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The Cardiometabolic Risk Profile of Underreporters of Energy Intake Differs from That of Adequate Reporters among Children at Risk of Obesity

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ABSTRACT

Background: Misreporting of energy intake (EI) in nutritional epidemiology is a concern because of information bias, and tends to occur differentially in obese compared with nonobese subjects.

Objective: We examined characteristics of misreporters within a cohort of children with a parental history of obesity and the bias introduced by underreporting.

Methods: The QUebec Adipose and Lifestyle InvesTigation in Youth (QUALITY) cohort included 630 Caucasian children aged 8–10 y at recruitment with ≥1 obese parent [body mass index (BMI; in kg/m^2) >30 or waist circumference >102 cm (men), >88 cm (women)] and free of diabetes or severe illness. Children on antihypertensive medications or following a restricted diet were excluded. Child and parent characteristics were measured directly or by questionnaire. Three 24-h dietary recalls were administered by phone by a dietitian. Goldberg's cutoff method identified underreporters (URs). Logistic regression identified correlates of URs. We compared coefficients from linear regressions of BMI after 2 y on total EI at baseline *1*) in all participants; *2*) in adequate reporters (ARs) (excluding URs); *3*) in all participants statistically adjusted for underreporting; *4*) excluding URs using individual physical activity level (PAL)-specific cutoffs; and *5*) in all participants statistically adjusted for underreporting using PAL-specific cutoffs.

Results: We identified 175 URs based on a calculated cutoff of 1.11. URs were older, had a higher BMI *z* score, and had poorer cardiometabolic health indicators. Parents of URs had a lower family income and higher BMI. Child BMI *z* score (OR: 3.07; 95% CI: 2.38, 3.97) and age (OR: 1.46/y; 95% CI: 1.14, 1.87/y) were the strongest correlates of underreporting. The association between BMI and total EI was null in all participants but became significantly positive after excluding URs (ß = 0.62/1000 kcal; 95% CI: 0.33, 0.92/1000 kcal) and after adjustment for URs (ß = 0.85/1000 kcal; 95% CI: 0.55, 1.06/1000 kcal).

Conclusions: URs in 8- to 10-y-old children differed from ARs. Underreporting biases measurement of nutritional exposures and the assessment of exposure-outcome relations. Identifying URs and using an appropriate correction method is essential. *J Nutr* 2019;149:123–130.

Keywords: cardiometabolic risk, glycemic index, glycemic load, adiposity, body mass index, energy intake, underreporting, 24-h recall, misreporting, children

Introduction

A common difficulty in nutritional epidemiology is to accurately assess dietary intake to represent true dietary consumption (1). Misreporting of dietary intake, specifically under- or overreporting, is defined as a discrepancy between self-reported intake and actual food consumption (2). Additions, omissions, substitutions, or imprecise portion sizes of foods reported are different alterations in reporting that can cause misreporting (2, 3). Underreporting, the most common type of misreporting, can be random or systematic and in some instances it could cause information bias and may affect the interpretation of

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diet-disease associations (4). Research has shown differential underreporting of energy intake among overweight and obese adolescents compared with normal-weight adolescents (5). Only a handful of studies have examined characteristics of underreporters (URs) among young children (3, 6–12), several of which focused on European, Australian, or Asian children, populations that are different in dietary culture and behaviors from North American children.

Identifying characteristics of URs is important to get a better understanding of the population being studied and to make informed methodologic decisions for addressing misreporting to improve our interpretation of diet-disease associations. The most common method for identifying misreporters is the Goldberg cutoff, which evaluates reported energy intake (EI) against calculated energy requirements (13, 14). Briefly, the Goldberg method classifies participants as either URs, acceptable reporters, or overreporters by comparing reported EI to the estimated energy requirements known as the physical activity level (PAL) (12, 13). This is achieved by comparing the ratio of reported EI to calculated basal metabolic rate (BMR)—EI:BMR—to calculated lower and upper cutoff values based on the variation in EI, BMR, and PAL specific to the population being studied (12, 13). Therefore, by definition, an EI:BMR ratio outside of the calculated range is metabolically impossible given the EI that was reported, and these individuals would be classified as misreporters (13). Although doubly labeled water remains the gold standard for assessing reporting error, it is costly and thus not always available. The Goldberg equation is based on population estimates and therefore not as definite; however, it remains a valuable method to use when more precise measures are not available.

The objectives of this study were to describe characteristics of presumptive URs relative to adequate reporters (ARs), to examine relations between reporting status and heart health indicators within a cohort of school-age children in Quebec, Canada with a parental history of obesity, and to discuss how to address potential bias during analyses.

Methods

Study population

We used baseline (July 2005–December 2008) and follow-up (July 2007–March 2011) data from the QUebec Adipose and Lifestyle InvesTigation in Youth (QUALITY) cohort, which was originally designed to study the natural history and consequences of the development of obesity in youth (15). Briefly, QUALITY is an ongoing study of 630 Caucasian children aged 8–10 y at baseline of Western European ancestry with ≥1 obese biological parent [BMI (in kg/m^2)] >30 or waist circumference >102 cm in men and >88 cm in women). In addition, both biological parents had to be available to participate in the baseline assessment. The cohort was restricted to only Caucasian families to facilitate future genetic studies. Families were excluded if the mother was pregnant or breastfeeding at the baseline evaluation, or if the family had pending plans to move out of the province. Moreover, children that had any of the following criteria were also excluded: *1*) a previous diagnosis of type 1 or type 2 diabetes; *2*) a serious illness, psychological condition, or cognitive disorder that hindered participation in some or all of the study components; *3*) treatment with antihypertensive medication or steroids (except if administered topically or through inhalation); and *4*) a very restricted diet (<600 kcal/d). The first follow-up visit included 564 children (89.5% retention). The QUALITY study received ethics approval from the Ethics Boards of the Centre Hospitalier Universitaire Sainte-Justine and Université Laval.

Detailed measurements included questionnaires for the children and the parents, biological and physiologic measures including an oral-glucose-tolerance test, anthropometrics (height, weight, waist circumference, skinfold thickness) of both children and parents, and measures of body fat composition among several other measures collected (15). Parental reports on the highest maternal and paternal education level obtained, household income, and family history of disease were collected.

Measurements

Anthropometric measurements were collected according to a standardized protocol with participants dressed in light indoor clothing with no shoes, using a stadiometer for height (to the nearest 0.1 cm) and an electronic scale for weight (to the nearest 0.1 kg). Height and weight measures were taken twice, and if the measures differed by ≥0.2 cm or ≥0.2 kg, a third measure was taken. The final value was the mean of the 2 closest measurements. BMI was calculated as kg/m^2.

Percentage body fat was assessed through the use of DXA (Prodigy Bone Densitometer System, DF-14664; GE Lunar Corporation). Blood was collected from children and parents by venipuncture after an overnight fast. Blood plasma samples were centrifuged, divided into aliquots, and stored at −80°C and were later analyzed in batches at the Department of Biochemistry of the Centre Hospitalier Universitaire Sainte-Justine Hospital, a site that participates in provincial and international quality control programs and is accredited by the International Federation of Clinical Chemistry (15). Blood lipids, including TGs, LDL cholesterol, and HDL cholesterol, were determined with a Synchron LX20 (Beckman Coulter) with Beckman Instruments reagents (16). Blood pressure was measured on the right arm with the participants in a seated position, at rest for a minimum of 5 min, with the use of an oscillometric instrument (Dinamap XL, model CR9340; Critikon Company) and an appropriate cuff size determined by arm circumference. Five consecutive readings were recorded and the mean value of the last 3 readings was used for systolic blood pressure and diastolic blood pressure.

Physical activity was measured objectively with the use of 7-d accelerometry (Actigraph LS 7164 activity monitor; Actigraph LLC) in the week after the baseline clinic visit. Accelerometry data were downloaded as 1-min epochs and underwent standardized quality control and data reduction procedures (17); participants with a minimum of 4 d with a minimum of 10 h of wear time/d were retained for analyses. Moderate to vigorous physical activity was computed by adding the total minutes spent daily in moderate and vigorous physical activity and averaging over the total number of valid days of wear (18). We used mean counts per minute as the physical activity variable, calculated as the total number of activity counts divided by total wear time in minutes.

Dietary data

Dietary intake was assessed 8–12 wk after the clinic visit with the use of 3 nonconsecutive unannounced 24-h recall interviews, including on 1 weekend day, administered over the phone by trained dietitians. Complete dietary data were obtained for 613 participants. A small disposable kit of food portion models was provided to participants at the baseline clinic visit, in conjunction with a short training and practice session for both children and their parents. Interviews were conducted with the child, but parents were asked about food description

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Supplemental Figures 1–4 and Supplemental Tables 1–4 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/jn/.

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Abbreviations used: AR, adequate reporter; BMR, basal metabolic rate; EI, energy intake; EI:BMR, ratio of energy intake to basal metabolic rate; PAL, physical activity level; QUALITY, QUebec Adipose and Lifestyle InvesTigation in Youth; UR, underreporter.

and cooking details when necessary. The dietary data were entered into the CANDAT Nutrient Analysis Software (Godin and associates; 2007), which provides a nutrient analysis based on the Canadian Nutrition Files (19). A research dietitian who supervised the staff audited every 10th entry for completeness and accuracy.

Statistical analysis

The Goldberg equation (13) was used to evaluate misreporting. The confidence limits were calculated from the Goldberg equation as described by Black (13) to determine if the mean reported EI was plausible. The Goldberg equation includes values of PAL and BMR and CVs for both, and a within-subject variation in EI, which we obtained from our data and from the published literature. For our population, PAL was defined as 1.65, which is a conservative value for children (20). The Schofield equation was used for calculating BMR, which has the best agreement with actual measurement, with a CV of 8.5 (13). The within-subject variation in EI was 23 (13). Finally, the total variation in PAL was 15 (13). The EI:BMR ratio for each individual was compared to the 1.11 cutoff below which an individual would be considered a UR and to the upper cutoff value of 2.46 above which one would be considered an overreporter. Only 2 participants had an EI:BMR ratio >2.46, and given that no difference in results was observed after excluding these 2 participants, we chose to include them in the AR group. For our sensitivity analysis, we also calculated PAL-specific cutoffs for each participant with the use of individual PAL values, which were calculated from available accelerometer data ($n = 535$), to classify children into 3 physical activity groups based on recommendations of 60 min/d of moderate to vigorous physical activity (sedentary: <30 min/wk, moderate: 30–60 min/wk, and active: >60 min/wk). We assigned PAL values of 1.45 for sedentary, 1.65 for moderate, and 1.9 for active (20). These PAL-specific cutoff values were used to identify URs.

We compared URs and ARs among all participants, separately for boys and girls, and by BMI category (under- and normal weight compared with overweight and obese). *t* Tests and chi-square tests were used for these comparisons, with a P value <0.05 indicating significance. We used logistic regression to identify correlates of URs. We examined the bias resulting from underreporting by comparing the coefficients from the linear regression of BMI z score at 2 y of follow-up on total EI at baseline in *1*) all participants, *2*) the AR subset, after excluding URs using an overall PAL of 1.65 (cutoff 1.11), and *3*) all participants after statistical adjustment for underreporting using an overall PAL of 1.65 (cutoff 1.11). As a sensitivity analysis, we repeated analyses *2*) and *3*) using the PAL-specific cutoffs calculated for individuals with complete accelerometer data. As a secondary analysis, we examined the effect of underreporting on energy-adjusted carbohydrate, protein, and fat using energy densities within the 5 population subsets used in the main bias analyses. We also used restricted cubic splines to examine different dietary exposure-outcome associations with flexible modeling, and results are shown graphically. STATA version 13 (StataCorp 2013) and SAS version 9.3 (SAS Institute) were used for the analyses.

Results

A total of 630 children aged 8–10 y were assessed at baseline (**Supplemental Figure 1**), of which 613 participated in the dietary interviews. Using the calculated Goldberg cutoff of 1.11, we identified 175 URs. In bivariate analyses, URs and ARs differed substantially (**Table 1**). Overall, URs had worse cardiometabolic health than ARs, including a higher BMI, with a much higher percentage being obese compared with the ARs (37.1% compared with 3.2%). Systolic and diastolic blood pressure and TGs and LDL cholesterol were significantly higher in URs and HDL cholesterol was lower. URs were also older

TABLE 1 Comparison of population characteristics between underreporters and adequate reporters among boys and girls aged 8–10 y from Quebec in the QUALITY cohort[1]

Characteristics	Underreporters ($n = 175$)	Adequate reporters ($n = 438$)	P
Age, y	9.9 ± 0.9	9.5 ± 0.9	<0.001
Boys, %	49.0	57.0	0.07
BMI category, %			<0.001
Underweight (z score <−2)	0	0.2	
Normal weight (−2 ≤ z score <1)	25.1	69.6	
Overweight (1 ≤ z score <2)	37.7	26.9	
Obese (z score ≥2)	37.1	3.2	
Tanner stage, %			<0.001
Prepubertal	66.7	83.8	
Pubertal	33.3	16.2	
Percentage fat mass	36.8 (27.8–42.8)	21.9 (15.6–30.1)	<0.001
Screen time, h/d	2.6 (1.4–4.3)	2.1 (1.3–3.4)	0.006
SBP, mm Hg	95.7 (91.0–102.7)	92.7 (87.7–98.3)	<0.001
DBP, mm Hg	50.7 (46.3–53.7)	47.7 (44.7–51.0)	<0.001
TGs,[2] mmol/L	0.9 (0.6–1.2)	0.7 (0.5–0.9)	<0.001
HDL cholesterol,[2] mmol/L	1.1 (0.9–1.2)	1.2 (1.0–1.4)	<0.001
LDL cholesterol,[2] mmol/L	2.5 (2.1–2.8)	2.3 (1.9–2.6)	0.003
Parent education, %			0.11
No parent with high school diploma	1.7	0.9	
One or both parents with high school diploma	8.1	5.3	
One or both parents with community college or equivalent	41.9	36.8	
One or both parents with university degree	48.3	57.1	
Family income, CAD	38,972 ± 18,056	43,907 ± 18,404	0.003
Physical activity,[3] CPM	519.4 (439.6–640.2)	580.3 (464.2–691.8)	0.005

[1]Values are means ± SDs or medians (IQRs), significantly different if $P < 0.05$. CAD, Canadian dollar; CPM, counts per minute; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[2]All analytes were measured in plasma.
[3]Accelerometry data were only completed for $n = 535$ at baseline.

TABLE 2 Comparison of dietary characteristics between underreporters and adequate reporters among children aged 8–10 y from Quebec in the QUALITY cohort[1]

Dietary characteristics	Underreporters ($n = 175$)	Adequate reporters ($n = 438$)	P
Macronutrients			
Carbohydrates, g/d	179.3 ± 38.6	239.8 ± 53.4	<0.001
Protein, g/d	56.0 ± 16.5	72.2 ± 17.8	<0.001
Total fat, g/d	47.2 ± 14.3	66.6 ± 17.2	<0.001
Saturated fat, g/d	16.4 ± 5.7	23.9 ± 7.1	<0.001
Total energy intake, kcal/d	1348 ± 276	1822 ± 351	<0.001
Boys	1405 ± 303	1901 ± 356	<0.001
Girls	1294 ± 237	1719 ± 316	<0.001
Energy-adjusted macronutrients			
Carbohydrate intake, % energy	53.5 ± 6.7	52.7 ± 6.2	0.15
Protein intake, % energy	16.7 ± 3.9	15.9 ± 3.1	0.012
Fat intake, % energy	31.2 ± 5.1	32.8 ± 4.7	0.004
Saturated fat intake, % energy	10.8 ± 0.2	11.8 ± 0.1	<0.001
Energy-adjusted micronutrients			
Calcium, mg/1000 kcal	484.2 ± 134.4	515.8 ± 155.0	0.018
Iron, mg/1000 kcal	7.1 ± 1.3	6.9 ± 1.7	0.22
Zinc, mg/1000 kcal	5.2 ± 1.4	5.2 ± 1.7	0.99
Sodium, mg/1000 kcal	1524 ± 352	1430 ± 319	0.001
Vitamin C, mg/1000 kcal	81.0 ± 62.8	79.5 ± 51.9	0.77
Thiamin, mg/1000 kcal	1.0 ± 0.3	1.0 ± 0.9	0.99
Riboflavin, mg/1000 kcal	1.1 ± 0.3	1.2 ± 0.4	0.13
Niacin, NE/1000 kcal	19.4 ± 5.4	18.1 ± 5.0	0.005
Vitamin A, RAE/1000 kcal	405.5 ± 226.2	400.6 ± 195.1	0.79
Vitamin D, μg/1000 kcal	2.9 ± 1.9	3.5 ± 2.2	0.002
Folate, DFE/1000 kcal	226.6 ± 78.1	218.1 ± 84.4	0.25
Food groups			
Fruits and vegetables, servings/d	3.7 ± 2.0	4.6 ± 2.1	<0.001
Grain products, servings/d	4.1 ± 1.5	4.9 ± 1.7	<0.001
Milk and dairy, servings/d	1.4 ± 0.7	2.1 ± 1.0	<0.001
Meat and alternatives, servings/d	1.6 ± 0.8	2.0 ± 0.9	<0.001
Sugar-sweetened beverages, mL/1000 kcal	91.5 ± 109.4	63.8 ± 73.8	0.003
Snacks/d	4.5 ± 2.2	4.9 ± 2.1	0.025
Fiber, g/1000 kcal	8.4 ± 2.3	7.8 ± 2.0	0.002

[1]Values are means ± SDs, significantly different if $P < 0.05$. DFE, mean dietary folate equivalent; NE, niacin equivalent; QUALITY, QUebec Adipose and Lifestyle InvesTigation in Youth; RAE, mean retinol activity equivalent.

and less physically active than ARs. The overall mean EI:BMR ratio was 1.32 and ranged from 0.39 to 2.54. The mean EI:BMR ratio in URs and ARs was 0.93 and 1.49, respectively (data not shown). URs reported a diet that contained less carbohydrate, fewer snacks, and lower overall EI than ARs, as well as fewer servings of all 4 food groups (**Table 2**). In addition, URs reported lower calcium and vitamin D and greater sodium intake per 1000 kcal than ARs (Table 2). Parents of URs had a lower family income and a higher BMI than parents of ARs (Table 1, **Supplemental Table 1**).

In multivariable logistic regression, age (OR: 1.46/y; 95% CI: 1.14, 1.87/y), and BMI z score (OR: 3.07; 95% CI: 2.38, 3.97) were the only significant correlates of underreporting (**Table 3**). Linear regressions showed no association between BMI at 2-y follow-up and total baseline EI when all participants were included but became significantly positive (ß = 0.62/1000 kcal; 95% CI: 0.33, 0.92/1000 kcal) after exclusion of the URs and when adjusted for underreporting in the model (ß = 0.80/1000 kcal; 95% CI: 0.55, 1.06/1000 kcal) (**Figure 1**A). Results were similar when we used PAL-specific cutoffs.

In our secondary analysis, linear regressions of energy-adjusted carbohydrate (Figure 1B), protein (Figure 1C), and fat (Figure 1D) showed no association with BMI z score in unadjusted and adjusted models for underreporting.

In stratified bivariate analyses, results were similar when stratified by sex (**Supplemental Table 2**). Within categories of obesity, the only significant differences observed between URs and ARs were age and BMI (**Supplemental Table 3**). URs were older, had a higher BMI, and were predominantly female compared with ARs.

Multivariate regression splines of glycemic load and BMI z score show a change in shape when URs are excluded from the analyses compared with when all participants are included. Including URs pulls the left side of the curve up, resulting in a shape that tends to be flat. The same phenomenon is observed with other cardiometabolic risk factors (**Supplemental Figures 2–4**).

Discussion

Using data from the QUALITY study, we identified characteristics of EI URs in a sample of school-age children at risk of obesity. Goldberg's cutoff is a commonly used method

TABLE 3 Children and parental characteristics that predict underreporting in children aged 8–10 y in Quebec in the QUALITY study[1]

	n	Crude OR (95% CI)	Adjusted[2] ($n = 563$) OR (95% CI)
BMI z score	613	3.48 (2.73, 4.44)	3.07 (2.38, 3.97)
Age, y	613	1.52 (1.25, 1.85)	1.46 (1.14, 1.87)
Percentage fat mass[3]	608	1.12 (1.10, 1.15)	—
Tanner, prepubertal vs. pubertal	612	2.58 (1.72, 3.87)	1.65 (0.99, 2.73)
Family income, per $10,000	608	0.86 (0.78, 0.95)	0.92 (0.82, 1.04)
Father's BMI	606	1.06 (1.02, 1.09)	1.02 (0.98, 1.06)
Mother's BMI	611	1.07 (1.04, 1.10)	1.03 (1.00, 1.07)

[1]Values represent the ORs and 95% CIs of being an underreporter (characterized as energy intake:basal metabolic rate ratio < 1.11). Variables tested but not found statistically significant: sex, screen time, parent education, physical activity.
[2]Adjusted model includes all variables except percentage fat mass.
[3]Percentage fat mass was excluded from the fully adjusted model because of multicollinearity with BMI z score.

to identify misreporters. This cutoff varies between studies depending on the CV used for EI, BMR equation, and PAL level. For this reason, the proportion of under- and overreporting is not easily comparable from one study to another and is only possible with a study that uses similar coefficients. Farajian et al. (11) used a cutoff interval of 1.09–2.21 in Greek children aged 10–12 y and identified 36% as URs and 16% as overreporters. Lioret et al. (9) classified 26% of their groups of children from France aged 11–17 as URs, but found no overreporters. The 29% of URs identified in our sample seems reasonable for the QUALITY cohort children who are at high risk of obesity. Other studies have used lower cutoff values, often because they selected a PAL ≤1.55. The PAL of 1.65 used in our analysis is the estimated required level of moderate physical activity for this age group suggested by the FAO of the UN in collaboration with the WHO and the United Nations University (20). Using a PAL of ≤1.55 to indicate a sedentary lifestyle is insufficient in children and may result in an underestimation of URs (12).

According to the most recently published 2015–2020 Dietary Guidelines for Americans (21), children between the ages of 8 and 10 y should consume between 1600 and 1800 kcal. In our cohort, ARs and URs reported an energy intake of 1822 kcal and 1348 kcal, respectively, resulting in a 474-kcal deficit for URs compared with ARs. An energy deficit of 500 kcal/d should result in 0.45 kg of weight lost per week (22); however, our URs had a higher BMI. URs and ARs reported similar proportions of their energy intake from carbohydrates, but URs had lower proportions of fat and slightly higher proportions of protein; however, these were all within normal recommended ranges of macronutrient consumption. Studies of macronutrient distributions in adult URs have reached conflicting conclusions, one study finding differential reporting of all macronutrients between URs and ARs (23) and another study finding no difference (24). Also, contrary to another study that found no difference of energy-adjusted micronutrients between URs and ARs, we observed lower calcium and vitamin D and higher sodium intake per 1000 kcal (25).

In our study, URs were older, more likely to be girls, and had a higher BMI compared with ARs, consistent with other studies in adults (1) and most studies in children and adolescents (5–7, 10, 11, 26–32), but not all (33–35). BMI is recognized as the strongest predictor of underreporting (1). It is not clear why obese individuals tend to underreport more than leaner individuals, but possible explanations include intentionally misreporting actual food intake, possibly because of social desirability or social approval biases, more frequent dieting compared with leaner individuals, or other factors (36). Children that follow a strict diet regimen may be classified as URs because of their low EI when they are actually accurately reporting their intake, which may result in misclassification of URs. In the QUALITY cohort, children on a restricted diet were excluded from the cohort, thereby reducing potential misclassification due to dieting (15). Parents of URs had a higher BMI and lower family income than parents of ARs, consistent with another study that observed an association with income (37).

In addition to being heavier, URs had worse cardiometabolic risk factors than ARs. Specifically, blood pressure and LDL cholesterol concentrations were higher and HDL cholesterol lower in URs than in ARs. These results are similar to the only other study that reported on biochemical markers, including LDL and HDL cholesterol and TGs, of URs in a small and underpowered sample of 96 South American adolescents (38).

When assessing dietary intake in relation to disease outcomes, URs tend to agglomerate in the upper left quadrant of a graph (as shown in **Supplemental Table 4**), pulling the left side of the regression up. Including these participants tends to shift the slope of a positive association towards either a null association or possibly an inverse association. To address underreporting bias, different methods have been proposed. Some authors recommend exclusion of URs to avoid spurious results (1, 39); however, exclusion of URs may be problematic for several reasons. First, the potential for selection bias, which occurs when the estimates of effect in the participants, in this case only ARs, differ from those in the target population, which includes both URs and ARs (40). Second, by excluding URs, the sample size is decreased and power to detect associations is diminished. Third, a number of false negatives may remain after excluding URs, depending on the cutoff used. Other methods that have been proposed involve stratification of results by reporting status, statistical adjustment for underreporting, and propensity score adjustment to account for all predictors of underreporting (41). Although it is clear that exclusion of URs results in selection bias, there is a lack of consensus as to which correction method is best (41–43). Despite the limitations of each method, it is crucial to account for URs in the analysis to avoid biased results.

Our secondary analysis showed that energy-adjusted nutrients were not associated with BMI z score, regardless of underreporting. This could indicate that energy adjustment addresses the issue of underreporting when examining associations of diet composition exposures with disease outcomes (44). However, we cannot assume that all macronutrients are

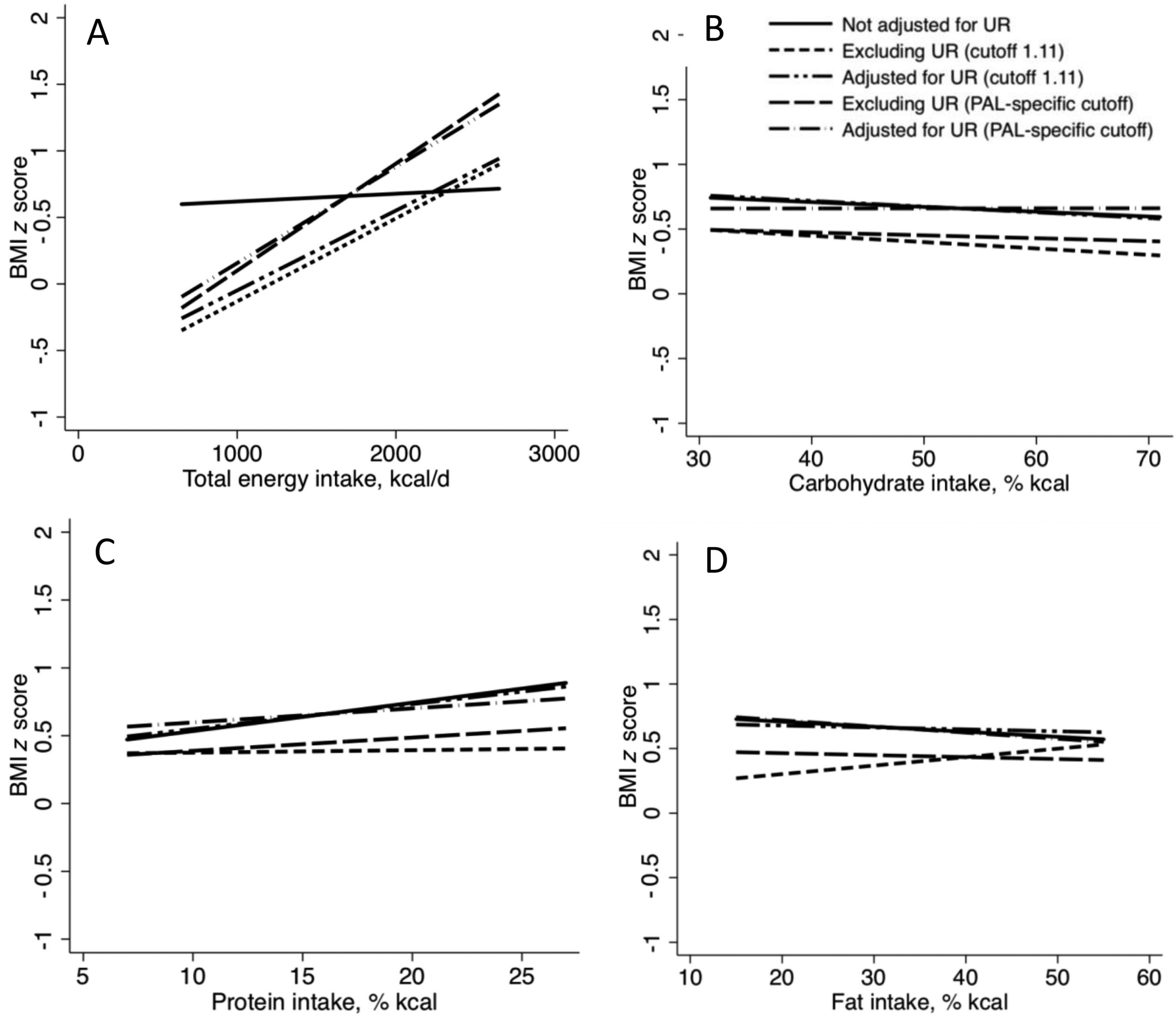

FIGURE 1 Associations of baseline intakes of total energy (A) and percentages of energy from carbohydrate (B), protein (C), and fat (D) with BMI *z* score after 2 y in 8- to 10-y-old children in the QUALITY cohort. Results with no adjustment are compared with results excluding URs and results with statistical adjustment for URs using a Goldberg cutoff of 1.11 for all participants and individual PAL-specific cutoffs. All participants, $n = 552$; adequate reporters, $n = 403$. All models are adjusted for Tanner stage, family income, parent education, moderate to vigorous physical activity (counts per minute), mother's BMI, and father's BMI. PAL, physical activity level; UR, underreporter.

underreported to the same extent given that some individuals may be more reluctant to report certain macronutrients (45, 46). Our results show that percentage of energy from fat and protein differed between URs and ARs and therefore it is not clear that energy adjustment could fully address underreporting given the fact that this error in particular is differential (46, 47). Further research should assess the role of energy adjustment in addressing underreporting.

Underreporting bias in dietary interviews varies with the type of dietary recall method used. A study comparing results from two 24-h recall interviews to doubly labeled water found that Goldberg's cutoff method had a sensitivity of 50%, a specificity of 99%, and a positive predictive value of 92% assuming a PAL of 1.55 (48). This suggests that Goldberg's cutoff correctly identifies the ARs but misclassifies a high percentage of URs. These validity measures depend on the Goldberg cutoff, which varies with the selected PAL. Sensitivity can be improved by assigning a higher overall PAL or specific PAL values based on physical activity measurements, but this will increase the cutoff and classify more individuals as URs. We used a PAL of 1.65 and three 24-h recall interviews, which likely improves the sensitivity of the Goldberg method. Despite the low sensitivity, underreporting bias remains important, and, to date, most of the current nutrition literature fails to account for this bias.

Our study has some potential limitations. First, there is controversy regarding the 24-h dietary recall because some believe it results in higher proportions of URs, compared with more thorough dietary assessment methods such as the diet record method (49); however, some evidence shows that underreporting does not differ from one dietary assessment method to another (1). Nevertheless, our study used repeated 24-h recalls on 3 nonconsecutive days, which remains more precise than most dietary assessment methods. Second, dietary misreporting tends to vary with cultural differences, thus, our results may not be representative of populations that differ significantly to our target population. Third, in our main calculation of the Goldberg cutoff, we did not use individual PAL and chose a more conservative cutoff because ~15% of our accelerometry data were missing. In addition, although the use of individual PAL is more precise, it would have resulted in >50% of participants being classified as URs and increased the risk of falsely classifying participants as URs. Nevertheless, other studies have also used conservative cutoffs in children to identify underreporting (9, 11). In addition, in our comparison of different adjustment approaches, the results obtained using PAL-specific cutoffs were similar to those obtained using the cutoff of 1.11. Authors should consider conducting sensitivity analyses with varying cutoffs to examine the precision of the cutoff selected and the robustness of their results.

In conclusion, URs in the QUALITY cohort tended to be generally unhealthy, with higher BMI, worse cardiometabolic risk factors, and lower PAL compared with ARs. It is of great importance to identify URs and address the bias that they introduce in study results, particularly when studying a cohort that is at a higher risk of obesity and with a high proportion of obese individuals because this may increase the proportion of URs. Failing to account for underreporting will likely result in spurious associations and incorrect interpretation of results.

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