Snack Frequency and Relative Weight in U.S. Toddlers and Preschoolers: Positively Associated After Adjusting for Confounding Factors

Desi Beckers
Radboud University Nijmegen
d.beckers@student.ru.nl

ABSTRACT
Most previous research found that snack frequency (SF) and relative weight (RW) were inversely or not associated, but may be biased by misreporting of energy intake. Main aim of this study was to examine the association of SF with RW in toddlers and preschoolers participating in the National Health and Nutrition Examination Survey (*N* = 3618). Multiple linear regressions revealed that SF was positively associated to RW after adjusting for confounding factors including reporting accuracy, while not associated without adjusting for confounding factors. When stratified by age group, similar results were evident in preschoolers; no associations were found in toddlers.

Keywords
Snack frequency, relative weight, toddlers, preschoolers.

INTRODUCTION

Childhood overweight and obesity has become a major problem all over the world. In 2014, 25% and 9.2% of U.S. children aged 2 to 5 years were overweight and obese, respectively [1]. Childhood overweight and obesity is related to a variety of health consequences including asthma, type 2 diabetes and cardiovascular disease [2], and is likely to persist into adulthood [3]. Overweight occurs when energy intake (EI) is persistently higher than energy expenditure [4]. In children as young as 1 year of age, meal intake and snack intake are the main contributors to EI [5].

Snack behaviors and snack EI have increased in recent decades in U.S. children. Between 1977-78 and 2003-06 the prevalence of children consuming snacks increased from 74% to 98%, the number of daily snack occasions with 1.41 events to almost three snack occasions per day, and the contribution of snacking to EI from 20.5% to 27% [6]. In 2003-06 desserts, salty snacks and sweetened dinks were the major sources of snack energy [6]. These foods and beverages are often low in nutrient density and high in energy density (ED), and therefore do not contribute to a healthy diet [7]. As increases in snack behaviors concurred with increases in prevalence of childhood overweight and obesity [6], it is important to examine whether and how snacking is related to children's relative weight (RW).

A great deal of studies examined the association of snack frequency (SF) with RW in children and adolescents. A review on snack behavior in children revealed that most studies examining this association found that SF was inversely or not related to RW [8]. As eating frequency was found to be positively associated with feelings of satiety [9], it has been suggested that increasing eating frequency might result in lower RW through increasing feelings of satiety and decreasing EI. But more research is needed to determine whether and how SF and RW are associated, as the relation of SF with RW may be convoluted by misreporting of EI.

Although most studies have found that SF and RW were inversely or not related in children, one recent study – not included in older review – found that SF was positively associated to RW, but only after controlling for energy reporting accuracy [10]. Overweight children were found to underreport their EI more often than normal-weight children [11], and underreport of EI often concurs with underreport of the number of daily eating occasions [12]. As studies reported in the review on snack behavior did not adjust for reporting accuracy, findings from those studies might be confounded. More research is needed to examine how SF is associated to RW after controlling for reporting accuracy. A better understanding about whether and how SF and RW are related in children might be useful for future overweight prevention programs.

Besides adjusting for reporting accuracy, previous studies on the association between SF and RW could also be confounded as they did not pay attention to what children eat as a snack. It may be that the energy density of snacks (SED) moderates the association between SF and RW. Previous studies found that young children consume a consistent weight of foods and drinks, independent of the ED of foods and drinks [13, 14]. Thus, an extra snack occasion when SED is high might affect energy balance largely, whereas an extra snack occasion when SED is low might only have a small effect. Due to the differential effect high and low ED snacks may have on EI, it might be that the positive association between SF and RW is stronger when SED is higher, and weaker when SED is lower. This hypothesis has never been tested before.

The main aim of the current cross-sectional was to examine the association of SF with RW in a representative sample of U.S. children aged 1 to 5 years, using secondary data from the National Health and Nutrition Examination Survey (NHANES). A secondary aim was to examine whether SED moderates the association between SF and RW. As reporting accuracy was taken into account, it was hypothesized that SF would be positively associated to RW. Further, it was expected that SED would moderate the relationship between SF and RW: the association of SF with RW would be stronger when SED was higher and weaker when SED was lower. More knowledge about the association of SF with RW could provide useful insights

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METHOD

Survey design and analytic sample

The current cross-sectional study used secondary data from NHANES 2007-08 to 2013-14. NHANES is a continuous population-based survey, creating a representative sample of the U.S. population using a complex sampling design. Data are collected by trained interviewers/examiners using interviews, standardized physical examinations and laboratory studies [15]. The sample included 1- to 5-year-old children. After excluding children for missing data on variables of interest, medication use, diabetes and/or consumption of infant feeding, the final sample contained 3618 participants (51.89% boys, 48.11% girls). Stratified by age group, the sample consisted of 595 toddlers (12-23 months old) and 3023 preschoolers (24-71 months old).

Measures

Demographic variables

Demographic data included the child's age, gender, race/ethnicity, household income and parental education level. These data were obtained using the Household interview. As the participants were 5 years or younger, proxy reporters (often one of the parents) were used. [15]

Dietary variables

Dietary information was collected by the use of two 24-hour dietary recalls. All information of foods and beverages consumed by the participant in a prior 24-hour period were collected by using the five-step U.S. Department of Agriculture Automated Multiple-Pass Method. The dietary information was provided by proxy reporters (often one of the parents) [16]. Dietary information was used to determine SF, meal frequency, SED, meal energy density (MED), ratio of reported energy intake and estimated energy requirement (EI:EER) and percentage of snack EI from caloric beverages. An eating occasion was defined as any occasion on a day when foods or beverages were consumed. Meal frequency and SF were determined by relying on participant's self-designation. SED and MED were defined as the total EI from snack or meal occasions (kcal) relative to the total grams consumed during snack or meal occasions. Two previously employed calculations of SED and MED were used; one on the basis of foods only, and one on the basis of foods and caloric beverages (i.e., ED $\geq$ 0.05) [17]. The estimated energy requirement (EER) was calculated by using formulas taking age, gender, RW and physical activity into account [18]. To calculate EI:EER, total reported EI was divided by EER. This variable was used to adjust for energy reporting accuracy [10]. To calculate snack EI from caloric beverages, the EI from caloric beverages consumed as a snack were summed. Thereafter, the percentage of snack EI from caloric beverages was calculated. If snack EI equaled zero, the percentage of snack EI from caloric beverages was considered to be zero as well.

Anthropometric variables

Children's height, length and weight were measured using a stadiometer, an infantometer and a digital weight scale, respectively [19]. These measures were used to determine RW – defined as weight for length *z*-scores (zWFL) for toddlers and body mass index *z*-scores (zBMI) for preschoolers – and weight status. WFL was calculated as weight divided by length (kg/m) and BMI as weight divided by height squared (kg/m^2). Growth charts were used to determine zWFL and zBMI [20]. For weight status two categories were defined; 'Normal' – WFL < 97.7th percentile in toddlers, BMI < 85th percentile in preschoolers – and 'Overweight/Obese' – WFL $\geq$ 97.7th in toddlers, BMI $\geq$ 85th percentile in preschoolers [21, 22].

Statistical analysis

The analyses were performed using Stata 14 software [23]. Sampling weights and strata variables provided by NHANES were used in all analyses. Differences between toddlers and preschoolers on dietary and anthropometric measures were examined using linear and logistic regression analyses for the continuous and categorical variables respectively. To examine the association of SF with RW and the moderation effect of SED, multiple linear regression analyses were used. SF and SED were centered at the mean. All associations were examined in three models. Model 1 was an unadjusted model; in model 2 adjustments were made for survey cycle, all previously mentioned demographic variables, and EI:EER; and in model 3 the adjustments of model 2 were expanded with MED calculated on the same basis as SED and meal frequency. Prior to the analyses, the assumptions for multiple linear regressions were checked. To overcome heteroskedasticity of the residuals, the analyses were performed with transformed variables as well. After adding a small number to SF and SED to ensure all values were greater than zero, a log-transformation was used for SF and an inverse-transformation for SED. The results with original variables are shown, as these were similar to the results with transformed variables. The results are presented for the full sample and for toddlers and preschoolers separately. Alpha was set at .05.

RESULTS

Dietary and anthropometric characteristics

Table 1 shows the dietary measures of the full sample. Compared to toddlers, preschoolers had lower mean values on SF and percentage of snack EI from caloric beverages and higher mean values on SED_{f+b} (all $p < .001$). Age group had a small effect on SF and SED_{f+b} ($d = 0.37$ and $d = 0.15$, respectively) and a medium effect on percentage of snack EI from caloric beverages ($d = 0.75$). Significant differences between the age groups were also found on RW and weight status (both $p < .001$). On average, toddler's RW ($M = 0.60$, $SD = 1.08$) was higher than preschooler's RW ($M = 0.33$, $SD = 1.07$), but preschoolers (20.91%) were more likely to be overweight/obese than toddlers (7.39%).

Table 1
Dietary Characteristics of the Full Sample (N=3618)

	M (*SD*)
Snack Frequency	3.19 (1.43)
SED based on foods	1.19 (1.07)
SED based on foods/caloric drinks	0.79 (0.54)
% of snack EI from caloric drinks	24.20 (25.42)

Note. SED = snack energy density; EI = energy intake.

Snack frequency, snack energy density and relative weight

In the full sample no significant associations or interactions of SF and SED on RW were found in model 1. In model 2 and model 3 and with both calculations of SED, SF was positively associated to RW (all $p < .05$; see Figure 1 for a visualization). The association of SED with RW and the interaction of SF and SED on RW remained not significant. When stratified by age group, similar results were evident in preschoolers with only significant associations of SF with RW in model 2 and model 3 (estimates of the slope of

SF were all comparable: $b = 0.04$, $SE = 0.02$, $p < .05$). In toddlers, no significant associations or interactions of SF and SED on RW were found in either of the models.

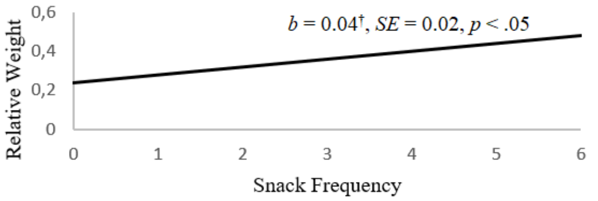

Figure 1. Slope of snack frequency predicting relative weight in the full sample in the adjusted models.
Note. †Exception: $b = 0.03$ in model 3 and with snack energy density based on foods and caloric beverages.

DISCUSSION

This study examined the association of SF with RW in U.S. toddlers and preschoolers. After adjusting for potential confounding factors including energy reporting accuracy, a positive association between SF and RW was found, whereas no associations were found without adjustments for confounding factors. When stratified by age group, similar results were evident in preschoolers; in toddlers no associations were found. Analyses also revealed that SED did not moderate the association between SF and RW.

Consistent with expectations and previous research [10], SF and RW were positively associated after adjusting for potential confounding factors including energy reporting accuracy. In contrast to these findings, a review on snacking in children revealed that the majority of previous studies suggest that SF and RW are not or inversely associated [8]. However, the studies reported in the review did not account for reporting accuracy. In a recent study in 6- to 19-year-old children and adolescents, adjusting for EI:EER changed the direction of the association between SF and RW from null or inverse associations to positive associations [10]. Also in the current study positive associations were only found after adjusted for confounding factors, including EI:EER. This suggests that controlling for EI:EER might change the direction of the estimates in the association of SF with RW in young children similarly as in older children. Thereby, this methodological difference between studies in the adjustments that were made, could account for the mixed results. Since underreporting of EI may coincide with underreport of SF, it has been suggested that adjusting for reporting accuracy is important in studies examining the relationship between SF and RW [10]. More research is needed to strengthen the evidence that including EI:EER as a covariate provides more accurate estimates of the association of SF with RW.

Age-related differences were found on the association between SF and RW. In preschoolers SF and RW were positive related. Hence, encouraging less snack occasions in preschoolers may be a tool to prevent childhood overweight and obesity. Although SF and RW were not related in toddlers, toddlers who snack more often might be at risk for increases in RW over time. Longitudinal studies should examine whether snacking more often induces weight gain in both toddlers and preschoolers.

There are several ways to explain the finding that SF and RW were positively associated in preschoolers but not in toddlers. First, it might be toddlers self-regulate their EI more accurately than preschoolers. In toddlers SF and portion size were inversely associated [24], and it has been suggested that the ability to self-regulate EI diminishes with age [25]. Thus, increases in SF might only in preschoolers result in a higher EI, and induce a higher RW. Second, differences between toddlers and preschoolers in milk consumption might explain the age-related difference as well. In the current study, the percentage of snack EI from caloric beverages was higher in toddlers than in preschoolers. Previous research found that toddlers consumed larger amounts of milk as a snack than preschoolers [5]. Together, it is presumable that also in the current study toddlers consumed more milk as a snack than preschoolers. Milk is an important source of calcium, which is crucial for bone health [26]. Thus, drinking milk may contribute to a healthy diet and might have little to no impact on RW. Additional studies examining these potential explanations are needed.

In contrast to what was hypothesized, SED did not modify the association between SF and RW, indicating that the association between SF and RW does not change with changes in SED. It might be that children compensate for SED by adjusting portion sizes. This would be in line with previous observational research [27], but in contrast to experimental studies [13, 14]. It may be that compensation does not occur immediately, but over other eating occasions or a long time period. This could clarify why compensation was not found in the experimental studies, as they were performed over a short time period [14] or did not include all daily eating occasions [13, 14]. Therefore, it is recommended to conduct longitudinal research over a long time period including all daily eating occasions to examine whether young children compensate for SED.

Strengths and limitations

The present study has several strengths: using a large dataset representative for U.S. toddlers and preschoolers; using direct measures of weight, height and length instead of self-reported measures; and using two calculations for SED, as there is no standard calculation for SED [17]. Several limitations have to be noted as well. First, RW was defined differently in toddlers than in preschoolers. As recommended, RW and weight status were determined by using growth charts for BMI in preschoolers and growth charts for WFL in toddlers [21, 22]. In the current study preschoolers were more likely to be overweight/obese than toddlers, but toddlers had on average a higher RW than preschoolers. This, together with the different cut-offs that had to be used in toddlers and preschoolers to determine weight status, raises the question whether zWFL and zBMI may be combined validly. Another issue of concern is the lack of a uniform definition for snack occasions [28]. The current study relied on self-designation by the participant to determine SF, and it could be that the results change if other definitions are used. However, previous research used two other approaches to determine SF and found similar results as in the current study [10]. This indicates that the definition of snack occasions might not have a large effect on the association between SF and RW.

Conclusion

The results of this cross-sectional study in a large representative sample of U.S. toddlers and preschoolers suggest that SF is positively associated to RW, but only when adjusted for potential confounding factors including energy reporting accuracy. When stratified by age group, these results were only evident in preschoolers; in toddlers no associations were found. The results also suggest that SED does not moderate the association between SF and RW. It is recommended to conduct additional research to examine whether controlling for reporting accuracy provides more accurate estimates of the association between SF and RW. Moreover, it is advised to conduct longitudinal studies to gain insight in the causal order of effects, mechanisms underlying a positive association of SF with RW, and explanations for the age-related difference on the association between SF and RW. This information could of use for prevention of childhood overweight.

ROLE OF THE STUDENT

This study was conducted by Desi Beckers under the supervision of Junilla Larsen and Jennifer Orlet Fisher. The student taught herself to work in Stata software. Data analyses, processing of the data, formulating the conclusions and the writing were all done by the student.

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