Comparison of total energy expenditure and energy intake in children aged 6–9 y[1–3]

Janice O'Connor, Elizabeth J Ball, Kate S Steinbeck, Peter SW Davies, Connie Wishart, Kevin J Gaskin, and Louise A Baur

ABSTRACT

Background: The accurate measurement of food intake in children is important for assessing nutritional status.

Objective: We sought to both compare measurements of energy intake (EI) from diet records and of total energy expenditure (TEE) by the doubly labeled water (DLW) method and to investigate misreporting of EI.

Design: Forty-seven children (22 boys and 25 girls) aged 7.4 ± 0.8 y ($\bar{x}$ ± SD) were recruited from 25 schools in western Sydney. TEE was measured by DLW over 10 d and EI by use of 3-d food records. Misreporting was defined as [(EI − TEE)/TEE] × 100%.

Results: Girls had a higher (P = 0.02) percentage of body fat (28.2 ± 7.0%) than did boys (22.9 ± 8.0%); otherwise there were no differences among sex. Although mean (±SD) values for EI (7514 ± 1260 kJ/d) and TEE (7396 ± 1281 kJ/d) were not significantly different, there was no significant correlation between EI and TEE. EI and TEE were 9% and 11% lower, respectively, than current World Health Organization recommendations for EI. The relative bias (mean difference, EI − TEE) was low at 118 kJ/d, but the limits of agreement (bias ± 2 SD of the difference) were wide at 118 ± 3345 kJ/d. Although the mean percentage of misreporting was low (4 ± 23%), the high SD indicates large intraindividual differences between EI and TEE. The most significant predictor of misreporting was dietary fat intake (r^2 = 0.45, P < 0.0001). Misreporting was not associated with sex or body composition.

Conclusions: In this age group, reported EI is not representative of TEE at the individual level. However, at the population level, 3-d food records may be used for surveys of EI by 6–9-y-old children. *Am J Clin Nutr* 2001;74:643–9.

KEY WORDS Food record, dietary energy intake, doubly labeled water, energy expenditure, children, misreporting, macronutrients, dietary fat, Sydney, Australia

INTRODUCTION

An accurate measurement of food intake in children is important for assessing nutritional status. Studies in which energy intake (EI) data in children were validated by using total energy expenditure (TEE) estimated by the doubly labeled water (DLW) method have shown that much of the data are prone to bias through both under- and overreporting (1–7). The DLW technique enables the noninvasive measurement of carbon dioxide production in free-living subjects over a 10–14-d period and is a well-established reference method for measuring TEE (8–10). Because EI must equal TEE in conditions of energy balance, the DLW technique can be used to validate estimates of EI.

Misreporting of dietary EI can be defined as the difference between EI (computed from food records) and TEE (estimated from the DLW method) as a percentage of TEE (11). Underreporting and overreporting may be due to either eating more or less than one's habitual intake during the period of the food record or failing to record accurately all foods consumed, either deliberately or because of forgetfulness. Mistakes can be also made in identifying types of food and in estimating portion sizes of foods consumed.

Although many studies have been conducted to validate EI and investigate misreporting in adults, few such studies have been conducted in children. Accuracy of food intake records in children may vary depending on age, developmental stage, and whether the food consumed is recorded by a parent or child. In studies of children and adolescents aged between 1 and 18 y in the United States, United Kingdom, and Sweden, both underreporting and good agreement of EI and TEE estimated by DLW were observed through the use of diet records (2–5, 7, 12).

Results from the small number of studies in children aged <10 y indicate that diet history, diet recalls, and food frequency questionnaires tend to overestimate EI, whereas diet records (weighed or measured) either underestimate or are in good agreement with TEE by DLW (1–7, 12, 13). However, validation studies of EI are limited in children aged 6–9 y. This age is of particular interest because it is a time when physical activity and eating patterns change as children become established in their school schedules and in other routines of middle childhood. To

[1] From the Department of Paediatrics and Child Health, University of Sydney, Australia; the James Fairfax Institute of Paediatric Nutrition, The Children's Hospital at Westmead, Westmead, Australia; Metabolism and Obesity Services, Royal Prince Alfred Hospital, Camperdown, Australia; and the Queensland University of Technology, Kelvin Grove, Australia.

[2] Supported by the Children's Hospital Fund and the James Fairfax Institute.

[3] Reprints not available. Address correspondence to LA Baur, Department of Paediatrics and Child Health, Locked Bag 4001, The Children's Hospital at Westmead, Westmead NSW 2145, Australia. E-mail: louiseb3@chw.edu.au.

Received November 7, 2000.

Accepted for publication March 2, 2001.

our knowledge, only 2 studies have been conducted that compared EI from diet records with TEE from DLW in children aged 6–9 y: one study with 12 subjects (aged 7 y) and another study that was restricted to only girls (n = 14, aged 8 y) (4, 7). Several studies, mostly in younger children, showed that measures of TEE by DLW are lower than current recommendations for EI (14–18). However, few such studies have been conducted in children aged 6–9 y. Therefore, the aims of the present study were to compare the level of agreement between reported EI and estimates of TEE by DLW and to investigate misreporting of EI in a group of Australian children aged 6–9 y.

SUBJECTS AND METHODS

Subjects

The 47 subjects (22 boys and 25 girls) in this study were from a subset of 62 children aged 6–9 y who were part of a larger study on energy expenditure (19). From the original sample of 62 children, parents of 51 of the children elected to complete a 3-d diet record. Of these 51 children, 4 were excluded from the analysis, 3 because the record was kept only for 2 d and 1 because the record was kept over a weekend, including only one weekday.

Subjects were recruited from state primary schools in western Sydney. All schools within a 10-km radius of the study center, an area that covers a wide range of persons of different socioeconomic status, were contacted by letter. With the approval of school principals, information was then distributed through the school systems to parents, inviting them to have their child participate in the study. Interested parents contacted us directly and children were recruited from 25 schools within the 10 km radius. Children with any chronic illness other than asthma, or those with acute illness at the time of study were not recruited. During the time of the study no children were taking medications, such as β_2 agonists or methylphenidate, that could have affected the results.

The study protocol was explained to both parents and children, and informed written consent was obtained from a parent. The study was approved by the Human Ethics Committee of The Children's Hospital at Westmead, and the New South Wales Department of Education and Training gave approval for children to be recruited through state schools.

Protocol

Children attended the study center (James Fairfax Institute of Paediatric Nutrition at The Children's Hospital at Westmead) after school or during school holidays. The subjects were studied between June 1998 and February 1999. At this visit, the study protocol was explained, anthropometric measurements were taken, and the doubly labeled water dose was given as explained in detail below.

Anthropometric measurements

Anthropometric measurements were made by using standardized techniques. Standing stretched height (±0.1 cm) was measured by using a Harpenden stadiometer (Holtain Ltd, Crymmych, United Kingdom). Body weight (±0.01 kg) in was measured by using digital scales while subjects wore light clothing. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2).

The heights, weights, BMIs, and ages of the subjects in our study were compared with those of a recent, well-sampled population of Australian schoolchildren (The Health of Young Victorians Study; 20) and with the National Center for Health Statistics (NCHS) reference population (21, 22). These measurements were normalized by being expressed as SD (z) scores (22, 23).

Total energy expenditure

TEE was measured over a period of 10 d by using the DLW method. A baseline urine sample was collected before subjects were given an oral dose of DLW (0.05 g ^2H_2O/kg and 0.125 g $H_2{}^{18}O$/kg) from a flask by use of a drinking straw. The flask was weighed before and after dosing to determine the actual dose of DLW administered. Isotopes were sourced from CK Gas Products Ltd, Berkshire, United Kingdom ($H_2{}^{18}O$) and the Australian Nuclear Science and Technology Organisation, Lucas Heights, Australia (^2H_2O). At home, subjects collected a urine sample 3–6 h postdose and then once daily for the next 10 d. Samples were frozen until collected by a research assistant at the end of the collection period. Samples were analyzed for ^2H_2O and $H_2{}^{18}O$ by isotope ratio mass spectrometry in the energy metabolism laboratory at the Queensland University of Technology. The technique has been described in detail elsewhere (12, 24). In brief, the multipoint approach was used with an assumed respiratory quotient over the 10-d period of 0.85. In subjects with a zero energy balance and zero or minimal growth over a period of days, TEE would also be equal to total EI. In the age range of children in this study, the energy stored in new tissue (ie, growth) would be a very small proportion (≈2%) of total EI.

Measurement of body composition

Fat-free mass measures were derived from the ^{18}O dilution space under the assumption that this was 1% larger than total body water and by using the appropriate value for the hydration of fat-free mass in children of different ages (25). Fat mass was calculated as the difference between body weight and fat-free mass. Percentage of body fat was calculated by using fat mass and body weight measurements.

Resting energy expenditure

Anthropometric, TEE, and body-composition measurements were taken in the afterschool period and it was therefore not possible to determine resting energy expenditure (REE) of each subject in the fasted state. It has been shown in our facility, and those of others, that there is good agreement between REE of prepubertal children measured by indirect calorimetry and REE predicted by the Schofield equations (26–28). For example, Firouzbakhsh et al (27) directly measured REE in 199 healthy children aged 5–16 y and found good agreement between measured REE and REE predicted by the Schofield equations. The Schofield equations have been widely used to predict REE in many studies in children (29–31). We therefore calculated predicted REE for each subject by using the Schofield equations (28), which are based on body weight, age, and sex. Physical activity level was defined as the ratio of TEE to REE.

Energy intake

The dietary intake record was explained to parents at the time of their visit to the study center. With assistance from their child, parents were asked to record their child's food and drink intake for 3 consecutive days, including 1 weekend day. Parents were asked to inform caretakers to document details of meals and snacks that were eaten by subjects when they were either away from home or in the absence of parents, for example,

TABLE 1
Physical characteristics of 47 children[1]

	Total (n = 47)	Boys (n = 22)	Girls (n = 25)
Age (y)	7.4 ± 0.8 (6.1–8.9)	7.2 ± 0.7 (6.1–8.5)	7.6 ± 0.9 (6.3–8.9)
Height (cm)	123.6 ± 6.1 (113.6–137.2)	123.3 ± 5.4 (115.7–136.8)	123.9 ± 6.8 (113.6–137.2)
Height z score	0.06 ± 0.77 (−1.53 to 2.36)	0.12 ± 0.86 (−0.93 to 2.36)	0.00 ± 0.70 (−1.53 to 1.64)
Weight (kg)	25.8 ± 5.2 (19.1–45.8)	25.0 ± 4.6 (19.1–37.9)	26.5 ± 5.8 (19.3–45.8)
Weight z score	0.50 ± 1.14[2] (−1.51 to 3.82)	0.48 ± 1.37 (−1.51 to 3.82)	0.52 ± 0.94[2] (−0.81 to 3.14)
BMI (kg/m^2)	16.8 ± 2.3 (13.46–25.06)	16.4 ± 2.3 (13.5–24.0)	17.1 ± 2.3 (13.6–25.1)
BMI z score	0.25 ± 1.06 (−1.64 to 3.14)	0.07 ± 1.16 (−1.64 to 3.14)	0.40 ± 0.97[2] (−1.42 to 2.53)
Body fat (%)	25.7 ± 7.9 (11.9–50.5)	22.9 ± 8.0 (11.9–40.2)	28.2 ± 7.0[3] (19.7–50.5)

[1] $\bar{x}$ ± SD; range in parentheses.
[2] Significantly different from the National Center for Health Statistics reference population median, $P < 0.05$.
[3] Significantly different from boys, $P = 0.02$.

during afterschool care. Household measures (eg, metric cup and spoons) were used to describe quantities of food items when possible. Instructions were given on how to record cooking methods, brand names of foods, and recipes used. Parents were asked to submit family recipes of any meals that had been made and consumed from such recipes during the record period. A booklet in which to record food and drink intake was provided, in addition to a sample of a completed record and metric measuring cups and spoons. A phone call was made to parents during the days the record was kept to discuss any problems, and a dietitian reviewed the food record upon completion. Further details and clarification of food items were obtained by phone calls to parents when necessary. Food records were analyzed using the DIET 1.0, version 4.0, computer program (Xyris Software, Highgate Hill, Australia), which is based on a database of Australian foods (32).

Goldberg's cutoffs for dietary records

Minimum cutoffs for habitual energy expenditure below which a healthy adult could not live a normal sedentary lifestyle have been established to evaluate EI data (33). The Goldberg tabulated cutoff limits identify minimum plausible levels of energy expenditure expressed as a multiple of REE (33). Although these cutoffs were developed for adults, they have been adopted for use in children (34) and we used them as a screening tool to detect those records likely to be false reflections of EI.

A ratio of EI:REE of 1.06 is the Goldberg cutoff to test whether EI reported from a 3-d diet record is a plausible measure of the food consumed during the actual measurement of dietary intake (33). In the current study, the mean ratio of EI:REE was 1.72 ± 0.24 (range: 1.26–2.26). Therefore, according to the appropriate Goldberg cutoff, no food records needed to be discarded due to failure by parents to record a significant proportion of their child's dietary intake.

Statistical analysis

Data were analyzed using SPSS for WINDOWS release 8.01 (SPSS Inc, Chicago). Data are expressed as means ± SDs. One-way analysis of variance was used to examine sex differences in physical characteristics, reported EI, measured TEE, misreporting, and reported macronutrient intake. Misreporting was defined as [(EI− TEE)/TEE] × 100%. This ratio was used to indicate the magnitude of the difference between EI and TEE in relation to the subject's average daily energy expenditure measured by use of DLW (11).

Student's t test was used to investigate the differences between children's height, weight, and BMI z scores and the NCHS reference population median. A nonparametric test (Mann-Whitney U test) was used to compare age, height, weight, and BMI of children in our study (n = 47) with those of children in the Health of Young Victorians Study (n ≥200; 20) because of the unequal number of subjects participating in the 2 studies. Reported EI and TEE data were analyzed by using the Bland and Altman technique for assessing agreement between 2 methods of measurement (35). Correlation was used to determine the level of association between variables. Linear regression was used to investigate relations between reported EI and measured TEE. Standard multiple linear regression techniques were used to develop a model that predicted the level of misreporting. P values < 0.05 were considered significant.

RESULTS

Subject characteristics

Physical characteristics of all subjects are shown in **Table 1**. There were no significant differences between boys and girls for mean age, height, height z score, weight, weight z score, BMI, or BMI z score. However, girls had a significantly higher percentage of body fat than did boys.

The mean height, weight, and BMI of the subjects were compared with those of children in the Health of Young Victorians Study (20). There was no difference between the 2 groups except that the 7-y-old girls were shorter and the 8-y-old boys were younger in the present study than in the Health of Young Victorians Study. Therefore, as would be expected, the 7-y-old girls were lighter and the 8-y-old boys had a lower BMI in the present study than in the Health of Young Victorians Study. The mean weight z score for the total group and the mean weight and BMI z scores of girls were significantly different from zero ($P < 0.05$), indicating that these groups were heavier and had a greater BMI than did the NCHS reference population (Table 1).

Energy intake data

Reported macronutrient intake and percentage of energy from protein, carbohydrate, and fat are shown in **Table 2**. There were no significant differences between boys and girls in macronutrient intake except that boys had a higher protein intake and percentage of energy from protein (70 ± 15 g/d and 16 ± 2% in boys compared with 61 ± 13 g/d and 14 ± 2% in girls).

TABLE 2
Total energy expenditure (TEE), energy intake (EI), percentage of misreporting, and EI and TEE as a percentage of current recommendations and macronutrient intake[1]

	Total group (n = 47)	Boys (n = 22)	Girls (n = 25)
TEE (kJ/d)	7396 ± 1281 (5020–10605)	7578 ± 1184 (5605–10040)	7237 ± 1364 (5020–10604)
EI (kJ/d)	7514 ± 1260 (5282–10211)	7737 ± 1474 (5306–10211)	7318 ± 1028 (5282–9542)
EI − TEE (kJ/d)	118 ± 1706 (−3538 to 3515)	159 ± 1746 (−2862 to 3515)	81 ± 1706 (−3538 to 3194)
Misreporting (%)[2]	4 ± 23 (−33 to 56)	4 ± 23 (−30 to 53)	5 ± 24 (−33 to 56)
EI/TEE	1.04 ± 0.23 (0.67–1.56)	1.04 ± 0.23 (0.70–1.52)	1.04 ± 0.24 (0.67–1.56)
EI (% of current recommendations)[3]	91 ± 16[4] (61–129)	90 ± 16[4] (67–129)	92 ± 15[4] (61–126)
TEE (% of current recommendations)[3]	89 ± 15[4] (60–136)	88 ± 16[4] (96–136)	90 ± 15[4] (64–130)
Protein			
(g/d)	65 ± 15 (38–100)	70 ± 15 (43–100)	61 ± 13[5] (38–97)
(% of energy)	15 ± 2 (10–21)	16 ± 2 (13–21)	14 ± 2[5] (10–19)
Carbohydrate			
(g/d)	237 ± 49 (138–339)	238 ± 63 (138–339)	236 ± 33 (177–298)
(% of energy)	52 ± 7 (31–61)	50 ± 7 (31–61)	53 ± 5 (41–61)
Fat			
(g/d)	67 ± 16 (35–106)	70 ± 17 (35–106)	64 ± 15 (39–94)
(% of energy)	34 ± 5 (25–49)	35 ± 7 (25–49)	33 ± 4 (26–42)

[1] $\bar{x}$ ± SD; range in parentheses.
[2] Misreporting = [(EI − TEE)/TEE] × 100%.
[3] Current recommendations for energy intake based on weight, age, and sex (14).
[4] Significantly lower than current recommendations, $P < 0.02$.
[5] Significantly different from boys, $P < 0.05$.

Sex differences in energy intake and expenditure variables

TEE, reported EI, level of misreporting, and comparison of TEE and EI with FAO/WHO/UNU recommendations for EI are shown in Table 2. There were no significant differences between boys and girls for TEE, reported EI, TEE as a percentage of current recommendations, or EI as a percentage of current recommendations. However, both TEE and EI were significantly lower than current recommendations for EI (11% and 9%, respectively).

Comparison of reported energy intake and measured energy expenditure

In the total group, mean EI and TEE were 7514 ± 1260 and 7396 ± 1281 kJ/d, respectively (Table 2). However, there was no significant relation between reported EI and measured TEE (r = 0.10, P = 0.51). A scatter plot of the mean daily total EI compared with the mean daily TEE for all subjects is shown in **Figure 1**. The mean ratio of EI:TEE was 1.04 ± 0.23, which was not significantly different from 1.00.

To assess bias between the 2 methods, it is more informative to examine a scatter plot of the difference between the measures of EI and TEE compared with the mean of the 2 measures (**Figure 2**). The relative bias, calculated as the mean difference between the 2 methods (EI − TEE) was 118 kJ/d. The limits of agreement, defined as the bias ± 2 SD of the difference, were −3226 kJ and 3462 kJ. There was a small bias (1.6% of average EI) for EI to be greater than TEE.

Misreporting

Misreporting of EI was defined as the difference between EI (computed from food records) and TEE (measured by the DLW method) as a percentage of TEE. Most children (55%) had a reported EI greater than measured TEE. Approximately one-third of the children had a reported EI within 10% of measured

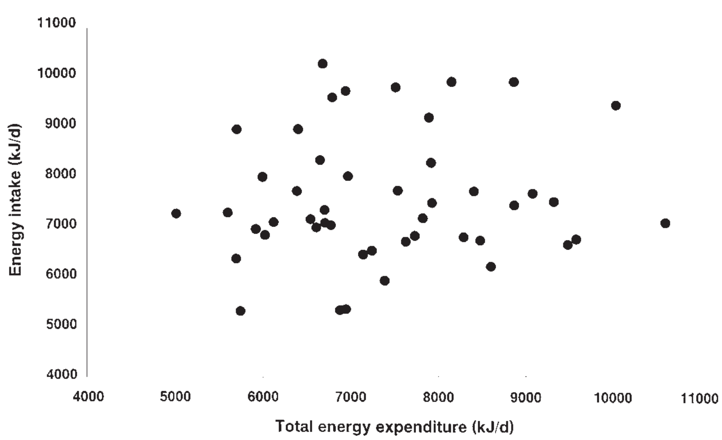

FIGURE 1. A scatter plot of mean total energy expenditure and mean energy intake in 47 children.

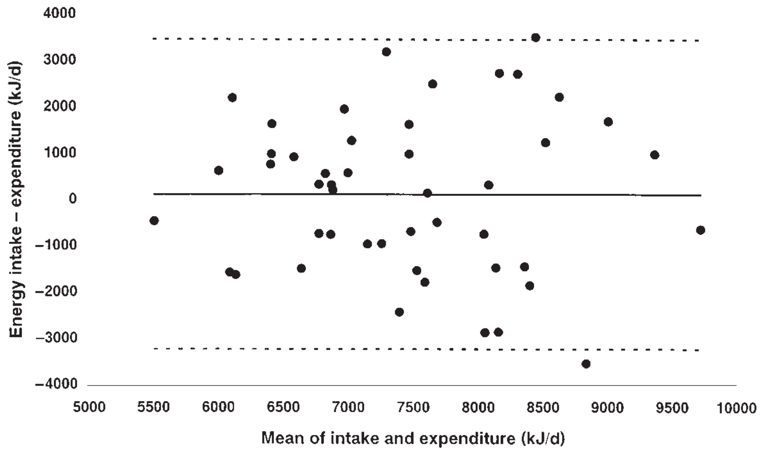

FIGURE 2. The difference between the measures of energy intake and total energy expenditure plotted against the mean of the 2 measures. The solid line indicates the mean differences between the 2 measures and the dashed lines indicate ±2 SDs.

TEE. The average percentage of misreporting was 4 ± 23%, with a range from an underestimation of 33% to an overestimation of 56%. As would be expected from the definition of misreporting, this variable was significantly and inversely related to TEE ($r = -0.66$, $P < 0.0001$). In a regression model that uses age, sex, and anthropometric and dietary variables to predict level of misreporting, fat intake (g/d) was the most significant predictor ($r = 0.67$, $P < 0.0001$). When fat intake as a percentage of EI was substituted into the regression equation, it was a less significant predictor than fat intake ($r = 0.31$, $P = 0.033$). There was a significant inverse relation between misreporting and physical activity level ($r = -0.77$, $P < 0.0001$).

DISCUSSION

The DLW method is considered to provide the most accurate measurement of TEE in free-living children (36). We therefore used the DLW method as the criterion to evaluate the accuracy of EI data from 3-d diet records in 47 prepubertal children. There were no sex differences among subjects, except, as previously reported, girls had a lower reported protein intake (37) and a higher percentage of body fat (38, 39) than did boys. In the total group, both EI and TEE were on average 10% lower than current recommendations for energy intake (14). Mean TEE and mean reported EI of subjects were similar, and the mean level of misreporting was low at 4%, indicating that there was a slight tendency to overestimate EI. The most significant predictor of misreporting was dietary fat intake, with a higher fat intake being associated with overreporting. Misreporting was not associated with sex or body composition of the children.

Children were recruited from a large number of schools. This may have inevitably been a biased sample of highly motivated parents and children, given the demands of the study, such as attendance at the study center, keeping of a 3-d diet record, and daily, timed urine collection over 10 d. Nevertheless, accuracy should be greater with well-motivated parents recording their child's EI. Our decision to use a 3-d diet record rather than a longer period of recording was based on the practical consideration that it is unreasonable to expect even highly motivated parents to record their child's EI for longer periods. In addition, because accurate food intake recording is very time consuming and requires recall of often complex daily events, the longer the time period of the food record, the greater the risk of mistakes, whether deliberate or unintentional.

Mean values for TEE and reported EI were similar in our study, and consequently the mean level of misreporting was low. Despite this, there were some large intraindividual differences between these 2 measures as evidenced by the wide range of the limits of agreement (−3226 and 3462 kJ/d) and the high SD for mean misreporting (23%), consistent with similar studies in children who were both younger and older than those in the present study (7, 13).

There are several explanations for these discrepant observations. First, it is possible that subjects were undereating or overeating during the period of the 3-d diet record, although subjects could still have been in energy balance over the 10-d period of the DLW study. Because of practical difficulties, we did not weigh the children at the end of the DLW study to detect whether they had been in energy balance; we recommend that future studies address this issue. In a study of obese adult men, most of whom underreported their EI, Goris et al (11) showed that total underreporting of EI could be explained by undereating as well as failure to record all food consumed.

A second possible explanation for the discrepancies between reported EI and measured TEE lies in the varied lifestyle patterns of children. For example, even for highly motivated parents, it is less easy to record accurately all foods eaten by more active children who are away from home for long periods during their various activities. Future validation studies of EI in children should include an independent measure of physical activity so that appropriate adjustments can be made. When evaluating EI from food records, one of the limitations of using the Goldberg cutoffs is that they are not adjusted for different levels of physical activity. Although our study was not designed to independently measure physical activity, we did find a significant inverse relationship between misreporting and physical activity level. However, although this result was significant, it would be expected from the definition of misreporting [(EI − TEE)/TEE × 100%] and of physical activity level (TEE/REE) that if TEE increases, physical activity level increases while the percentage of misreporting decreases, thus resulting in an inverse relation between these 2 variables. Clearly, the relation between a child's reported dietary EI and physical activity requires further investigation.

A third possible explanation for the individual discrepancies between reported EI and measured TEE is that the underrecording or overrecording of a child's dietary intake by parents may be deliberate or unintentional. In Western society, there is a high degree of sensitivity about personal information, such as food intake, and an awareness that individuals are judged on the type and amount of food they eat. McDiarmid et al (40) showed that adults who were found to underreport their food intake admitted in a subsequent interview that their food records were not representative of their habitual intake. Similarly, parents may be embarrassed about the type or amount of food that their children eat and may offer them what they consider to be healthy foods during the period of the food record or deliberately not record foods that were eaten (underrecording). In addition, although parents may accurately record their child's EI at home, if their child spends a significant amount of time in activities under the supervision of other adults, parents must rely on reports of EI either from their child or from other adult caretakers who may not be as committed to the study.

Consistent with findings in adults, our study showed that a higher reported fat intake was associated with a tendency to overestimate EI (41). However this finding would be expected from the definition of misreporting because increased consumption of fat, an energy dense macronutrient, is related to greater EI and hence a higher degree of overreporting.

Fifty-five percent of children in the current study had reported EI higher than TEE, indicating that there was a slight bias toward overreporting. In addition, there was no relationship between misreporting and either age, sex, BMI, BMI z score, weight, weight z score, or percentage of body fat. These results are contrary to those reported in adults showing that EI by weighed diet record is biased toward underestimation of habitual intake, especially in heavier individuals (11, 42). The influence of parental adiposity on misreporting of EI in children has yielded inconsistent results and this complex area requires further investigation (4, 13, 43). Studies in older children (aged 10 y) and adolescents have shown a positive association, similar to that found in adults, between underreporting and a tendency toward greater body fatness and body weight (2, 3, 7). There are many possible reasons for the difference in the determinants of misreporting between the current study and those in older subjects. For the young children in our study, EI was recorded by parents, whereas older children, adolescents, and adults take the responsibility for recording their own food intake. Issues pertaining to body image and current dieting behavior become more important influences in the lives of older children and could therefore affect the accuracy of self-reported food records, as was shown in adult studies (44, 45).

The results of the present study and the existing EI studies in younger children (aged 1–9 y) suggest less misreporting of dietary EI than in older children and adolescents (3, 4, 7, 12). A possible explanation is that in younger children, there is more parental control and supervision of food intake and therefore the parent can more accurately report the child's EI. In contrast, in older children who normally self-report their EI, there is a tendency toward more unstructured eating patterns and eating away from home, leading to a greater degree of forgetfulness and thus, underestimation of EI. Although misreporting appears to be age-related, we minimized this effect in our study by selecting prepubertal children in a tight age range (6–9 y).

The children and parents in our study were reasonably representative of the Australian population and hence our findings are likely generalizable to other westernized societies. The use of TEE from DLW as an independent marker of food intake in the present study has shown that, at the individual level, 3-d food records lack precision. However, our findings of a low mean level of 4% of misreporting for the total group suggest that 3 d food records may be used for population surveys of EI in schoolchildren aged 6–9 y.

We thank the children and their parents who gave their time to this study and Melissa Wake and Ross Lazarus for making the raw data from the Health of Young Victorians Study available to us.

REFERENCES

1. Lindquist CH, Cummings T, Goran MI. Use of tape-recorded food records in assessing children's dietary intake. Obes Res 2000;8:2–11.
2. Champagne CM, Fada RD, Baker NB, DeLany JP, Garsha DW, Bray GA. Assessment of energy intake underreporting by doubly labeled water and observations on reported nutrient intakes in children. J Am Diet Assoc 1998;98:430–3.
3. Bratteby LE, Sandhagen B, Fan H, Enghardt H, Samuelson G. Total energy expenditure and physical activity as assessed by the doubly labeled water method in Swedish adolescents in whom energy intake was underestimated by 7-d diet records. Am J Clin Nutr 1998;67:905–11.
4. Bandini LG, Cyr H, Must A, Dietz WH. Validity of reported energy intake in preadolescent girls. Am J Clin Nutr 1997;65(suppl):1138S–41S.
5. Champagne CM, DeLany JP, Harsha DW, Gray GA. Underreporting of energy intake in biracial children is verified by doubly labeled water. J Am Diet Assoc 1996;7:707–9.
6. Kaskoun MC, Johnson RK, Goran MI. Comparison of energy intake by semiquantitative food-frequency questionnaire with total energy expenditure by the doubly labeled water method in young children. Am J Clin Nutr 1994;60:43–7.
7. Livingstone MB, Prentice AM, Coward WA, et al. Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. Am J Clin Nutr 1992;56:29–35.
8. Schoeller DA, Ravussin E, Schutz Y, Acheson KJ, Baertschi P, Jequier E. Energy expenditure by doubly labeled water: validation in humans and proposed calculation. Am J Physiol 1986;250:R823–30.
9. Schoeller DA, van Santen E. Measurement of energy expenditure in humans by doubly labeled water method. J Appl Physiol 1982;53:955–9.
10. Seale JL, Conway JM, Canary JJ. Seven-day validation of doubly labeled water method using indirect room calorimetry. J Appl Physiol 1993;74:402–9.
11. Goris AHC, Westerterp-Plantenga MS, Westerterp KR. Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake. Am J Clin Nutr 2000;71:130–4.
12. Davies PSW, Coward WA, Gregory J, White A, Mills A. Total energy expenditure and energy intake in the pre-school child: a comparison. Br J Nutr 1994;72:13–20.
13. Johnson RK, Driscoll P, Goran MI. Comparison of multiple-pass 24-hour recall estimates of energy intake with total energy expenditure determined by the doubly labeled water method in young children. J Am Diet Assoc 1996;96:1140–4.
14. FAO/WHO/UNU. Energy and protein requirements. World Health Organ Tech Rep Ser 1985;724.
15. Goran MI, Carpenter WH, Poehlman ET. Total energy expenditure in 4- to 6-yr-old children. Am J Physiol 1993;264:E706–11.
16. Fontvieille AM, Harper IT, Ferraro RT, Spraul M, Ravussin E. Daily energy expenditure by five-year-old children, measured by doubly labeled water. J Pediatr 1993;123:200–7.

17. Davies PSW, Gregory J, White A. Energy expenditure in children aged 1.5 to 4.5 years: a comparison with current recommendations for energy intake. Eur J Clin Nutr 1995;49:360–4.
18. Prentice AM, Lucas A, Vasquez L, Davies PS, Whitehead RG. Are current dietary guidelines for young children a prescription for overfeeding? Lancet 1988;2:1066–9.
19. Ball EJ, O'Connor J, Abbott R, et al. Total energy expenditure, body fatness, and physical activity in children aged 6–9 y. Am J Clin Nutr 2001;74:524–8.
20. Lazarus R, Wake M, Hesketh K, Waters E. Change in body mass index in Australian primary school children, 1985–1997. Int J Obes 2000;24:679–84.
21. World Health Organization. Measuring change in nutritional status. Geneva: WHO, 1983:61–101.
22. Hammer LD, Kraemer HC, Wilson DM, Ritter PL, Dornbusch SM. Standardized percentile curves of body-mass index for children and adolescents. Arch Dis Child 1991;145:259–62.
23. Dibley MJ, Staehling NW, Nieburg P, Trowbridge FL. Interpretation of *Z*-score anthropometric indicators derived from the international growth reference. Am J Clin Nutr 1987;46:749–62.
24. Coward WA. The doubly labeled water ($^2H_2{}^{18}O$) method: principles and practice. Proc Nutr Soc 1988;47:209–18.
25. Fomon SJ, Haschke F, Ziegler EE, Nelson SE. Body composition of reference children from birth to age 10 years. Am J Clin Nutr 1982; 35:1169–75.
26. Allen JR, McCauley JC, Waters DL, O'Connor J, Roberts DCK, Gaskin KJ. Resting energy expenditure in children with phenylketonuria. Am J Clin Nutr 1995;62:797–801.
27. Firouzbakhsh S, Mathis RK, Dorchester WL, et al. Measured resting energy expenditure in children. J Pediatr Gastroenterol Nutr 1993;16:136–42.
28. Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr 1985;39(suppl): 5–41.
29. Amarri S, Coward WA, Harding M, Weaver LT. Importance of measuring CO_2-production rate when using ^{13}C-breath tests to measure fat digestion. Br J Nutr 1998;79:541–5.
30. Ksiazyk J, Lyszkowska M, Kierkus J. Energy metabolism in portal hypertension in children. Nutrition 1996;12:469–74.
31. Spurr GB, Reina JC, Hoffmann RG. Basal metabolic rate of Colombian children 2–16 y of age: ethnicity and nutritional status. Am J Clin Nutr 1992;56:623–9.
32. National Food Authority. NUTTAB91-92: nutrient data table for use in Australia. Canberra, Australia: Australian Government Publishing Service, 1991.
33. Goldberg GR, Black AE, Jebb SA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr 1991;45:569–81.
34. Sichert-Hellert W, Kersting M, Schoch G. Underreporting of energy intake in 1 to 18 year old German children and adolescents. Z Ernahrungswiss 1998;37:242–51.
35. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1: 307–10.
36. Torun B, Davies PSW, Livingstone MBE, Paolisso M, Sackett R, Spurr GB. Energy requirements and dietary energy recommendations for children and adolescents 1 to 18 years old. Eur J Clin Nutr 1996;50(suppl):S37–81.
37. McLennan W, Podger A. National Nutrition Survey: nutrient intakes and physical measurements. Australia 1995. Canberra, Australia: Australian Bureau of Statistics, 1998. [ABS catalogue no. 4805.0.]
38. Ruxton CHS, Reilly JJ, Kiek TR. Body composition of healthy 7- and 8-year-old children and a comparison with the 'reference' child. Int J Obes Relat Metab Disord 1999;23:1276–81.
39. Fomon SJ, Haschke F, Ziegler EE, Nelson SE. Body composition of reference children from birth to age 10 years. Am J Clin Nutr 1982; 35:1169–75.
40. McDiarmid J, Blundell JE. Dietary under-reporting: what people say about recording their food intake. Eur J Clin Nutr 1997;51:199–200.
41. Tomoyasu NJ, Toth MJ, Poehlman ET. Misreporting of total energy intake in older African Americans. Int J Obes Relat Metab Disord 2000;24:20–6.
42. Toyomasu NJ, Toth MJ, Poehlman ET. Misreporting of total energy intake in older men and women. J Am Geriatr Soc 1999;47:710–5.
43. Livingstone MBE, Robson RJ. Measurement of dietary intake in children. Proc Nutr Soc 2000;59:279–93.
44. Johansson L, Solvoll K, Bjorneboe GE, Drevon CA. Under- and overreporting of energy intake related to weight status and lifestyle in a nationwide sample. Am J Clin Nutr 1998;68:266–74.
45. Lafay L, Basdevant A, Charles MA, et al. Determinants and nature of dietary underreporting in a free-living population: the Fleurbaix Laventie Ville Sante (FLVS) Study. Int J Obes Relat Metab Disord 1997;21:567–73.