalls repeatedly over 10 y. Lastly, the availability of measures of in this data set gave us the opportunity to include additional measures of the family environment that are associated to girls' beverage intake and measures of adiposity.

The fact that higher sweetened beverage intake was associated with greater adiposity and weight status in this study suggests that guidance and specific recommendations about limiting the amounts of sweetened beverages in the diets of children and adolescents is needed to reduce the intake. Current recommendations provide no specific guidance regarding specific quantities of sweetened beverages. The US Dietary Guidelines for Americans advises consumers to decrease the intake of beverages with caloric sweeteners (98). Recommendations are based on the amount of discretionary calories and range from about ~8 to 15% of energy needs. Parents and caregivers may be in need of dietary advice about a concrete amount of sweetened beverage intake for children.

In conclusion, this study provides evidence that early patterns of sweetened beverage intake persist and predict weight status and adiposity in girls over a 10 year period. Although no one factor is responsible for the obesity epidemic, this study suggests that among non-Hispanic white girls, diets high in sweetened beverage intake can negatively impact adiposity. Furthermore, these results suggest that prevention efforts should include a focus on promoting healthy beverage patterns early in childhood, as these patterns were relatively well established by age 5, to reduce risk of higher weight status and adiposity. Such prevention efforts need to target family environments characterized by lower parental education, lower SES, and higher parental weight status and limit their sweetened beverage intake since early childhood. Further, prevention efforts should identify ways to limit the early introduction and intake of sweetened beverages and reduce the availability of sweetened beverages. Substituting alternative healthy beverages, such as reduced fat milk, water, and limited fruit juice, within recommended levels by the American Academy of Pediatrics (23) should be promoted.

**Table 3.1** Mean percent body fat, waist circumference, BMI-for-age percentile and proportion of girls classified as overweight from 5-to 15 y (N=170)

| | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | Change | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | F- value | p-value |
| Percent body fat (%) | 20.6 $\pm$ 4.3[1] | 21.8 $\pm$ 5.6 | 26.8 $\pm$ 7.5 | 27.3 $\pm$ 7.1 | 26.9 $\pm$ 6.8 | 27.9 $\pm$ 6.0 | 365.8 | <0.01 |
| Waist circumference (cm) | __[2] | 66.9 $\pm$ 8.5 | 73.4 $\pm$ 10.7 | 73.4 $\pm$ 10.7 | 78.7 $\pm$ 10.7 | 78.8 $\pm$ 10.1 | 1307.5 | <0.01 |
| BMI-for-age percentile [3] | 59.3 $\pm$ 26.6 | 58.2 $\pm$ 27.7 | 64.0 $\pm$ 26.9 | 63.5 $\pm$ 27.5 | 62.4 $\pm$ 26.1 | 61.3 $\pm$ 24.9 | 6.65 | <0.05 |
| Overweight (%)[4] | 18 | 19 | 29 | 29 | 25 | 20.5 | 4.42 | <0.05 |

[1] Mean $\pm$ SD (all such values)
[2] Data not available
[3] Mean body mass index percentiles correspond directly to the sample mean BMI using age- and sex specific CDC growth charts (46).
[4] Overweight is defined as ≥85$^{th}$ BMI-for-age percentile (46).

**Table 3.2** Spearman correlations between measurement occasions for beverages from 5 to 15 y

| | Age | | | | | |
|---|---|---|---|---|---|---|
| Beverages | 5-7 (n=169) | 7-9 (n=166) | 9-11 (n=166) | 11-13 (n=166) | 13-15 (n=163) | 5-15 (n=166) |
| Milk | 0.40*** | 0.47*** | 0.36*** | 0.35*** | 0.43*** | 0.35*** |
| Fruit juice | 0.47*** | 0.37*** | 0.31*** | 0.25** | 0.20** | 0.12 |
| Sweetened beverage | 0.48*** | 0.57*** | 0.51*** | 0.32*** | 0.35*** | 0.27** |

Significant at * $p<0.05$; ** $p<0.01$; *** $p<0.0001$

**Table 3.3** Standardized regression coefficients for girls' beverage intake at 5 y predicting percent body fat from 5- to 15 y[1]

| Variable | Age 5 (n=160) | Age 7 (n=169) | Age 9 (n=158) | Age11 (n=164) | Age13 (n=150) | Age 15 (n=160) |
|---|---|---|---|---|---|---|
| Milk, unadjusted | -0.02 | 0.02 | -0.03 | 0.01 | -0.03 | -0.04 |
| Fruit juice, unadjusted | 0.09 | 0.02 | 0.01 | 0.02 | 0.00 | -0.02 |
| SB[2], unadjusted | 0.33*** | 0.30*** | 0.30*** | 0.23** | 0.18* | 0.19* |
| SB, adjusted for current age SB | — | 0.32** | 0.28** | 0.20* | 0.19* | 0.16* |
| SB, adjusted for energy intake at 5 y | 0.31*** | 0.29** | 0.28** | 0.20* | 0.18* | 0.20* |
| SB, adjusted for maternal BMI at study entry [3] | 0.29** | 0.26** | 0.25** | 0.17* | 0.11 | 0.12 |
| SB, adjusted for parental education at study entry [4] | 0.32** | 0.27** | 0.23** | 0.15 | 0.09 | 0.09 |
| SB, adjusted for family income at study entry | 0.34*** | 0.31*** | 0.29** | 0.23** | 0.19* | 0.20* |

[1]Standardized parameter estimates from independent linear regression analysis, estimates are statistically significant at following levels: *$p<0.05$; ** $p<0.01$; *** $p<0.0001$
[2]SB= sweetened beverage
[3]Covariate is a significant predictor of percent body fat at13 and 15 y at $p<0.05$
[4]Covariate is a significant predictor of percent body fat at 11, 13, and 15 y at $p<0.05$

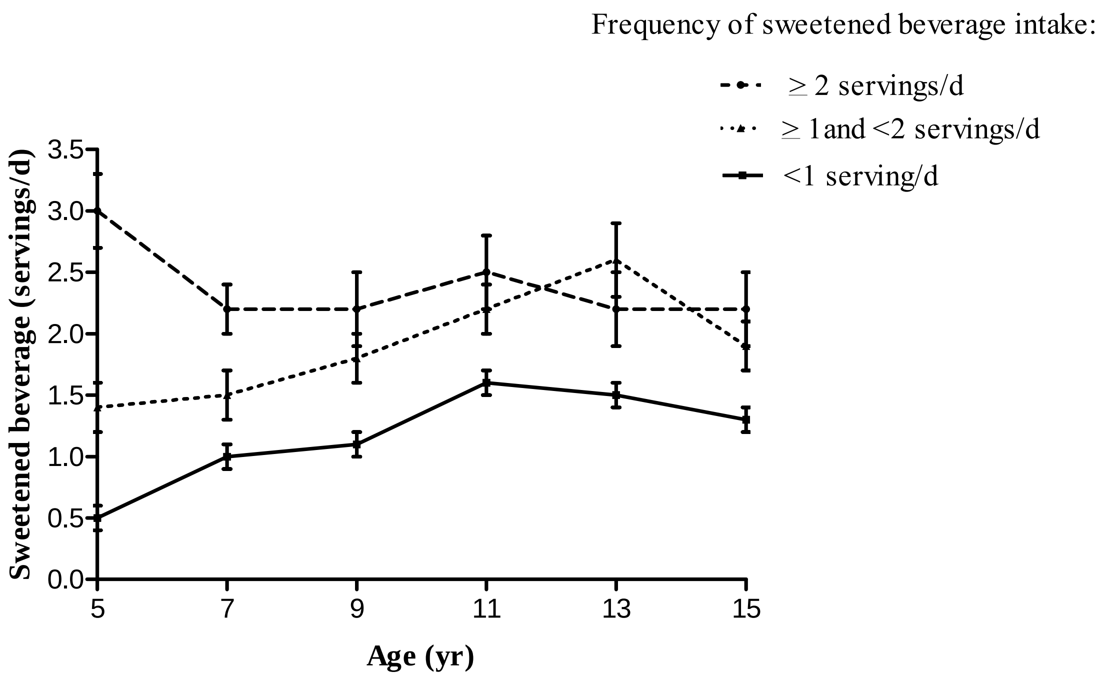


**Figure 3.1:** Sweetened beverage intake change from 7- to 15 y, for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y.
Plotted values are group means ± Standard error.
Differences in sweetened beverage intake at 5 y among groups are based on the categorization criteria, thus the change in sweetened beverage intake was tested from 7- to 15 y. The main effect for group membership ($F= 22.70$, $p<0.0001$) and age ($F= 16.80$, $p<0.0001$) was significant.

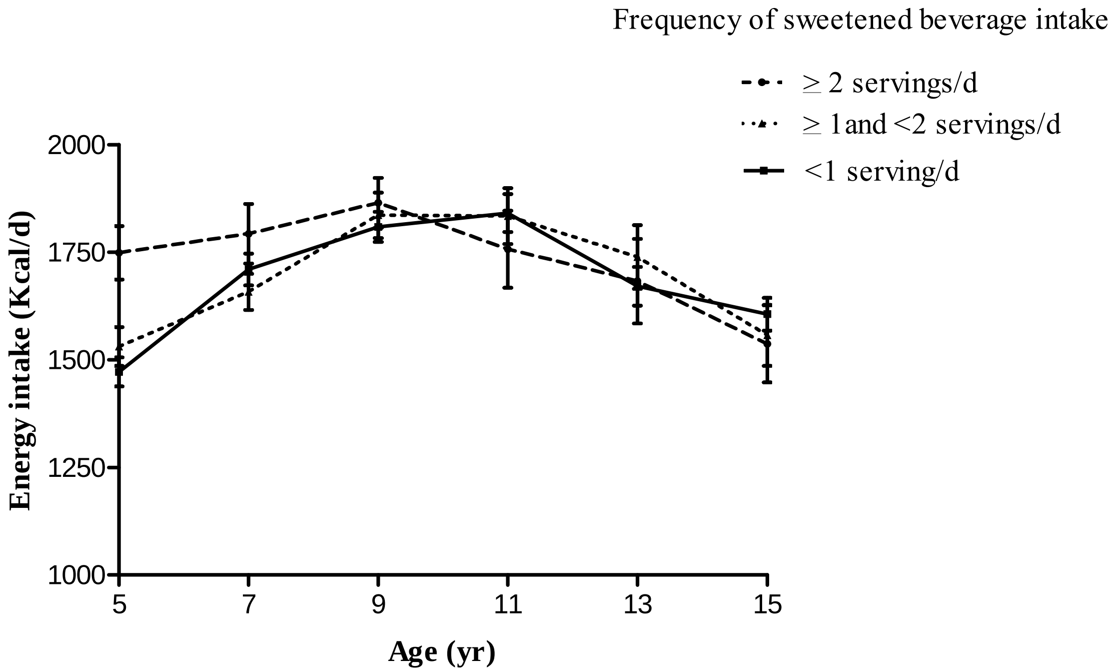


**Figure 3.2:** Energy intake change from 5- to 15 y, for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y.
Plotted values are group means ± Standard error.
Neither the main effect or interaction were significant

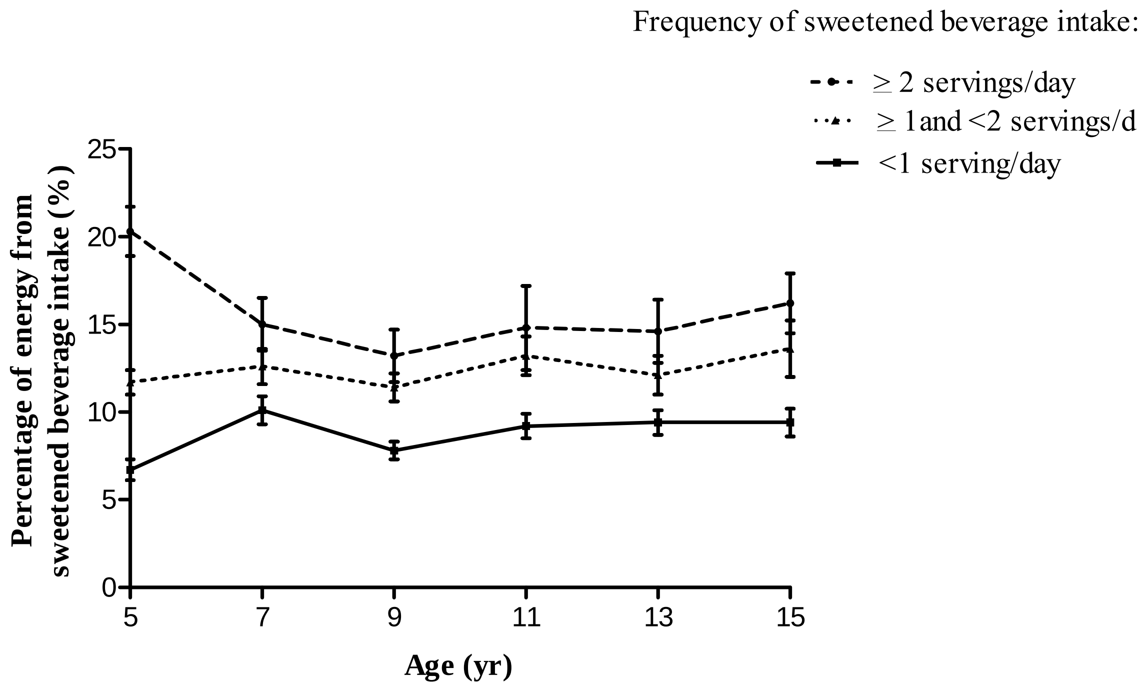


**Figure 3.3** Percentage of energy intake from sweetened beverages change from 5- to 15 y, for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y. Plotted values are group means ± Standard error.

Differences in the percentage of energy from sweetened beverage intake at 5 y among groups are based on the categorization criteria, thus the change in the percentage of energy from sweetened beverage intake was tested from 7- to 15 y. The main effect for group membership ($F= 22.58$, $p<0.0001$) was significant.

**Table 3.4** Mean percent body fat, waist circumference, BMI-for-age percentile, and percent of girls classified as being overweight for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y, from 5 to 15 y [1,2]

| Variable | Frequency of intake (Servings/d)[3] | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 |
|---|---|---|---|---|---|---|---|
| Percent body fat (%FM) | <1 | 20.1 ± 1.4[a] [4] | 21.2 ± 4.9 [a] | 25.6 ± 6.9 [a] | 26.8 ± 6.8 [a] | 26.5 ± 6.5 [a] | 27.3 ± 5.1 [a] |
| | ≥ 1 and <2 | 20.1 ± 3.8 [a] | 21.0 ± 5.0 [a] | 26.5 ± 7.3 [a] | 26.8 ± 7.8 [a] | 26.5 ± 7.3 [a] | 27.8 ± 7.0 [ab] |
| | ≥ 2 | 23.5 ± 6.5 [b] | 25.6 ± 7.5 [b] | 31.2 ± 8.3 [b] | 31.2 ± 5.6 [b] | 29.2 ± 6.5 [a] | 30.2 ± 6.2 [b] |
| Waist circumference (cm) | <1 | __ [5] | 58.4 ± 5.4 [a] | 65.2 ± 7.2 [a] | 71.4 ± 9.2 [a] | 77.2 ± 8.7 [a] | 77.3 ± 8.2 [a] |
| | ≥ 1 and <2 | __ | 59.1 ± 6.1 [a] | 67.1 ± 8.9 [a] | 74.4 ±12.5 [a] | 78.8 ±12.8 [ab] | 79.8 ± 11.6 [ab] |
| | ≥ 2 | __ | 63.1 ± 7.9 [b] | 72.4 ±10.0 [b] | 78.9 ±10.7 [b] | 83.6 ± 11.9 [a] | 82.4 ± 12.7 [b] |
| BMI-for-age percentile | <1 | 55.5 ± 25.4[a] | 54.8 ± 26.5[a] | 59.3 ± 27.1 [a] | 59.5 ± 26.7 [a] | 59.8 ± 25.7 [a] | 59.5 ± 24.0 [a] |
| | ≥ 1 and <2 | 60.7 ± 26.7[ab] | 58.3 ± 28.2[a] | 65.1 ± 27.3 [a] | 63.6 ± 29.8 [a] | 61.6 ± 25.9 [a] | 60.2 ± 26.1 [a] |
| | ≥ 2 | 70.6 ± 28.6[b] | 71.0 ± 28.4 [b] | 78.8 ± 20.0[b] | 78.0 ± 20.5 [b] | 73.6 ± 25.7 [b] | 70.0 ± 25.3 [a] |
| Overweight (%)[6] | <1 | 12.5 [a] | 12.5 [a] | 22.3 [a] | 20.8 [a] | 21.5 [a] | 17.0 [a] |
| | ≥ 1 and <2 | 18.8 [ab] | 16.7 [b] | 33.3 [ab] | 29.8 [ab] | 18.8 [a] | 19.2 [a] |
| | ≥ 2 | 38.5 [b] | 46.2 [b] | 46.2 [b] | 57.7 [b] | 50.0 [b] | 36.0 [a] |

[1] mean ± SD (all such values)
[2] Mixed modeling analyses of variance
[3] Frequency of sweetened beverage intake defined at 5 y: <1 (n=96); <2 or ≥2 (n=48); >2 (n=26).
[4] Mean variable and mean within an age, followed by different superscripts indicate significant differences among sweetened beverage groups at $^{*}p<0.05$
[5] Data not available
[6] Overweight is defined as ≥85th BMI-for-age percentile (46).

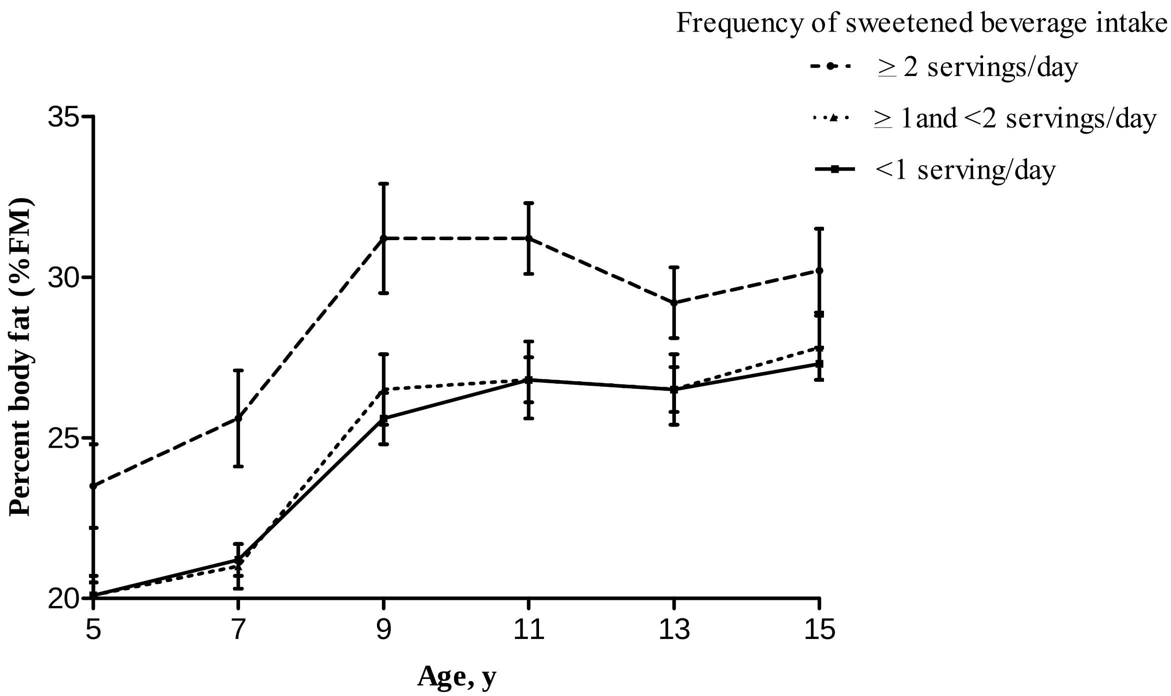


**Figure 3.4** Percent body fat mass change from 5- to 15 y, for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y.
Plotted values are group means ± Standard error.
The main effect for group membership (F= 7.07, p<0.001) and age (F= 261.85, p<0.0001) was significant.

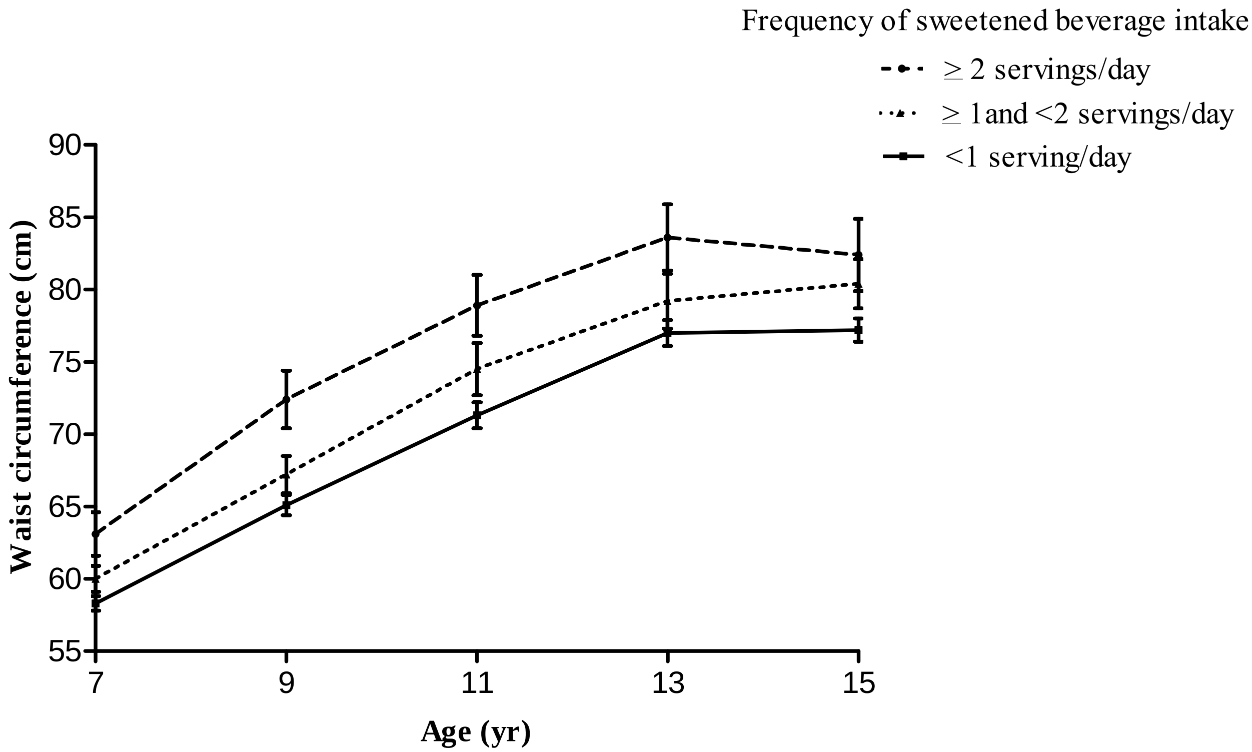


**Figure 3.5** Waist circumference change from 5- to 15 y, for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y.
Plotted values are group means ± Standard error
The main effect for group membership ($F= 3.74$, $p<0.05$) and age ($F= 995.61$, $p<0.0001$) was significant.

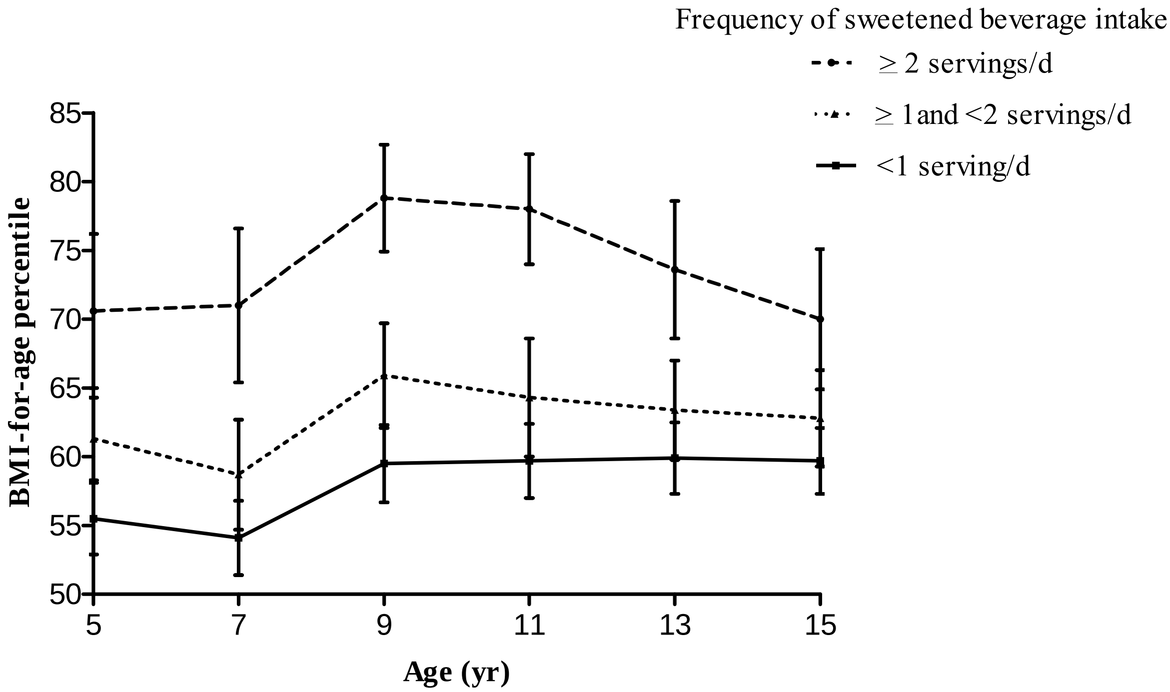


**Figure 3.6** BMI-for-age percentile change from 5- to 15 y for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y.
Plotted values are group means ± Standard error
The main effect for group membership was significant ($F = 5.71$, $p < 0.01$).

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# Chapter 4

## GENERAL DISCUSION

The overall objective of the present study was to describe changes in girls' beverage intake and to assess whether early beverage intake patterns persisted and predicted dietary intake, adiposity, and weight status from 5 to 15 years. Results from the two studies presented in the preceding chapters provide evidence that among girls' the contribution of servings of milk and fruit juice declined from 5 to 15 y, while soda and tea/coffee increased. Fruit drink intake remained relatively unchanged. Results also provided evidence that differences in soda intake already present at 5 y tended to persist over time and were predictive of differences in milk intake and in beverage-related food group and nutrient intakes. Lastly, while neither milk nor fruit juice intake were related to girls' adiposity or weight status, girls consuming more servings of sweetened beverage consumed at 5 y had greater adiposity and overweight from 5 to 15y.

Study one was designed to describe changes in girls' beverage intake and whether early beverage intake patterns persisted and influenced dietary intake across childhood and adolescence. Previous research has shown that early dietary intake patterns can influence intake patterns later in life (1-15), and limited research has focused on either the stability of milk or soda intake from adolescence into adulthood (8, 9, 11). This study provided new evidence that early differences in soda consumption were predictive of differences in soda and milk intake across childhood and adolescence. Furthermore, this study extends the existing cross-sectional data (16-19), suggesting that drinking soda is a marker for a less healthy diet quality. Early differences in soda and milk intake predicted long-term differences in beverage-related food groups and nutrient intake. Relative to girls who were not consuming soda at 5y, soda consumers had lower milk intake over the study period, which was associated with a diet higher in added sugars and lower in milk-related nutrients. Results from this study illustrate the importance of early beverage intake patterns, which can have persistent effects on children's diet quality across childhood and adolescence. This study began when girls were 5 y, when 60% of our sample were already soda consumers, but there is little systematic evidence on the development of soda consumption. It is probable that girls were drinking soda prior to 5 y and that patterns were already established. With respect to intervention programs, results from this study highlight the necessity of preventing and limiting the early introduction of soda and other sweetened beverages and instead promoting the intake of water, reduced fat milk, while limiting fruit juice intake, within recommended levels by the American Academy of Pediatrics (20).

Study two was designed to build upon the findings of study 1. In study two, we explored whether early beverage intake was predictive of girls' 24-h energy intake, adiposity, and weight status across childhood and adolescence. This study was impelled by the fact that most of the research to date assessing the association between sweetened beverage intake and measures of adiposity were cross-sectional in nature. Thus, these studies measured sweetened beverage intake and weight at only one point in time and cannot address whether higher sweetened beverage intake causes higher weight (21). Results from this longitudinal study provide more definitive evidence than previous cross-sectional (22-25) research of the relation between sweetened beverage intake and some measure of adiposity, and concur with findings from other longitudinal studies (26-31) in children and adolescents. The main findings of this study were that while neither milk nor fruit juice intake were related to girls' adiposity or weight status, servings of sweetened beverage consumed at 5 y predicted girls adiposity and overweight from 5 to 15y. It is important to note that we observed that higher intake of sweetened beverage intake at 5 y predicted higher adiposity from 5 to 15 y, even after adjusting for sweetened beverage intake at the same time that adiposity was measured. It is also possible that increasing under-reporting bias with age might have masked the association between girls' concurrent age sweetened beverage intake and adiposity. However, the fact that controlling for concurrent age intake did not attenuate the ability of early sweetened beverage intake to predict adiposity later on suggests the possibility that early sweetened beverage intake may be particularly important in shaping individual differences in adiposity.

Results from these two studies highlight the importance of focusing not just at the consumption of one type of beverage, but rather intake of different beverages and their impact on dietary intake and measures of adiposity. Recent research on beverage intake and health has tended to focus either on milk intake or sweetened beverage intake (15, 23, 27, 29, 32-37). However, milk and sweetened beverage intake tend to be negatively correlated (10, 16, 38-41), so that focusing on one type of beverage intake fails to take into account the possible impact of consuming one beverage on intake of other beverages, which may result not only from choosing that beverage, but also from the absence of the alternatives not chosen. Results from the first study suggest that early differences in soda intake were associated with differences in milk intake. Soda consumers showed higher soda and lower milk intake from 5 to 15 y than non-soda consumers. Furthermore, contrary to other studies, results from study two revealed that neither milk or fruit juice were related to adiposity. Servings of sweetened beverage, but not servings of milk or juice, consumed at 5 y predicted girls' adiposity and overweight from 5 to 15 y.

Findings of these two studies suggest that the family environment is an important factor associated in determining children's early beverage intake patterns. In both studies, differences in beverage patterns were associated with differences in parental weight status, with parents of girls classified as soda consumers and drinking more servings of sweetened beverage per day at 5 y having higher BMIs at study entry. Evidence of family resemblances in adiposity indicates that overweight parents tend to have overweight children (42). Although, familial similarity in weight status is partially attributed to genetics (43), characteristics of parents and family environments also have a substantial influence on childhood weight status (44, 45). There is evidence (46) that family environments characterized by higher parental weight status also are obesigenic, characterized by poorer diet quality and fewer opportunities for an active lifestyle, which may include differences in beverage availability (46). While in the second study, girls drinking more sweetened beverage servings per day had higher adiposity from 5 to 15 than girls drinking fewer servings of sweetened beverage at 5 y, no differences between soda consumption groups were noted in girls' weight status in the first study. This suggests that differences in girls' weight status are attributed to substantial amounts of fruit drinks girls consumed from 5 to 15 y. In addition, in study two sweetened beverage groups differed in familial SES and education with parents of girls drinking more servings of sweetened beverage intake having lower SES, education at study entry compared with girls drinking fewer servings per day. There is evidence that the lower cost of sweetened beverages is implicated in the increasing prevalence of obesity, especially among those with lower incomes, to higher weight status (47). In this context parents may have made more sweetened beverage and less milk available during early childhood, and thus developing a beverage intake pattern that would persist throughout childhood and adolescence, affecting girls' diet quality and adiposity. Future research is needed to further assess characteristics of the family environment that are associated with the development of beverage intake patterns. Identification of these factors may highlight modifiable behaviors that can be the focus of these intervention efforts.

The present studies contribute significantly to the literature, because we utilized a longitudinal dataset to examine girls' early beverage patterns to predict dietary intake and measures of adiposity in childhood and adolescence. The longitudinal data set offers advantages over previous cross-sectional research by allowing us to examine change and persistence in beverage intake patterns within individuals across childhood and adolescence and its impact on girls' diet quality and adiposity. Associations between the relationship of beverage intake and dietary intake and measures of adiposity were examined across childhood and adolescence, which is a developmental period where major social, environmental, and biological changes occur which may persist throughout life. However, we could not assess the extent to which the observed changes in beverage intake patterns are attributable to developmental changes or secular trends.

Several limitations of our study suggest avenues for future research. Our sample was racially and demographically homogeneous sample of girls; despite this homogeneity, we found that girls' early beverage intake patterns persisted and influenced beverage-related food groups and nutrient intake, and measures of adiposity from 5 to 15 y. Thus, findings from this research should be further explored in more diverse samples.

Additionally, this research did not provide data on girls' water intake. Therefore, we could not determine how water intake relates to the consumption patterns of other beverages, girls' dietary intake, and measures of adiposity. Furthermore, dietary intake data were self-reported; thus, there is a potential for reporting bias, which may have limited our ability to find associations between beverage intake and outcomes. For example, we did not consider the possibility of girls' selectively under-reporting intakes of sweetened beverages. Therefore, future research is needed to explore how reporting accuracy influences the association between beverage intake and measures of adiposity. In addition, we collected three, 24-h dietary recall at each assessment point, which may have led to misclassifying girls as "soda non-consumers" who consumed soda rarely at 5 y. Finally, our findings were exploratory and correlational by nature; which limits our ability to address causality. For example, we cannot conclude from this study that: (1) higher intake of soda causes lower intake of milk; (2) or that higher sweetened beverage intake causes higher adiposity and weight status. Future research should attempt to establish these causal relations, for example, through intervention studies where beverage intake can be modified and tested as intervention group against a no treatment control group.

In combination, findings from these studies suggest that early patterns of beverage intake can have persistent effects on girls' diet quality and adiposity during childhood and adolescence. Thus, the research presented here suggests that prevention efforts should include a focus on promoting healthy beverage patterns early in childhood, prior to age 5, as these patterns were relatively well established by age 5, to reduce the risk of lower diet quality and higher adiposity and overweight. Such prevention efforts should include targeting family environments characterized by lower parental education, SES, and higher parental weight status. Furthermore, prevention efforts should focus of preventing and limiting the early introduction of soda and other sweetened beverages and instead promoting the intake of water, reduced fat milk, while limiting fruit juice, within recommended levels by the American Academy of Pediatrics (20).

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# Appendix A

## Chapter 2: Relative contribution of servings of milk, fruit juice, and sweetened beverages to total beverages (N=170)

**Appendix A.** Relative contribution of servings of milk, fruit juice, and sweetened beverages to total beverages (N=170)

| Beverages (% of servings) | Age 5 | Age7 | Age 9 | Age 11 | Age 13 | Age 15 |
|---|---|---|---|---|---|---|
| Milk | 40.5 ± 26.4[1] | 39.9 ± 24.7 | 40.3 ± 27.2 | 36.7 ± 27.2 | 29.9 ± 25.2 | 28.5 ± 29.4 |
| Fruit juice | 25.4 ± 24.8 | 19.4 ± 20.2 | 18.3 ± 20.3 | 13.8 ± 19.5 | 15.3 ± 19.9 | 17.6 ± 25.1 |
| Total sweetened beverage | 34.2 ± 25.0 | 40.7 ± 25.9 | 41.4 ± 25.6 | 49.4 ± 28.4 | 54.8 ± 27.2 | 53.9 ± 31.9 |
| Fruit drinks | | | | | | |
| Sugar sweetened | 17.8 ± 17.3 | 18.7 ± 18.1 | 15.3 ± 17.3 | 13.7 ± 15.9 | 10.3 ± 16.8 | 11.9 ± 22.1 |
| Artificially sweetened | 3.7 ± 8.3 | 4.1 ± 7.8 | 4.2 ± 7.8 | 6.9 ± 12.3 | 13.6 ± 18.9 | 7.9 ± 14.4 |
| Soda | | | | | | |
| Sugar sweetened | 8.9 ± 12.7 | 12.7 ± 16.3 | 14.8 ± 16.1 | 19.3 ± 20.8 | 19.3 ± 21.5 | 15.8 ± 23.7 |
| Artificially sweetened | 1.4 ± 4.2 | 1.4 ± 5.6 | 2.2 ± 6.5 | 2.8 ± 8.2 | 5.2 ± 11.9 | 7.3 ± 15.2 |
| Tea/coffee | | | | | | |
| Sugar sweetened | 1.5 ± 4.5 | 2.3 ± 5.9 | 3.3 ± 7.0 | 3.4 ± 7.9 | 3.0 ± 7.7 | 5.4 ± 10.2 |
| Artificially sweetened | 0.9 ± 3.5 | 1.5 ± 6.5 | 1.6 ± 4.6 | 3.4 ± 8.9 | 3.4 ± 9.6 | 5.6 ± 13.1 |

[1]mean ± SD (all such values)

# APPENDIX B

## Chapter 2: Nutrient recommendations by the Dietary Reference Intakes (DRIs) for girls 5 to 15 y

**Appendix B.** Nutrient recommendations by the Dietary Reference Intakes (DRIs) for girls 5 to 15 y

| | Recommendations | | | | | |
|---|---|---|---|---|---|---|
| Nutrient | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 |
| Energy [1] (kcal/day) | 1233-2140 | 1233-2140 | 1500-2700 | 1500-2700 | 1500-2700 | 1500-2700 |
| Carbohydrates (% of energy) | 45-65 | 45-65 | 45-65 | 45-65 | 45-65 | 45-65 |
| Protein (% of energy) | 10-30 | 10-30 | 10-30 | 10-30 | 10-30 | 10-30 |
| Fat (% of energy) | 25 -35 | 25 -35 | 25-35 | 25 -35 | 25 -35 | 25 -35 |
| Saturated fat (% energy) | <10 | <10 | <10 | <10 | <10 | <10 |
| Added sugars (% of energy) | <25 | <25 | <25 | <25 | <25 | <25 |
| Fiber (g) | 25 | 25 | 26 | 26 | 26 | 26 |
| Calcium (mg) | 800 | 800 | 1300 | 1300 | 1300 | 1300 |
| Vitamin D (µg) | 5 | 5 | 5 | 5 | 5 | 5 |
| Phosphorous (mg) | 500 | 500 | 1250 | 1250 | 1250 | 1250 |
| Magnesium (mg) | 130 | 130 | 240 | 240 | 240 | 360 |
| Potassium (mg) | 3800 | 3800 | 4500 | 4500 | 4500 | 4500 |
| Iron (mg) | 10 | 10 | 8 | 8 | 15 | 15 |

[1]A range of Energy Estimate Requirements (EER) was created for girls 4-8 yr and 9-18 yr. Girls' mean age, weight and height and physical activity (PA) coefficients (Sedentary, low active, active and very active) were used to create the ranges. The range of values in EER reflects possible differences in the physical activity coefficients of participants (69).

# APPENDIX C

## Chapter 2: Daily MyPyramid recommendations for girls 4 to 18 y

**Appendix C.** Daily MyPyramid recommendations for girls 4 to 18 yr

| | MyPyramid recommendations | | |
|---|---|---|---|
| | Age 4-8[1] | Age 9 to 13[2] | Age 14-18[3] |
| Grains | 4-6 oz **(4-6 servings)** | 5-7 oz **(5-7 servings)** | 6-8 oz (**6-8 servings)** |
| Vegetable | 1.5-2.5 cups **(3-5 servings)** | 2-3 cups **(4-6 servings)** | 2.5-3 cups **(5-6 servings)** |
| Fruit | 1-1.5 cups **(2-3 servings)** | 1.5-2 c **(3-4 servings)** | 1.5-2 c **(3-4 servings)** |
| Dairy group | 2 cups **(2 servings)** | 3 cups **(3 servings)** | 3 cups **(3 servings)** |
| Meat | 3-5 oz **(3-5 servings)** | 5-6 oz **(5-6 servings)** | 5-6.5 oz **(5-6.5 servings)** |
| Discretionary calorie allowance[4] | 171-195 kcal **(14-11% of kcal)** | 132-290 **(8-13% of kcal)** | 195-362 **(11-15% kcal)** |

[1]Based on 1200-1800 kcal/d range diet as recommended by MyPyramid for 4-8 yr girls, with a daily physical activity level sedentary to active (48)
[2]Based on 1600-2200 kcal/d range diet as recommended by MyPyramid for 9-13 yr girls, with a daily physical activity level sedentary to active (48)
[3]Based on 1800-2400 kcal/d range diet as recommended by MyPyramid for 14-18yr girls, with a daily physical activity level sedentary to active (48)
[4]Discretionary calorie allowance: is the remaining amount of calories in a food intake pattern after accounting for the calories needed for all food groups. These are saturated fats, added sugars, and alcohol (48)

# APPENDIX D

## Chapter 2: Total diet energy intake and energy intake from beverages from 5 to 15 y (N=170)

**Appendix D**. Total diet energy intake and energy intake from beverages from age 5 to 15 y (N=170)

| Energy intake | Age 5 | Age7 | Age 9 | Age 11 | Age 13 | Age 15 | Change F-value | Change p-value |
|---|---|---|---|---|---|---|---|---|
| Total diet (kcal/d) | 1531 ± 334± | 1707 ± 340 | 1825 ± 339 | 1826 ± 438 | 1693 ± 467 | 1582 ± 416 | 0.90 | 0.34 |
| Total beverage | | | | | | | | |
| Percentage (%) | 25.8 ± 11.1 | 24.9 ± 11.5 | 20.8 ± 8.9 | 22.9 ± 11.7 | 21.8 ± 10.6 | 21.1 ± 12.4 | 22.75 | <0.01 |
| Energy (kcal/d) | 400 ± 214 | 421 ± 203 | 374 ± 158 | 406 ± 197 | 364 ± 185 | 323 ± 193 | 22.69 | <0.01 |
| Milk | | | | | | | | |
| Percentage (%) | 10.7 ± 8.5 | 9.4 ± 7.2 | 8.3 ± 6.5 | 9.0 ± 8.6 | 7.3 ± 6.8 | 6.4 ± 6.3 | 42.87 | <0.01 |
| Energy (kcal/d) | 168 ± 162 | 157 ± 116 | 146 ± 110 | 155 ± 135 | 121 ± 111 | 101 ± 104 | 39.68 | <0.01 |
| Fruit juice | | | | | | | | |
| Percentage (%) | 4.8 ± 4.7 | 3.9 ± 4.4 | 2.9 ± 3.3 | 2.8 ± 4.1 | 3.5 ± 4.5 | 3.1 ± 4.8 | 13.17 | <0.01 |
| Energy (kcal/d) | 72 ± 71 | 68 ± 80 | 53 ± 62 | 48 ± 64 | 58 ± 76 | 49 ± 77 | 12.04 | <0.01 |
| Fruit drinks | | | | | | | | |
| Percentage (%) | 6.4 ± 5.8 | 6.9 ± 5.9 | 4.9 ± 4.1 | 5.3 ± 6.2 | 4.6 ± 5.7 | 5.8 ± 7.3 | 6.90 | <0.01 |
| Energy (kcal/d) | 100 ± 98 | 120 ± 112 | 89 ± 78 | 97 ± 116 | 77 ± 99 | 82 ± 89 | 11.64 | <0.01 |
| Soda | | | | | | | | |
| Percentage (%) | 3.2 ± 3.9 | 3.9 ± 4.2 | 3.8 ± 3.5 | 4.7 ± 4.1 | 5.4 ± 5.6 | 4.2 ± 5.3 | 14.00 | <0.01 |
| Energy (kcal/d) | 49 ± 62 | 64 ± 66 | 69 ± 66 | 85 ± 73 | 90 ± 87 | 66 ± 83 | 16.79 | <0.01 |
| Tea/Coffee | | | | | | | | |
| Percentage (%) | 0.7 ± 2.0 | 0.7 ± 1.8 | 1.0 ± 2.1 | 1.1 ± 2.7 | 0.9 ± 2.8 | 1.6 ± 2.9 | 13.89 | <0.01 |
| Energy (kcal/d) | 11 ± 31 | 13 ± 32 | 17 ± 36 | 21 ± 57 | 18 ± 59 | 25 ± 44 | 12.58 | <0.01 |

Mean ± SD (all such values)

# APPENDIX E

## Chapter 2: Differences on family demographics at study entry for girls who were soda consumers and non consumers at 5 y

**Appendix E.** Differences in family demographics at study entry for girls who were soda non consumers and consumers at 5 y.

| | Soda consumers (n = 102) [1] | Soda non consumers (n = 67) |
|---|---|---|
| Family income[2] | 2.0 ± 1.0 | 2.1 ± 0.8 |
| Average parental education (years) | 14.6 ± 2.2 | 14.9 ± 2.1 |
| Breastfeeding duration (months) | 6.4 ± 6.5 | 7.9 ± 8.0 |
| Birth weight (pounds) | 7.6 ± 1.2 | 7.6 ± 1.2 |
| Maternal BMI | 24.8 ± 4.4 | 27.2 ± 6.6 ** |
| Parental BMI | 27.3 ± 3.4 | 28.6 ± 4.6 * |

[1]Soda consumers and non-consumers defined at age 5
[2]Variable coding: 0= less than $20,000; 1= $20-35,000; 2=$35-50,000; 3= over $50,000
Significantly different at * p<0.05; **p<0.01

# Appendix F

## Chapter 2: Mean weight, weight status, and percent body fat for girls who were soda consumers (SC) and non consumers (SNC) at 5 y, from 5 to 15 y

**Appendix F.** Mean weight, weight status, and percent body fat for girls who were soda consumers (SC) and non consumers (SNC) at 5 y, from 5 to 15 y [1]

| | | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | p-value | |
| BMI ($kg/m^2$) | SNC | 15.8 ± 1.5[2] | 16.2 ± 2.1 | 17.9 ± 2.8 | 19.5 ± 3.3 | 21.1 ± 3.8 | 21.9 ± 3.2 | ns | <0.01 | ns |
| | SC | 15.9 ± 1.5 | 16.7 ± 2.2 | 18.6 ± 3.2 | 20.1 ± 3.9 | 21.3 ± 4.4 | 22.4 ± 4.6 | | | |
| BMI percentile | SNC | 58.1 ± 25.6 | 54.0 ± 28.1 | 61.0 ± 26.4 | 61.5 ± 27.4 | 62.6 ± 25.7 | 61.4 ± 23.8 | ns | <0.01 | <0.05 |
| | SC | 60.1 ± 27.4 | 61.1 ± 27.2 | 66.0 ± 27.2 | 64.8 ± 27.6 | 62.3 ± 26.5 | 61.2 ± 25.8 | | | |
| Percent body fat (%) | SNC | 20.4 ± 4.1 | 21.5 ± 5.5 | 25.7 ± 6.6 | 27.3 ± 7.2 | 27.1 ± 6.6 | 27.6 ± 5.4 | ns | <0.01 | ns |
| | SC | 20.8 ± 4.5 | 22.0 ± 5.7 | 27.5 ± 8.0 | 27.6 ± 7.0 | 26.8 ± 6.9 | 28.0 ± 6.2 | | | |

[1] Soda non-consumers (n=68) and consumers (n=102) defined at age 5
[2] mean (SD) (all such values)

# Appendix G

## Chapter 3: Spearman correlations between measurement occasion for BMI percentiles, percent body fat, and waist circumference from 5 to 15 y

**Appendix G** Spearman correlations between measurement occasion for BMI-for-age percentiles, percent body fat, and waist circumference from 5 to 15y

| Variable | Age 5-7 (n=169) | 7-9 (n=166) | 9-11 (n=166) | 11-13 (n=166) | 13-15 (n=163) | 5-15 (n=166) |
|---|---|---|---|---|---|---|
| BMI-for-age percentiles | 0.87*** | 0.88*** | 0.92*** | 0.86*** | 0.85*** | 0.60*** |
| Percent body fat (%) | 0.79*** | 0.78*** | 0.85*** | 0.85*** | 0.81*** | 0.29*** |
| Waist circumference | __[1] | 0.84*** | 0.89*** | 0.61*** | 0.66*** | 0.58*** |

[1]Data not available
Significant at * $p<0.05$; ** $p<0.01$; *** $p<0.0001$

# Appendix H

## Chapter 3: Mean beverage intake for girls consuming <1, ≥1 and <2, or ≥2 of sweetened beverage at 5 y, from 5 to 15 y

**Appendix H.** Mean beverage intake for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y, from 5 to 15 y [1,2]

| Beverages (servings/d) [3] | Frequency of intake (Servings/d)[4] | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 | group | age | group*age |
|---|---|---|---|---|---|---|---|---|---|---|
| Total beverage | <1 | 2.9 ± 1.4 [a 5] | 3.1 ± 1.3 [a] | 3.0 ± 1.3 [a] | 3.4 ±1.6 [a] | 3.3 ± 1.3 [a] | 2.9 ± 1.3 [a] | <0.01 | ns | <0.01 |
| | ≥ 1 and <2 | 3.5 ± 1.5 [a] | 3.4 ± 1.5 [ab] | 3.6 ± 1.3 [b] | 4.2 ± 1.6 [b] | 4.1 ± 2.3 [ab] | 3.1 ± 1.8 [a] | | | |
| | ≥ 2 | 5.1 ± 1.7 [b] | 4.0 ± 1.4 [b] | 4.0 ± 1.7 [b] | 4.6 ± 2.0[b] | 3.8 ± 1.8 [b] | 3.7 ± 2.4 [a] | | | |
| Milk | <1 | 1.3 ± 1.0 [a] | 1.3 ± 0.9 [a] | 1.2 ± 0.8 [a] | 1.3 ± 1.1 [a] | 1.1 ± 1.0 [a] | 1.0 ± 0.9 [a] | ns | <0.01 | ns |
| | ≥ 1 and <2 | 1.4 ±1.3 [a] | 1.2 ± 0.8 [a] | 1.2 ± 0.8 [a] | 1.3 ± 1.0 [a] | 0.9 ± 0.9 [a] | 0.7 ± 0.7 [a] | | | |
| | ≥ 2 | 1.6 ± 1.1 [a] | 1.2 ± 0.9 [a] | 1.0 ± 0.9 [a] | 1.6 ± 1.5 [a] | 0.9 ± 0.7 [a] | 0.8 ± 1.0 [a] | | | |
| Fruit Juice | <1 | 1.1 ± 1.2 [a] | 0.8 ± 1.0 [a] | 0.6 ± 0.8 [a] | 0.6 ± 1.0 [a] | 0.7 ± 1.0 [a] | 0.6 ± 1.0 [a] | ns | <0.05 | ns |
| | ≥ 1 and <2 | 0.7 ± 0.8 [ab] | 0.7 ± 0.9 [a] | 0.6 ± 0.9 [a] | 0.7 ± 0.8 [a] | 0.5 ± 0.9 [a] | 0.7 ± 0.8 [a] | | | |
| | ≥ 2 | 0.5 ± 0.8 [b] | 0.6 ± 0.6 [a] | 0.9 ± 1.0 [a] | 0.6 ± 0.9 [a] | 0.6 ± 0.8 [a] | 0.7 ± 0.9 [a] | | | |
| Sweetened beverage | <1 | 0.5 ± 0.3 [6] | 1.0 ± 0.7 [a] | 1.1 ± 0.9 [a] | 1.6 ± 1.2 [a] | 1 .5 ± 1.1 [a] | 1 .3 ± 0.9 [a] | <0.01 | <0.01 | ns |
| | ≥ 1 and <2 | 1.4 ± 0.3 | 1.5 ± 1.0 [b] | 1.8 ± 1.1 [b] | 2.2 ± 1.6 [a] | 2.6 ± 2.0 [b] | 1.9 ± 1.7 [b] | | | |
| | ≥ 2 | 3.0 ± 0.8 | 2.2 ± 1.1 [c] | 2.2 ± 1.3 [b] | 2.5 ± 1.4 [b] | 2.2 ± 1.4 [b] | 2.2 ± 1.5 [b] | | | |

[1] mean ± SD (all such values)
[2] Mixed modeling analyses of variance
[3] 1 serving of milk = 1 cup equivalent (8 oz) (67), 1 serving of fruit juice = 8 oz; 1 serving of sweetened beverages = 8 oz.
[4] Frequency of sweetened beverage intake defined at 5 y: <1 (n=96); <2 or ≥2 (n=48); >2 (n=26).
[5] Mean variable and mean within an age, followed by different superscripts indicate significant differences among sweetened beverage groups at *p<0.05
[6] Differences in sweetened beverage intake at 5 y among groups are based on the categorization criteria.

# Appendix I

## Chapter 3: Mean food group and nutrient consuming for girls consuming <1, $\geq$1 and <2, or $\geq$2 of sweetened beverage at 5 y, from 5 to 15 y

**Appendix I.** Mean food group and nutrient intake for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y, from 5 to 15 y [1,2]

| servings/d | Frequency of intake (Servings/d)[3] | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 |
|---|---|---|---|---|---|---|---|
| Grain | <1 | 5.3 ± 1.7 [a 4] | 6.0 ± 1.7 [a] | 6.7 ± 1.4 [a] | 6.5 ± 2.0 [a] | 6.0 ± 2.1 [a] | 5.8 ± 1.9 [a] |
| | ≥ 1 and <2 | 5.2 ± 1.7 [a] | 5.8 ± 1.5 [a] | 6.0 ± 1.7 [a] | 6.0 ± 2.0 [ab] | 5.8 ± 1.9 [a] | 5.6 ± 2.1 [a] |
| | >2 | 5.6 ± 1.9 [a] | 6.0 ± 1.7 [a] | 6.6 ± 2.3 [a] | 5.5 ± 1.8 [b] | 5.9 ± 2.3 [a] | 5.4 ± 1.8 [a] |
| Vegetable | <1 | 1.5 ± 1.2 [a] | 1.7 ± 1.0 [a] | 1.8 ± 1.0 [a] | 2.0 ± 1.3 [ab] | 1.7 ± 1.0 [a] | 1.7 ± 1.1 [a] |
| | ≥ 1 and <2 | 1.6 ± 1.1 [a] | 1.8 ± 0.8 [a] | 2.1 ± 1.1 [a] | 2.3 ± 1.4 [a] | 1.9 ± 1.1 [a] | 1.9 ± 1.4 [a] |
| | >2 | 1.2 ± 0.5 [a] | 1.6 ± 0.8 [a] | 2.0 ± 0.9 [a] | 1.6 ± 0.6 [b] | 1.6 ± 1.1 [a] | 1.6 ± 0.9 [a] |
| Fruit | <1 | 2.0 ± 1.7 [a] | 1.7 ± 1.5 [a] | 1.6 ± 1.2 [a] | 1.4 ± 1.4 [a] | 1.3 ± 1.4 [a] | 1.3 ± 1.5 [a] |
| | ≥ 1 and <2 | 1.6 ± 1.2 [ab] | 1.7 ± 1.6 [a] | 1.5 ± 1.5 [a] | 1.4 ± 1.6 [a] | 1.1 ± 1.3 [a] | 1.1 ± 1.3 [a] |
| | >2 | 1.1 ± 1.1 [b] | 1.4 ± 0.8 [a] | 1.5 ± 1.2 [a] | 1.0 ± 1.1 [a] | 1.0 ± 0.9 [a] | 1.8 ± 2.1 [a] |
| Dairy | <1 | 2.6 ± 1.2 [a] | 2.8 ± 1.3 [a] | 2.8 ± 1.1 [a] | 2.9 ± 1.4 [a] | 2.7 ± 1.5 [a] | 2.4 ± 1.2 [a] |
| | ≥ 1 and <2 | 2.3 ± 1.2 [a] | 2.6 ± 1.1 [a] | 2.8 ± 1.3 [a] | 2.5 ± 1.1 [a] | 2.6 ± 1.1 [a] | 1.9 ± 1.2 [a] |
| | >2 | 2.4 ± 1.0 [a] | 2.6 ± 0.8 [a] | 2.5 ± 0.8 [a] | 2.6 ± 1.1 [a] | 2.2 ± 1.3 [a] | 2.0 ± 1.2 [a] |
| Meat | <1 | 2.7 ± 1.2 [a] | 3.0 ± 1.4 [a] | 3.2 ± 1.4 [a] | 3.5 ± 1.6 [a] | 3.3 ± 1.7 [a] | 3.8 ± 2.2 [a] |
| | ≥ 1 and <2 | 3.0 ± 1.4 [ab] | 3.0 ± 1.2 [a] | 3.7 ± 1.6 [a] | 3.4 ± 1.7 [a] | 3.6 ± 2.0 [a] | 3.7 ± 2.1 [a] |
| | >2 | 3.4 ± 1.4 [b] | 3.5 ± 1.7 [a] | 3.8 ± 1.7 [a] | 3.4 ± 1.8 [a] | 3.6 ± 1.4 [a] | 2.8 ± 0.9 [a] |
| Energy (kcal/d) | <1 | 1472 ± 327 [a] | 1710 ± 358 [a] | 1809 ±339 [a] | 1841 ± 433 [a] | 1671 ± 436 [a] | 1606 ± 370 [a] |
| | ≥ 1 and <2 | 1531± 314 [a] | 1658 ±289 [a] | 1836 ± 365 [a] | 1834 ± 445 [a] | 1739 ± 512 [a] | 1557 ± 486 [a] |
| | ≥ 2 | 1749 ± 316[b] | 1793 ± 353 [a] | 1865 ± 290 [a] | 1757± 456 [a] | 1683 ± 500 [a] | 1537± 448 [a] |

| servings/d | Frequency of intake (Servings/d)[3] | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 |
|---|---|---|---|---|---|---|---|
| Carbohydrates (% energy) | <1 | 56.4 ± 6.0 [a] | 56.8 ± 5.7 [a] | 55.9 ± 5.7 [a] | 54.7 ± 6.4 [a] | 53.5 ± 6.7 [a] | 52.0 ± 6.4 [a] |
| | ≥ 1 and <2 | 58.3 ± 5.2 [a] | 58.1 ± 4.4 [a] | 55.7 ± 5.5 [a] | 54.7 ± 6.4 [a] | 54.3 ± 6.1 [a] | 53.6 ± 8.4 [a] |
| | ≥ 2 | 58.0 ± 6.0 [a] | 56.9 ± 6.1 [a] | 56.2 ± 7.0 [a] | 55.7 ± 5.9 [a] | 55.0 ± 6.4 [a] | 53.8 ± 7.2 [a] |
| Protein (% energy) | <1 | 14.2 ± 3.5 [a] | 13.5 ± 2.2 [a] | 13.7 ± 2.5 [a] | 14.3 ± 2.7 [a] | 15.3 ± 3.5 [a] | 15.6 ± 3.2 [a] |
| | ≥ 1 and <2 | 13.7 ± 2.5 [ab] | 13.2 ± 2.5 [a] | 13.7± 2.4 [a] | 13.2 ± 2.5 [a] | 14.5 ± 2.9 [a] | 15.2 ± 3.4 [a] |
| | ≥ 2 | 12.8 ± 2.4 [b] | 13.0 ± 2.2 [a] | 13.5 ± 2.5 [a] | 13.8 ± 2.6 [a] | 14.2 ± 3.2 [a] | 14.0 ± 3.5 [a] |
| Fat (% of energy) | <1 | 30.9 ± 5.1 [a] | 31.3 ± 5.0 [a] | 31.9 ± 4.2 [a] | 31.9 ± 4.2 [a] | 32.5 ± 5.3 [a] | 33.7 ± 5.2 [a] |
| | ≥ 1 and <2 | 29.6 ± 4.5 [a] | 32.2 ± 4.3 [a] | 32.2 ± 4.3 [a] | 32.2 ± 4.4 [a] | 32.6 ± 5.5 [a] | 32.6 ± 7.3 [a] |
| | ≥ 2 | 30.8 ± 4.9 [a] | 31.4 ± 5.2 [a] | 31.7 ± 6.2 [a] | 31.7 ± 4.6 [a] | 32.0 ± 5.4 [a] | 33.6 ± 5.6 [a] |
| Saturated fat (% energy) | <1 | 11.6 ± 2.6 [a] | 11.7 ± 2.4 [a] | 11.9 ± 2.2 [a] | 12.2 ± 2.2 [a] | 12.5 ± 2.7 [a] | 12.6 ± 2.6 [a] |
| | ≥ 1 and <2 | 11.0 ± 2.4 [a] | 11.0 ± 2.0 [a] | 11.9 ± 2.2 [a] | 11.6 ± 2.3 [a] | 11.9 ± 2.3 [a] | 11.8 ± 3.3 [a] |
| | ≥ 2 | 11.1 ± 2.2 [a] | 11.5 ± 2.5 [a] | 11.4 ± 2.6 [a] | 12.1 ± 2.6 [a] | 11.5 ± 2.5 [a] | 12.5 ± 3.2 [a] |
| Added sugars (% energy)[5] | <1 | 16.8 ± 5.0 [a] | 20.0 ± 5.7 [a] | 18.8 ± 6.4 [a] | 18.9 ± 6.4 [a] | 17.1 ± 6.2 [a] | 16.1 ± 5.9 [a] |
| | ≥ 1 and <2 | 22.2 ± 5.4 [b] | 20.4 ± 6.9 [a] | 21.5 ± 6.2 [a] | 22.2 ± 6.6 [b] | 20.2 ± 7.7 [b] | 18.2 ± 8.1 [ab] |
| | ≥ 2 | 26.3 ± 5.5 [c] | 23.3 ± 6.1 [b] | 20.8 ± 6.7 [a] | 24.5 ± 7.1 [b] | 21.2 ± 5.9 [b] | 19.8 ± 5.8 [b] |

[1] mean ± SD (all such values)
[2] Mixed modeling analyses of variance
[3] Frequency of sweetened beverage intake defined at 5 y: <1 (n=96); <2 or ≥2 (n=48); >2 (n=26).
[4] Mean variable and mean within an age, followed by different superscripts indicate significant differences among sweetened beverage groups at $^{*}p<0.05$
[5] Added sugars refers to sugars added in the processing or preparation of foods and beverages

# Appendix J

## Chapter 3: Differences in family demographics at study entry for girls consuming <1, ≥1 and <2, or ≥2 of sweetened beverage at 5 y

**Appendix J.** Differences on family demographics at study entry for girls consuming <1, ≥1 and <2 or ≥2 servings of sweetened beverage at 5 y.

| | Frequency of sweetened beverage intake (servings/d) | | | |
|---|---|---|---|---|
| | < 1 (n = 96)[2] | ≥ 1 and <2 (n = 48) | ≥ 2 (n = 26) | p-value |
| Family income[1] | 2.2 ± 0.9[a] | 2.0 ± 0.9[ab] | 1.7 ± 1.0.9[b] | <0.05 |
| Average parental education (years) | 15.3 ± 2.2[a] | 14.3 ± 1.8[b] | 13.4 ± 1.7[b] | <0.01 |
| Breastfeeding duration (months) | 7.3 ± 1.2[a] | 7.1 ± 0.8[a] | 5.8 ± 0.8[a] | ns |
| Birth weight (pounds) | 7.6 ± 1.2[a] | 7.8 ± 1.1[a] | 7.6 ± 1.1[a] | ns |
| Maternal BMI | 25.1 ± 5.2[a] | 27.7 ± 6.8[b] | 27.9 ± 6.3[b] | <0.05 |
| Parental BMI | 27.6 ± 3.9[a] | 27.9 ± 3.9[b] | 30.0 ± 6.3[b] | <0.05 |

[1]Variable coding: 0= less than $20,000; 1= $20-35,000; 2=$35-50,000; 3= over $50,000
[2a,b] Means in a row followed by different superscripts are significantly different.

## Appendix K

**Chapter 3: Proportion of girls classified as under-, plausible, and over-reporters from 5 to 15 y (N=170)**

**Appendix K**. Proportion of girls classified as under-, plausible, and over-reporters from age 5 to 15 y (N=170)

| Reporting status (%) | Age 5 | Age 7 | Age 9 | Age 11 | Age 13 | Age 15 |
|---|---|---|---|---|---|---|
| Under reporters[1] | 13 | 12 | 13.5 | 34 | 56 | 72 |
| Plausible reporters[2] | 57 | 55 | 59.5 | 51 | 36 | 26 |
| Over reporters[2] | 29 | 33 | 27 | 15 | 8 | 2 |

[1]Sample restricted to 1 ± standard deviation

*Note:* The interaction between age and group membership was significant (Chi-square= 243.31, p<0.0001). There is a greater decrease in the proportion of plausible and over reporters from 5-to 15-y, compared with the proportion of under-reporters.

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Fiorito, L., Ventura, A.K., Mitchell, D.C., Smiciklas-Wright, H., Birch, L.L. (2006). Girls' dairy intake, energy intake, and weight status. Journal of the American Dietetic Association. 106(11):1851-1855.

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**ORAL PRESENTATIONS:**

Fiorito, L.M. "Development of food preferences: " Tal Palo, Tal Astilla". XVI Congreso de Nutrición. Sociedad Argentina de Nutrición. Noviembre 17-20 2007.

[1] CESNI is a non-governmental, non-profit, government approved foundation, created in 1976 with the initial support of UNICEF. It is dedicated to research, teaching, and advisory to intervention programs in the areas of child nutrition and development. In 1992 it was designated a WHO-PAHO Collaboration Center in Research and Teaching in Pediatric Nutrition.