Published in final edited form as:

J Am Diet Assoc. 2008 January ; 108(1): 131–135. doi:10.1016/j.jada.2007.10.006.

Plausible Reports of Energy Intake May Predict Body Mass Index in Pre-Adolescent Girls

JENNIFER S. SAVAGE, MS, DIANE C. MITCHELL, MS, RD, HELEN SMICIKLAS-WRIGHT, PhD, RD, DANIELLE SYMONS DOWNS, PhD, and LEANN L. BIRCH, PhD

J. S. Savage is a research assistant, Graduate Program in Nutrition, D. C. Mitchell is coordinator, Diet Assessment Center, and H. Smiciklas-Wright is a professor of nutrition, Department of Nutritional Sciences; D. Symons Downs is an assistant professor, Department of Kinesiology; and L. L. Birch is a distinguished professor, Department of Human Development and Family Studies and the Graduate Program in Nutrition; all at The Pennsylvania State University, University Park.

Abstract

Inaccurate reporting of energy intake makes it difficult to study the associations between diet and weight status. This study examined reported energy intake at age 9 years as a predictor of girls' body mass index (BMI) at age 11 years, before and after adjusting for parents' BMI and girls' pubertal status. This prospective, observational cohort study included 177 non-Hispanic white girls and their parents. When the subjects were 9 years of age, three 24-hour recalls were used to categorize girls as plausible or implausible over-reporters and under-reporters based on previously published methods. Height and weight was measured to calculate BMI. Linear and hierarchical regression analyses were used to predict girls' BMI. Results revealed that girls who under-reported had significantly higher BMIs than plausible and overreporters. Among the total sample and among implausible reporters, reported energy intake was not a significant predictor of BMI; however, among plausible reporters, reported energy intake explained 14% of the variance in BMI and remained a significant predictor after adjusting for parental BMI and girls' pubertal status. Systematic bias related to underreporting in dietary data can obscure relationships with weight status, even among young girls. A relatively simple analytical procedure can be used to identify the magnitude and nature of reporting bias in dietary data.

Obesity and overweight are due to an imbalance between energy intake and energy expenditure, in which intake exceeds expenditure (1). Among youth, previous research has failed to consistently reveal positive relations between reported energy intake and weight status (2-4). This has led to the conclusion that low energy expenditure, rather than excessive energy intake, is responsible for weight gain and an increase in overweight among adolescents (2). However, failure to note relations between reported energy intake and weight status may be due to bias in reporting dietary intake. Doubly labeled water studies reveal weight-related reporting bias among older children and adults, with heavier children under-reporting to a greater extent than thinner children (5-9).

Although doubly labeled water studies provide clear evidence for bias in reporting of energy intake (9-12), it is expensive and laboratory-based, which is not feasible for use in screening most studies. Recently, Huang and colleagues developed screening procedures, using the logic developed in the use of doubly labeled water studies, to allow the classification of individuals as plausible, under-reporters, and over-reporters (13,14) using error propagation to establish

cutoffs of reported energy intake as a percentage of predicted energy requirements (15). Cross-sectional studies examining associations between diet and weight status in children revealed that excluding implausible reporters may be necessary to understand the relationship between diet and health (15-17).

The purpose of this research was to examine the extent to which girls' reported energy intake assessed at age 9 years predicted girls' body mass index (BMI) at age 11 years, before and after adjusting for pubertal status and parent BMI. Girls were classified as plausible or implausible under-reporters and over-reporters, based on the method of Huang and colleagues (15), to test the hypothesis that (1) under-reporters would be heavier than plausible reporters, obscuring relations between reported energy intake and weight status in the total sample and (2) among plausible reporters, reported energy intake would emerge as a significant predictor of BMI.

METHODS

Subjects

The study participants were part of a larger longitudinal study designed to examine parental influences on girls' growth and development (18-20). Only data for girls age 9 years (n=183) and 11 years (n=177) and their parents (mothers, n=182; fathers, n=169) who were assessed when girls were age 9 and 11 were included in this sample. Eligibility criteria for girls' participation included the absence of dietary restrictions, severe food allergies, or chronic medical problems affecting food intake. Families were not recruited based on child or parent weight status or concern about weight. The Pennsylvania State University Institutional Review Board approved all study procedures.

Measures

24-Hour Energy Intake—Girls' energy intake at age 9 was assessed from three 24-hour recall interviews conducted by the Dietary Assessment Center at the Pennsylvania State University using the computer-assisted Nutrition Data System for Research (NDS-R) (Database Version 4.01_30, Nutrition Coordinating Center, University of Minnesota, Minneapolis). Girls provided three 24-hour recalls within a 2-to 3-week period, including 2 randomly selected weekdays and 1 weekend day. Girls reported food intake; mothers were present to provide information about recipes and improve accuracy. Posters depicting food portions (2D Food Portion Visual, Nutrition Counseling Enterprises, Framingham, MA) were used as visual aids. Reported energy intake was calculated by taking the mean of 3 days of dietary recall data.

Pubertal Development—Nurses assessed girls' pubertal status at age 9 using Tanner breast staging (21). Tanner stages range from 1 (no development) to 5 (mature development).

Weight Status—Girls' height and weight measurements were assessed at age 9 and 11 by a trained research assistant following procedures outlined by Lohman and colleagues (22), and were used to calculate body mass index (BMI, calculated as kg/m^2). BMI values were converted to age- and sex-specific BMI percentiles using Centers for Disease Control and Prevention 2000 growth charts; overweight was defined as BMI greater than or equal to the 85th percentile based on standardized reference criteria (23). BMI was used in all analyses rather than z scores or percentiles because the girls were all the same age and sex (24). Parents' height and weight were measured and BMIs calculated using the same procedure described above for girls, and parents were classified as overweight (BMI ≥ 25) or obese (BMI ≥ 30) (25).

Screening for Implausible Reporters

Physiologically plausible reports of energy intake were determined by comparing reported energy intake with predicted energy requirements. A detailed description of this procedure is described elsewhere (15,26,27). Briefly, sex- and age group-specific ± 1 standard deviation (SD) cutoffs were created for reported energy intake as a percent of predicted energy requirement (15,28,29). A report was considered plausible if reported energy intake as a percent of predicted energy requirements was within ± 1 SD cutoff (84.8% to 115.2% at 9 years of age). Those with values exceeding the upper bounds of the cutoff were categorized as “over-reporters,” and those with values below the lower cutoff value were categorized as “under-reporters.”

Statistical Analyses

To examine reporting accuracy, girls were categorized as implausible under-reporters, plausible reporters, or implausible over-reporters at age 9 using the screening procedure described above. Analysis of variance was used to assess differences among under-, plausible, and over-reporters on measures of reported energy intake and weight status. A series of independent regression analyses were conducted to examine the contribution of reported energy intake at age 9 for predicting BMI at age 11 for the total sample, (n=169); for plausible reporters, (n=102); and for implausible reporters, (n=67) (Model 1). Next, hierarchical regression analyses were conducted, adjusting models for parental BMI (Model 2) and for girls' pubertal status at age 9 (Model 3). All analyses were conducted using SAS software (version 8.02, 2001, SAS institute, Cary NC).

RESULTS AND DISCUSSION

Descriptive statistics, presented in Table 1, reveal that mean reported energy intake at age 9 and mean BMI at age 11 were similar to the National Health and Nutrition Examination Survey III (NHANES III) data in which 9-year-old girls had a mean BMI of 20.7 (30) and mean reported energy intake was 1,882 kcal among 9- to 11-year-old girls (2). Mothers and fathers were slightly over-weight at entry into the study, with a mean BMI score of 27.5 and 28.9, respectively. Moreover, 60% and 82% of mothers and fathers were classified as overweight (BMI ≥ 25) (25). Parents were well-educated; mothers mean education was 15 ± 2 years (range=12 to 20) and fathers was 15 ± 3 years (range=12 to 22). Fifteen percent of reported family incomes were below \$35,000, 28% between \$35,000 and \$50,000, and 57% above \$50,000 (data not shown).

As shown in Table 1, there were significant group differences between under-reporters, plausible reporters, and over-reporters. Under-reporters had significantly higher BMI, BMI z score, and BMI percentile, and reported significantly lower energy intakes in comparison to both plausible and over-reporters. No group differences were noted for pubertal status, maternal BMI or paternal BMI. When participants were grouped by weight status, a similar proportion of the total sample (31%) and subgroup of plausible reporters (27%) were classified as overweight (BMI >85th percentile) based on age- and sex-specific growth charts (23); in contrast, nearly two thirds of implausible reporters were overweight. Moreover, plausible reporters who were overweight (mean=1,897, SD=242) had significantly higher reported energy intake than normal weight (mean=1,713, SD=170) girls; however, no differences in reported energy intake were noted between normal and overweight girls for the total sample or among implausible reporters (data not shown).

Results of the linear regression models for reported energy intake appear separately for the total sample (n=169) and subgroups of plausible (n=102) and implausible reporters (n=67) in Table 2. In Model 1, reported energy intake was not a significant independent predictor of BMI

in the total sample or among the subgroup of implausible reporters; however, among plausible reporters, reported energy intake was a significant predictor, explaining 14% of the variance for BMI at age 11. In Model 2, adjusting for maternal and paternal BMI explained 27% and 32% of the variance in girls BMI among the total and subgroup of implausible reporters, respectively. No additional variance was explained when reported energy intake was added to the model. Among plausible reporters, parental BMI explained 23% of the variance in girls BMI at age 11. However, when reported energy intake was added to the model, reported energy intake explained an additional 9% of the variance, over and above the variance explained by parental BMI.

In Model 3, among the total sample and subgroup of implausible reporters, no additional variance was explained by reported energy intake after adjusting for parent BMI and girls' pubertal status. In contrast, among the subgroup of plausible reporters, after adjusting for parent BMI and girls' pubertal status, reported energy intake explained an additional 4% of the variance. Model 3 accounted for a total of 46% of the variance in BMI in girls with a plausible reported energy intake. In this case, even after adjusting for two well established predictors of girls' weight status, the addition of reported energy intake resulted in a small but significant increase in R^2 .

Consistent with previous studies, under-reporters were significantly heavier than plausible and over-reporters, providing support for the first hypothesis (5-10,15,31). For example, Fisher and colleagues (31) who examined whether weight status and macronutrient intake influence the accuracy of dietary reports among children (ages 4 to 11 years) found that under-reporting tended to occur among children with the highest body fat content and relative weight. Similarly, a doubly labeled water study revealed that error in reporting was significantly greater among overweight compared to normal weight children, reflecting a weight-related bias in reporting accuracy (9). These findings indicate that it is important to identify implausible under- and over-reporters to evaluate the impact bias may have on relations between reported energy intake and weight status. The present findings reveal that because under-reporters tend to be heavier than plausible reporters and have lower (but implausible) reported energy intakes, this reporting bias may obscure positive relations between energy intake and measures of weight status.

As predicted, reported energy intake at age 9 was not a significant determinant of BMI in the total sample or subgroup of implausible reporters at age 11. The lack of relationship observed in the total sample is consistent with a number of epidemiological and experimental studies, which have also failed to find that reported energy intake predicts weight status (2-4,32,33). Such negative findings have been used in support of the view that positive energy balance is primarily a result of low levels of energy expenditure, minimizing the contributions of energy intake to positive energy balance, weight gain, and obesity (2-4). However, results of this study show that among plausible reporters, reported energy intake is a significant positive predictor, with and without adjusting for parent BMI and girls' pubertal status. While this is the first study to adjust for parent BMI and pubertal status, others that have used this relatively simple screening procedure report similar findings (15-17). For example, a study using nationally representative data found that in the total sample, daily energy intake was not significantly related to BMI percentile among 3- to 19-year-old girls and boys; however, a relationship emerged between energy intake and BMI percentile in older children after eliminating implausible reporters (15). The findings of the current study and others provide further evidence that this relatively simple analytical procedure can be used to identify the nature and impact of systematic bias in dietary data on interpretations of relations between energy intake and weight status, while serving as an inexpensive alternative to the doubly labeled water technique.

This study is not without limitations. First, this sample was racially and demographically homogenous, and included only girls, which prevents the generalization of study findings to

boys or to other racial and socioeconomic groups. Moreover, this sample was relatively highly educated and thereby may be more aware of their nutrient intake and have different energy intakes than the general population. Finally, a potential limitation of this study is that the procedure used to identify implausible reporters may be identifying girls who are actually under-eating rather than under-reporting.

CONCLUSIONS

Results from this study do not support the view that obese and overweight children and adolescents consume significantly fewer calories than normal weight children (3,4,32,33), and provide evidence that under-reporting is common and that the magnitude of under-reporting tends to increase as weight status increases. This simple screening procedure can be used to identify individuals as plausible and implausible under- and over-reporters to compare individuals across reporting categories, which allows for a better understanding of sources of reporting bias and the impact of reporting bias on the relation between reported energy intake and weight status.

Acknowledgements

This research was supported by the National Institutes of Health Grant NIH HD 32973 and The National Dairy Council. The services provided by the General Clinical Research Center of the Pennsylvania State University (supported by the NIH Grant M01 RR10732) are appreciated.

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Table 1

Mean baseline and outcome characteristics of girls and their parents for the total sample and mean comparisons by reporting accuracy subgroups using a procedure that identifies plausible and implausible under-reporters and over-reporters^a

	Total sample (n=183)	Implausible under-reporters (n=30, 16.4%)	Plausible reporters (n=107, 58.4%)	Implausible over-reporters (n=46, 25.1%)
		<i>mean±SD^b</i>		
Predictors (age 9)				
Girl rEI (kcal/day) ^c	1,823.6±344.9	1,394.6±190 ^x	1,763.1±208 ^y	2,224.9±244 ^z
Covariates (age 9)				
Girl pubertal status	1.8±0.8	1.9±0.9	1.7±0.7	1.8±0.9
Maternal BMI ^d	27.5±4.4	29.3±6.7	27.4±6.4	26.6±5.9
Normal weight	21.9±1.7			
Overweight	31.1±5.6			
Paternal BMI	28.9±4.4	30.3±5.5	28.5±4.0	29.1±4.5
Normal weight	23.6±1.3			
Overweight	30.9±4.0			
Dependent variables (age 11)				
Girl BMI	20.0±4.0	21.5±4.1 ^x	19.4±3.9 ^y	18.5±3.0 ^y
Normal weight	17.9±1.8			
Overweight	24.9±3.7			
Girl BMI z score	0.5±1.0	0.9±0.9 ^y	0.3±1.0 ^y	0.1±0.9 ^y
Girl BMI percentile	64.0±27.4	88.0±23.0 ^x	72.0±28.0 ^y	58.0±27.2 ^y

^a Reporting subgroups were identified using a procedure that creates sex- and age group-specific cutoffs for reported energy intake as a percent of predicted energy requirements.

^b SD=standard deviation.

^c rEI=reported energy intake.

^d BMI=body mass index; calculated as kg/m².

^x Superscripts indicate significant group differences ($P<0.05$); analysis of variance was used to test group differences.

^y Superscripts indicate significant group differences ($P<0.05$); analysis of variance was used to test group differences.

^z Superscripts indicate significant group differences ($P<0.05$); analysis of variance was used to test group differences.

Table 2

Girls' rEI^a at age 9 years predicting girls' BMI^b at age 11 years for the total sample and subgroups of plausible and implausible reporters^c: Regression analysis, Model 1 is unadjusted, Model 2 is adjusted for parental BMI, and Model 3 is adjusted for parental BMI and girls' pubertal status

Predictors	Total Sample (n=169) ^d					Plausible Subgroup (n=102)					Implausible Subgroup (n=67)				
	R ² change	B	SE β	β^1	β^2	R ² change	B	SE β	β^1	β^2	R ² change	B	SE β	β^1	β^2
Model 1. Independent effect of rEI															
Block 1	0	0	0	0.05		0.14	0.01	0	0.39	***	0.01	0	0	-0.17	
Model 2. Effect of rEI including parental BMI as covariates															
Block 1	0.27	0.28	0.05	0.43	***	0.23	0.28	0.06	0.44	***	0.32	0.26	0.07	0.40	***
Mother BMI					0.42					0.43				0.39	***
Father BMI		0.21	0.06	0.23	***		0.14	0.09	0.14	0.15		0.28	0.09	0.33	***
Block 2	0	0	0	0	0.22	0.09	0.01	0		0.32	0	0	0		0.32
rEI					0.03					***					-0.11
Model 3. Effect of rEI including parental BMI and girls' pubertal status as covariates															
Block 1	0.41	0.21	0.04	0.33	***	0.38	0.23	0.06	0.34	***	0.46	0.19	0.06	0.31	***
Mother BMI					0.32					0.33					0.30
Father BMI		0.18	0.06	0.20	***		0.14	0.09	0.14	0.08		0.23	0.08	0.30	***
Pubertal status		20.05	0.34	0.38	***		20.10	0.48	0.38	0.34		10.78	0.49	0.37	***
Block 2	0	0	0	0	0.02	0.04	0	0		0.24	0	0	0		0.39
rEI										**					-0.09

^a rEI=reported energy intake.

^b BMI=body mass index.

^c Reporting subgroups were identified using a procedure that creates sex- and age group-specific cutoffs for rEI as a percent of predicted energy requirements.

^d SE β =standard error of the regression coefficient; β^1 -2=standardized regression coefficients for Equation 1 and 2.

* $P<0.05$.

** $P<0.01$.

*** $P<0.001$.