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# Bias in food intake reporting in children and adolescents with type 1 diabetes: the role of body size, age and gender

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Background: An assessment of total daily energy intake is helpful in planning the overall treatment of children with type 1 diabetes (T1D). However, energy intake misreporting may hinder nutritional intervention.
Aims: To assess the plausibility of energy intake reporting and the potential role of gender, body mass index (BMI) z-score (z-BMI), disease duration and insulin requirement in energy intake misreporting in a sample of children and adolescents with T1D.
Methods; The study included 58 children and adolescents aged 8–16 yr with T1D. Anthropometry, blood pressure and glycated hemoglobin (HbA1c) were measured. Subjects were instructed to wear a SenseWear Pro Armband (SWA) for 3 consecutive days, including a weekend day and to fill out with their parents a weighed dietary record for the same days. Predicted energy expenditure (pEE) was calculated by age and gender specific equations, including gender, age, weight, height and physical activity level (assessed by SWA). The percent reported energy intake (rEI)/pEE ratio was used as an estimate of the plausibility of dietary reporting.
Results: Misreporting of food intake, especially under-reporting, was common in children and adolescents with T1D: more than one-third of participants were classified as under-reporters and 10% as over-reporters. Age, *z*-BMI and male gender were associated with the risk of under-reporting (model $R^2 = 0.5$). Waist circumference was negatively associated with the risk of over-reporting (model $R^2 = 0.25$).
Conclusions: Children and adolescents with T1D frequently under-report their food intake. Age, gender and z-BMI contribute to identify potential under-reporters.

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Nutrition therapy is a basic component of diabetes management (1–3). The International Society of Pediatric and Adolescent Diabetes (ISPAD) and the American Diabetes Association (ADA) recognize the importance of nutrition as an essential component of an overall healthy lifestyle, in addition to its role in controlling diabetes.

The assessment of total daily energy and nutrient intake is helpful in planning the treatment of children with type 1 diabetes (T1D) and in studying associations between dietary habits and disease complications and co-morbidities. However, in both adults and children, energy intake misreporting is common in the general population, so that information could be biased (4–16). Food intake misreporting is associated with the level of adiposity; in particular, consistent evidence is available on under-reporting of food intake in obese individuals (4, 7, 9, 11, 12, 14–18).

The prevalence of overweight and obesity in children and adolescents with T1D varies in the different populations but, usually, it is at least comparable if not higher than in children and adolescents without

T1D (19, 20). Therefore, it is likely that also a portion of children and adolescents with T1D under-report their food intake.

To the best of our knowledge, very few data are available on the validity of energy intake reporting by children and adolescents with T1D assessed by a comparison with their daily energy expenditure (21). Therefore, the aims of this study were to assess the plausibility of energy intake reporting in a sample of children and adolescents with T1D and the relationships between gender, BMI z-score (z-BMI), disease duration and insulin requirement with energy intake reporting in this sample.

## Methods

### Study sample

The study included children and adolescents with T1D recruited consecutively from the diabetes clinic at the Regional Center for Pediatric Diabetes in Verona, Italy, between January 2014 and December 2014. Inclusion criteria were age range (9–16), Caucasian ethnicity, diabetes onset >1 yr before recruitment, T1D diagnosis confirmed by positivity for at least two among diabetes-associated autoantibodies (GADA, ZnT8A, IAA or IA-2A); exclusion criteria were chronic diseases other than T1D (except obesity), dieting, eating disorders, chronic use of drugs other than insulin, retinopathy or microalbuminuria. The children and adolescents were all following multiple dose injection (MDI) treatment with at least four injections a day, one with long-acting insulin and three or more with short-acting or regular insulin before meals or continuous subcutaneous insulin infusion (CSII). The standard nutrition education program with periodic nutrition education sessions based on ADA and ISPAD guidelines was followed (1, 2). Dietary education tools were selected carefully for each child and family to achieve maximum understanding and adherence. Families were provided with a reproducible meal plan with several food options that could easily be maintained.

Parents were asked to report the duration of their school education as a measure of their education level. Socio-economic status (SES) was determined based on the presence or absence of the 7RQ code on the parents' health cards, corresponding, in the Veneto region, to an annual family income <29,000 euros.

Of 93 eligible families, 35 did not accept to participate in the study. Children/adolescents from families who decided not to participate did not have a significantly different age ($p = 0.53$), diabetes duration ($p = 0.10$), z-BMI ($p = 0.72$), HbA1c ($p = 0.38$), gender distribution ($p = 0.88$) and daily insulin requirement/kg of body weight ($p = 0.48$), than those of families who accepted. Their parents did not report any significantly different duration of school education ($p = 0.88$ and $p = 0.05$, for mothers and fathers, respectively) nor were they more likely to have an overall income <29,000 euros ($p = 0.13$) compared with parents who participated.

### Detailed study protocol

After the informed consent was signed, the children were given a physical examination to measure anthropometry and blood pressure. A venous blood sample was collected to measure HbA1c. Afterwards, the children were provided with a SenseWear Pro Armband (SWA) 6.1 (BodyMedia, Inc., Pittsburgh, PA, USA), which was positioned on the right arm. The SWA was placed on the subjects' arms for a period of 30 min before data collection to allow for acclimation of skin temperature. In order to obtain objectively measured data, the subjects were instructed to wear the SWA for 3 consecutive days, including a weekend day.

The children and their parents were instructed by a dietician to fill out a weighed dietary record for the 3 d that they wore the SWA. During the days preceding the test the children were on an unrestricted diet.

### Physical characteristics

The same investigator measured height, weight, waist circumference (WC) and blood pressure, as previously reported (22). BMI was calculated as weight (in kilograms) divided by height (in meters) squared. BMI values were standardized (BMI *z-scores*) using age (to the nearest 6th month) and sex-specific median, standard deviation, and power of the Box-Cox transformation (least mean square method) (23). Normal weight, overweight and obesity were defined according to the International Obesity Task Force method based on age and gender BMI cut-offs, using cut-offs from national growth charts (23). Waist-to-height ratio (WHtR) was considered a measure of body fat distribution, as previously described (24).

### Biochemical parameters

HbA1c was measured using high-performance liquid chromatography with a Biorad variant 2 cation exchange column; the instrument was calibrated against Diabetes Control and Complication Trial (DCCT) approved standards.

### Energy intake

A 3-d weighed dietary record of food and fluid, and the amounts consumed, was kept by the children/adolescents and their parents (25, 26). Food was weighed on an electronic scale by the parents and, in a few instances, by one of the grandparents. Parents reported the food intake of their children at meals, and the children/adolescents were encouraged to report all the foods, including snacks, consumed outside the home. At school, every child had a personalized food tray with a defined quantity of food (first and second course, bread and fruit). For this study the kitchen supervisory staff weighed and recorded the uneaten foods on a specific sheet.

Each family was provided with a logbook for recording foods and beverages consumed. Written instructions with examples of completed forms were provided. A complete description of how the food was prepared and recipes for composite dishes were also requested. A dietician checked the logbooks with each family for completeness and accuracy on the day after the recording. As an aid to determine the amount of food and drinks consumed outside the home, pictures of different items were shown, along with cups, glasses, spoons and food shapes of different portion sizes. Food and drink energy values were calculated from tables of food comparison set out by the National Institute of Nutrition, with the use of a computerized database and analysis program (Metadieta, Meteda, S.Benedetto del Tronto, Italy) (27).

### Energy expenditure

Total daily energy expenditure was predicted by age- and gender-specific equations provided by the NIH 2002 Dietary Reference Intakes (28), including weight, height and physical activity constants corresponding to physical activity level (PAL) categories. Predicted energy expenditure highly correlated with observed energy requirements from indirect calorimetry and double labeled water (29). PAL was defined as the energy expenditure/basal metabolic rate (EE/BMR) ratio, and PAL categories were: sedentary ($PAL \geq 1.0 < 1.4$), low active ($PAL \geq 1.4 < 1.6$), active ($PAL \geq 1.6 < 1.9$) and very active ($PAL \geq 1.9 < 2.5$). For each subject, the average PAL over the 3-d period of nutritional recording was estimated from the SWA data. The SWA is a wireless multisensory body monitor worn on the triceps of the right arm. The monitor enables continuous collection of various physiological and movement parameters through multiple sensors, including an accelerometer and sensors measuring heat flux, galvanic skin response, skin temperature and near body ambient temperature. The SWA software (SenseWear Professional software, version 6.1) provided measures of time spent lying down (sleeping time + non-sleep lying), corresponding to 1.0 MET expenditure rate, and time spent performing physical activities along with estimated METs associated with these active periods. The remaining time, consisting in sedentary activities, was attributed a 1.4 MET expenditure rate, based on the Recommended Daily Intake (RDI) charts (28). PAL was calculated as the weighed average METs spent every day and converted into PAL category. Predicted energy expenditure based on RDI equations including SWA-estimated PAL has been shown to be more accurate than (a) predicted energy expenditure (pEE) calculated by RDI formulas using a fixed sedentary PAL category for all children, and (b) pEE fully derived from armband equations (12).

### Identification of implausible food intake reporters

On the basis of the method developed by Huang et al. (15), the percent reported energy intake/predicted energy expenditure (rEI/pEE) ratio was used as an estimate of plausibility of dietary reporting, and rEI/pEE ratios falling under or over 100% ± 1 SD of rEI/pEE were considered implausible: under- or over-reports, respectively. In total, four standard deviations (SDs) to define plausibility ranges were calculated, in two age ranges (9–13 yr, and ≥14 yr) within each gender separately, according to an equation adapted from Goldberg's cut-off calculations (15, 30):

$$1\ \text{SD} = \text{squared root}\ \left(\text{CV}^2_{\text{rEI}}/d + \text{CV}^2_{\text{pEE}} + \text{CV}^2_{\text{mTEE}}\right)$$

where $CV_{rEI}$ is the sample-specific coefficient of variation in energy intake reporting, calculated by averaging individual CVs (individual SD of rEI/individual average of 3 d rEI); $d$ is the number of reporting days, 3 in the present study; CVpEE is the gender and age range-specific coefficient of variation in pEE based on the Dietary Reference Intakes data (27), for instance, 4.2 and 2.97% for 9- to 13-yr olds and 14- to 19-yr-old boys, respectively, and 4.81 and 4.13% for 9- to 13-yr-olds and 14- to 19-yr-old girls, respectively, as previously reported in the literature (31, 32), which corresponds to 8.2% for both genders and age range groups. In our sample, the value of 1 SD was 12% in all the four gender and age range groups, so in the whole sample, participants were considered plausible reporters if their rEI/pEE fell within the 88–112% range, probable under-reporters if it was lower than 88% and probable over-reporters if it was higher than 112%. The difference between rEI and pEE was also calculated as a descriptive, clinically valuable estimate of plausibility.

*Ethics statement.* The protocol is in accordance with the 1975 Declaration of Helsinki as revised in 2008.

Informed consent was obtained from the children and their parents. The study was approved by the Institutional Ethics Committee of Verona (Italy).

### Statistical analysis

Results are expressed as means (SD) or proportion (percentage). Means of continuous variables were compared by the ANOVA test across the three plausibility groups (under-, plausible- and over-reporters), in case of normal distribution and variance homogeneity of variable, or by the Kruskal–Wallis test, in different cases.

Associations of energy under-reporting and over-reporting with normally distributed, skewed and categorical variables were explored by comparing, respectively, variable means, rank means or proportions between under-reporters and other participants, and over-reporters and other participants, using the Student's *t*-test the Mann–Whitney test, or the $\chi^2$ test. Forward conditional binary logistic analyses were run to build models predicting under-reporting and over-reporting, entering variables with a p value $\leq 0.05$ in univariate analyses and removing variables showing a p $\geq 0.05$ after insertion in the multi-variate model. Continuous variables were entered as such, without any categorization.

Relationships between rEI/pEE, as a continuous estimate of reporting plausibility, and physical, biochemical and clinical variables were assessed using Pearson's correlations between rEI/pEE and the candidate continuous variables, after checking for normal distribution, and by Student's *t*-test comparison of rEI/pEE means, between groups, while considering gender and weight categories. An analysis of co-variance (ANCOVA) was done to build a model predicting rEI/pEE, using, as covariates, binary or continuous variables that were, respectively, associated or correlated with rEI/pEE with at least a 0.05 p value, in preliminary univariate analyses.

Differences in the principle candidate predictors (z-BMI, age, gender) between under-reporters and other participants, that had an 80% probability to be detected by the convenience sample of 58 children/adolescents, were calculated (33). The sample had an 80% power to detect a 0.54 difference in z-BMI, a 2 yr difference in age and a 38% difference in male gender prevalence, between under-reporters and other participants, with a 0.05 $\alpha$-error.

Data were analyzed using SPSS version 20.0 software (SPSS, Chicago, IL, USA). A p value <0.05 was considered statistically significant.

## Results

Characteristics of the sample studied are shown in Table 1. The total sample included 29 boys and 29 girls; 7 (12%) 3 males and 4 females – were overweight, one male and one female were underweight. BMI, BMI z-scores, HbA1c, insulin requirements, parental education and SES were similar in males and females. The boys were older and had a longer T1D duration than the girls, even if these differences did not reach statistical significance. Height and SBP were significantly higher in males than in females. Girls had significantly lower rEI, PAL and pEE than boys, higher rEI/pEE and lower (rEI-pEE) than boys (Table 1).

A total of 32 subjects (55%) were plausible reporters whereas 6 (10%) were over-reporters and 20 (35%) were under-reporters (Fig. 1 and Table 2). The total sample had an average rEI/pEE of 93%, under-reporters, plausible reporters and over-reporters of 78, 99 and 116%, respectively (Fig. 1).

ANOVA showed that age, z-BMI and T1D duration significantly decreased across under-, plausible- and over-reporting groups (Table 2).

Under-reporters were older and had significantly higher BMI, z-BMI, WC and systolic blood pressure, a longer duration of diabetes and higher insulin requirements than other participants (Table 2). They also included more than twice the percentage of boys (75 vs. 36%, p = 0.012) compared with other participants, and more than double the percentage of overweight (20 vs. 8%, p = 0.15). Overweight/obesity was associated with a 10-fold higher risk of having a rEI/pEE < −2DS, i.e., serious under-reporting – 42% compared with 3.9% among other participants, p = 0.006 (not shown). Binary logistic regression showed that a 1-yr increase in age and a unitary increase in z-BMI were associated, respectively, with 67 and 527% higher odds of energy under-reporting [odds ratio (OR) = 1.67 (1.13–2.48), p = 0.01; OR = 5.27 (1.60–17.34), p = 0.006], whereas male gender with about a 17-fold higher odds [OR = 17.24 (2.52–125), p = 0.004]. The model explained 51% of variance in under-reporting probability ($R^2$ of Nagelkerke = 0.508).

Over-reporters had lower BMI, z-BMI, WC and absolute insulin requirements than others (Table 2). Binary logistic regression showed that a 1 cm increase in WC was associated with 25% lower odds of over-reporting [WC OR = 0.85 (0.72–0.97), p = 0.019, $R^2$ of Nagelkerke = 0.25].

rEI/pEE was inversely correlated with z-BMI (r = −0.47, p < 0.001) and WHtR (r = −0.40, p = 0.001) (Fig. 2). Moreover, boys had a lower rEI/pEE than girls [89.7 (15) vs. 97.6 (13), p < 0.001] and overweight participants had a lower rEI/pEE than normal weight participants [78.8 (17) vs. 95.4(13), p = 0.003]. The ANCOVA showed that rEI/pEE was predicted by gender [B coefficient for males (95% c.i.) = −12.3(−18.4; −6.08), p < 0.001), z-BMI [B coefficient for unitary increase = −5.2 (−9.4; −0.96), p = 0.01] and WHtR [B coefficient for 0.01 increase = −1.4 (−2.5; −0.2), p = 0.02], which explained 22, 10 and

Table 1. Physical characteristics, HbA1c, insulin treatment, diabetes duration, reported energy intake, physical activity level, predicted energy expenditure, parental education and socio-economic status of males and females and total sample. Data are shown as mean (standard deviation) or proportion (percentage) or median (range)

| | Males (n = 29) | Females (n = 29) | p | Total (n = 58) |
|---|---|---|---|---|
| Age (yr) | 13.9 (2.3) | 12.9 (3.2) | 0.087 | 13.3 (2.9) |
| Height (cm) | 162.9 (14.1) | 151.8 (12.6) | 0.002 | 157.1 (14.2) |
| Weight (kg) | 55.2 (14.0) | 49.1 (14.8) | 0.106 | 51.7 (13.9) |
| BMI (kg/m$^2$) | 20.4 (2.9) | 20.7 (3.6) | 0.748 | 20.5 (3.1) |
| BMI z-score | 0.12 (1.2) | 0.38 (0.91) | 0.327 | 0.26 (0.90) |
| WC (cm) | 73.0 (8.8) | 70.9 (8.9) | 0.367 | 71.7 (8.4) |
| WHtR | 0.45 (0.04) | 0.47 (0.03) | 0.064 | 0.46 (0.03) |
| SBP (mmHg) | 109.4 (10.4) | 101.9 (10.4) | 0.007 | 105.7 (10.9) |
| DBP (mmHg) | 63.6 (7.8) | 64.3 (9.3) | 0.754 | 64.1 (8.6) |
| HbA1c (%) | 7.78 (1.04) | 7.80 (1.04) | 0.962 | 7.82 (1.01) |
| HbA1c (mmol/mol) | 61.5 (11.4) | 61.7 (11.3) | 0.953 | 61.9 (11.0) |
| T1D duration (months) | 77.6 (63.2) | 66.2 (49.4) | 0.440 | 72.1 (56.6) |
| Total insulin (U/d) | 47.5 (19.3) | 42.4 (17.5) | 0.286 | 45.6 (18.4) |
| Total insulin/kg/BW/d | 0.85 (0.24) | 0.86 (0.19) | 0.925 | 0.87 (0.20) |
| Rapid or short-acting I (U/d) | 24.3 (13.0) | 22.5 (10.8) | 0.575 | 23.9 (11.8) |
| Rapid or short-acting I/kg BW/d | 0.43 (0.18) | 0.45 (0.13) | 0.673 | 0.44 (0.15) |
| Rapid or short-acting I (%) | 48.2 (10.6) | 51.9 (8.4) | 0.144 | 50.76 (8.11) |
| Long-acting I (U/day) | 23.2 (7.2) | 19.8 (7.8) | 0.085 | 21.7 (7.7) |
| Long-acting I/kg/BW/day[1] | 0.4 (0.1) | 0.4 (0.1) | 0.619 | 0.4 (0.1) |
| Long-acting I (%) | 51.8 (10.6) | 48.1 (8.4) | 0.144 | 49.2 (8.1) |
| Reported energy intake (rEI) (kcal) | 1,983 (343) | 1,648 (206) | <0.001 | 1,816 (327) |
| Physical activity level (PAL) | 1.34 (0.07) | 1.30 (0.05) | 0.007 | 1.32 (0.06) |
| Predicted energy expenditure (pEE) (kcal) | 2,252 (366) | 1,696 (154) | <0.001 | 1,974 (395) |
| rEI/pEE | 89.2 (15.0) | 97.6 (12.7) | 0.025 | 93.4 (14.4) |
| (rEI-pEE) (kcal) | −269 (363) | −48 (224) | 0.008 | −158 (319) |
| Father's education (yr) | 13 (5–17) | 13 (8–17) | 0.540 | 13 (5–17) |
| Mother's education (yr) | 13 (8–17) | 13 (8–17) | 0.075 | 13 (8–17) |
| Socio-economic status (SES) (overall income <29 000 euros/yr) | 6/29 | 10/29 | 0.380 | 16/58 |

BMI, body mass index; CSII, continuous subcutaneous insulin infusion; DBP, diastolic blood pressure; HbA1c, glycated hemoglobin; MDI, multiple dose injection; rEI-pEE, reported energy intake/predicted energy expenditure; SBP, systolic blood pressure; T1D, type 1 diabetes; WHtR, waist to height ratio.

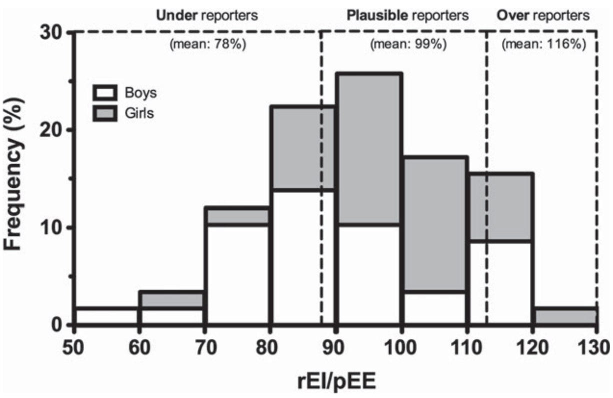


*Fig. 1.* Statistical distribution of the reported energy intake/predicted energy expenditure (rEI/pEE) ratio in boys (n = 29) and girls (n = 29).

10% of rEI/pEE variance, respectively, and 40% altogether.

## Discussion

To the best of our knowledge, this is the second study on youth with T1D to assess the validity of food intake reporting by a comparison with total energy expenditure (21), and the first to use armband measures of physical activity, instead of questionnaires, to this purpose. The main results of this study were: (i) misreporting of food intake, especially under-reporting, was common in children and adolescents with T1D; (ii) age, z-BMI and gender accounted for more than 50% of inter-individual variability of the risk of energy under-reporting; WC accounted for 25% of inter-individual variability of the risk of energy over-reporting (the lower WC, the higher the risk). WHtR, z-BMI and gender accounted for 40% of inter-individual variability of rEI/pEE.

The prevalence of under-reporting is consistent with data on both healthy children and adolescents, especially data based on the Huang method to assess reporting plausibility (15, 16) and with those reported in the only previous study on misreporting in youth with T1D (21).

These data suggest that T1D neither increases nor decreases the risk of energy misreporting in children and adolescents. Interestingly, duration of diabetes and glycometabolic control (expressed as HbA1c) were not associated with misreporting of energy intake, further suggesting that diabetes *per se* does not promote a different behavior in children and their parents in regards to food intake reporting. This implies that the

Table 2. Differences between the under-, plausible- and over-reporters. Data are shown as mean (standard deviation) or median (range)

| | Under-reporters (n = 20) | Plausible reporters (n = 32) | Over-reporters (n = 6) | p between groups comparison | p under-reporters vs. others | p over-reporters vs. others |
|---|---|---|---|---|---|---|
| Males/total | 15/20 (75) | 12/32 (37.5) | 2/6 (33.3) | 0.022 | 0.012 | 0.39 |
| Age (yr) | 14.7 (2.0) | 12.7 (2.8) | 11.8 (4.2) | 0.019 | 0.006 | 0.17 |
| BMI (kg/m$^2$) | 22.3 (2.8) | 20.0 (2.8) | 17.5 (2.4) | 0.001 | 0.001 | 0.011 |
| BMI z-score | 0.62 (0.92) | 0.17 (0.84) | −0.50 (0.61) | 0.018 | 0.025 | 0.028 |
| WC (cm) | 76.3 (6.6) | 70.5 (7.7) | 63.2 (8.7) | 0.001 | 0.002 | 0.008 |
| WHtR | 0.47 (0.04) | 0.45 (0.03) | 0.44 (0.02) | 0.23 | 0.131 | 0.25 |
| SBP (mmHg) | 110.6 (10.1) | 102.2 (10.2) | 107.7 (11.9) | 0.021 | 0.011 | 0.64 |
| DBP (mmHg) | 63.3 (7.3) | 63.9 (9.1) | 68.3 (10.3) | 0.45 | 0.596 | 0.21 |
| HbA1c (%) | 7.9 (0.6) | 7.7 (1.1) | 8.0 (1.5) | 0.76 | 0.769 | 0.56 |
| HbA1c (mmol/mol) | 62.8 (6.6) | 61.1 (12.3) | 64.7 (16.6) | 0.74 | 0.764 | 0.52 |
| Duration of T1D (months) | 102.7 (72.5) | 56.4 (38.4) | 53.7 (40.1) | 0.009 | 0.013 | 0.40 |
| CSII/total (CSII + MDI) | 4/20 (20) | 5/32 (15.6) | 1/6 (16.6) | 0.92 | 0.68 | 0.97 |
| Total insulin (U/d) | 57.0 (15.1) | 41.6 (16.9) | 29.2 (17.1) | <0.001 | <0.001 | 0.020 |
| Total insulin/kg | 0.94 (0.20) | 0.83 (0.18) | 0.79 (0.25) | 0.09 | 0.030 | 0.35 |
| Rapid or short-acting I (U/d) | 30.7 (10.8) | 21.6 (10.7) | 13.4 (8.2) | 0.001 | 0.001 | 0.020 |
| Rapid or short acting I/kg | 0.50 (0.15) | 0.42 (0.13) | 0.36 (0.12) | 0.049 | 0.023 | 0.15 |
| Rapid or short-acting I (%) | 52.7 (6.6) | 50.5 (9.0) | 46.0 (6.1) | 0.20 | 0.196 | 0.15 |
| Long-acting I (U/d) | 26.3 (5.4) | 19.9 (7.4) | 15.7 (9.1) | 0.001 | 0.001 | 0.044 |
| Long-acting I/kg | 0.4 (0.1) | 0.41 (0.1) | 0.43 (0.15) | 0.44 | 0.256 | 0.76 |
| Long-acting I (%) | 47.3 (6.6) | 49.5 (9.0) | 54.0 (2.5) | 0.20 | 0.196 | 0.15 |
| Normal weight/total (%) | 16/20 (80) | 29/32 (90.7) | 6/6 (100) | 0.33 | 0.15 | 0.33 |
| Overweight/total (%) | 4/20 (20) | 3/32 (9.3) | 0/6 (0) | 0.33 | 0.15 | 0.33 |
| Paternal education (yr) | 8 (5–17) | 13 (8–17) | 13 (8–17) | 0.21 | 0.15 | 0.88 |
| Maternal education (yr) | 13 (8–17) | 13 (8–17) | 13 (13–17) | 0.21 | 0.28 | 0.18 |
| Family SES (overall income <29 000 euros/yr) | 4/20 | 11/32 | 1/6 | 0.43 | 0.53 | 0.88 |

BMI, body mass index; CSII, continuous subcutaneous insulin infusion; DBP, diastolic blood pressure; HbA1c, glycated hemoglobin; MDI, multiple dose injection; rEI/pEE, reported energy intake/predicted energy expenditure; SBP, systolic blood pressure; SES, socio-economic status; T1D, type 1 diabetes; WC, waist circumference; WHtR, waist to height ratio.



nutrition education program we offered to children and adolescents and their families was not enough to raise adequate consciousness on food intake. Further actions in promoting family-based meal times and meal structure might be necessary to improve food intake awareness. Moreover, counseling strategies designed to break down reluctance to admitting one's over-eating, another plausible reason for under-reporting, could also be helpful, especially among overweight patients. The inverse relationship between z-BMI and rEI/pEE is in agreement with a large amount of previous evidence on non-diabetic children and adolescents (4, 7, 9, 11, 12, 14–18), but it is in contrast with the only above-mentioned previous study of youth with T1D, which did not find any association between energy intake reporting and adiposity (21). It is noteworthy that our sample had a low prevalence of overweight/obesity (12%), in line with that observed and discussed in previous studies assessing cardiovascular risk factors in an independent sample of children/adolescents with T1D recruited in the same area (22), and a much lower prevalence than that reported in the above-cited study (34%) (21).

This may imply profound differences in the average nutritional consciousness and behavior as well as in the average willingness to admit one's energy intake, between the two studied populations. This may in turn imply different roles of adiposity in affecting energy reporting.

Under-reporting was predicted by z-BMI and over-reporting by WC. Both z-BMI and WHtR independently accounted for 10%, each, of the variability in rEI/pEE considered as a continuous variable. This suggests that both total adiposity and its distribution influence the plausibility of energy reporting. A potential explanation of this finding may be that the higher

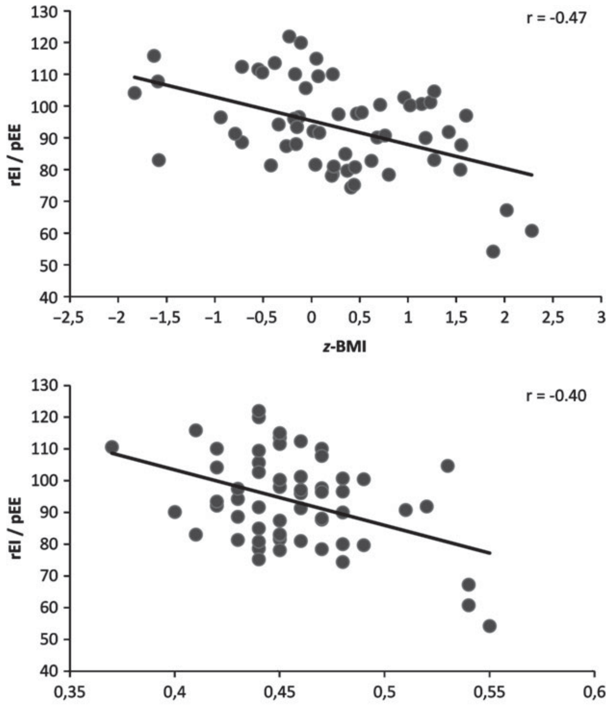


*Fig. 2*. Inverse relationship between the reported energy intake/predicted energy expenditure (rEI/pEE) ratio and body mass index (BMI) (expressed as *z*-scores) and waist-to-height ratio in the total sample.

fat accumulation in the abdominal area may induce a higher concern of one's own adiposity and, by implication, to encourage a lower self-reporting of the food actually ingested. Consistently, a relationship between weight concern and under-reporting of food intake was previously showed in children and adolescents (4, 14, 16).

Interestingly, in our sample, boys were three times more likely to under-report energy intake than girls, but the average magnitude of under-reporting was modest (11% in boys vs. about 3% in girls). This was independent of z-BMI and age, and, moreover, gender explained the same percentage of inter-individual variability in rEI/pEE as z-BMI and WHtR taken together. To the best of our knowledge, this is not consistent with previous evidence on a gender effect on energy reporting in children. Of 13 studies assessing gender, 3 found significant differences, 2 with females more likely to under-report energy intake, and 1 with males modestly more likely to do the same (10, 14). It is not easy to hypothesize plausible explanations for this important gender effect, which could arise from intrinsic male gender-associated difficulties in healthy nutrition and plausible dietary reporting in populations with T1D, or possibly from unconsciously unequal or not equally effective nutrition education provided to boys and girls and their families by our team. A potential systematic over-estimation of energy expenditure in males compared with females by the method adopted in this study is unlikely on the basis of objectively assessed minutes of physical activity by Armband instead of self-reported data on a questionnaire as performed in other studies (14). Nevertheless, further studies are needed to explore the role of gender on energy reporting and factors modulating this role in this age group.

Ten percent of the total sample over-reported their energy intake and had a z-BMI ranging from −2 to 0 (average: −0.50). This suggests that some children/adolescents with T1D could be concerned with food intake and overestimate it even in absence of an overt restrictive weight disorder. Longitudinal studies are warranted to assess whether energy over-reporting is a predictor of energy restriction in patients with T1D.

Our study has some potential limitations: (i) the studied sample, although ≥80% powerful to detect the reported associations of gender, z-BMI and age with misreporting, was too small to provide accurate estimates of the effect size of these variables, whose ORs display, in fact, large confidence intervals. Therefore, further studies with a larger sample size may help to reduce the uncertainty concerning the effect sizes; (ii) the cut-off points used in this paper for the degree of energy intake plausibility may be challenged, although the approach presented has been used by other investigators (15, 16). In fact, it may be argued that the ±1 SD of pEI/pEE interval could be ineffective in separating children who really under-reported energy intake for inherent measurement error or behavioral factors from those who simply had a lower energy intake than predicted, during the 3-d recording period, because of a 'natural' variation in the day-to-day energy intake in human subjects. Nevertheless, in order to validate our approach, we calculated the intra-individual day-by-day variation (CV) of energy intake in our sample, which was on average 10.5% (6.2) for males and 11.8% (6.2) for females. These values are very close to the SD stated in the formula we adopted to assess the plausibility interval (12%), which reinforces the formula's reliability. (iii) The lack of a control group. However, the aim of the study was to assess differences in reporting energy intake in a sample of children and adolescents with T1D and not to compare subjects with and without diabetes; (*iv*) ethnicity. The results of our study on a sample of children of European ancestry may not be directly extended to children of other ethnic groups without further studies; (v) the method used to assess EI and EE. Previous studies showed that all the methods available for measuring energy intake in children and adolescents in free-living conditions show a certain level of inaccuracy. The weighed dietary method we used in this study proved to be fairly accurate from a comparison with total energy expenditure measured by the doubly labeled water (DLW) method (13). To estimate total energy expenditure we predicted EE by RDI equations including physical activity coefficients, which proved to be reasonably accurate in comparison with energy expenditure measured by indirect calorimetry and the DLW (31). Obviously, the use of the DLW method might be preferable. However, high costs, difficulty of $^{18}O$ availability in the world, and technical complexity for isotope measurements limit the use of the DLW method in a clinical setting. Therefore, considering the purposes of this study, the use of dietary recording and RDI equations for pEE can be considered fairly accurate.

The study also has several points of strength: (i) the simultaneous measure of EI and EE in free-living conditions, with the use of SWA to assess PAL more accurately than by 'guesstimate'; (ii) the simultaneous exploration of several potential predictors of energy misreporting, among which disease-related variables.

In conclusion, children and adolescents with T1D tend to report inadequately their energy intake – in particular to under-report. Under-reporting is positively associated with z-BMI, age and male gender. These findings suggest that clinicians must be cautious in trusting the energy intake data reported by children and adolescents with T1D. In practical terms, a greater effort should be devoted to increasing the food intake awareness of children and adolescents with T1D.

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