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Title: A Comparison and Validation of Child Versus Parent Reporting of Children's Energy Intake Using Food Frequency Questionnaires versus Food Records: whose an accurate reporter?

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26 **Short running head:** Validation of a child FFQ with DLW

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Abstract:

Background and Aims: The aim of this study was to (i) to compare the accuracy of reporting for child's total energy intake from a food frequency questionnaire (FFQ) completed independently by the mother, father and child in comparison to total energy expenditure (TEE) measured using doubly labelled water (DLW) (ii) compare the accuracy of the weighed food record (WFR) and DLW.

Methods: Healthy weight children (mean $\pm$ SD age 9.8 ± 1.3 years, $n=6$ girls/3 boys) and their parents independently completed an FFQ about children's intake. A 4-day WFR of child intake was recorded simultaneously. The accuracy of energy intakes reports were determined by the absolute and percentage differences between estimated energy intake and TEE measured by DLW.

Results: The mean difference (limits of agreement LOA, ± 2 SD) when compared to DLW was; child 130 (-1518, 1258) kcal or ($113 \pm 35\%$ of TEE); father 398 (0,796) kcal or ($121 \pm 13\%$); mother 807 (-213, 1824) kcal or ($144 \pm 26\%$) and for the WFR -153(1089, -1395) kcal or $95 \pm 32\%$.

Conclusions: Children were the most accurate reporters when compared to their parents, with fathers more accurate than mothers. The 4-day WFR was approximately equal to the child report FFQ in estimating EI in children 8-11 years.

Keywords: dietary assessment, child, FFQ

Introduction

It is by many agreed that there is no perfect method of assessing dietary intake¹ and that dietary intake measurement is complex. Measuring dietary intake in children is particularly challenging as limited valid tools exist to assess dietary intake in pediatric populations¹. Food frequency questionnaires (FFQs) ask respondents to report their usual food intake frequency of a defined list of foods over a nominated period of time and are a potentially valuable tool for assessing dietary intake in children. FFQs have been recommended for use in large cross-sectional and cohort studies¹ as they capture usual dietary intake over longer periods of time compared to other methods and can be collected from a large number of people in a relatively short time frame². In addition FFQs have a relatively low respondent and analytic burden^{3,4} and can be presented using a range of options including self, proxy, interviewer or web administration. However, FFQs have been criticised on the grounds of overestimation of intake⁵, limited food lists, portion sizes, and recall bias⁵.

There are specific additional concerns in using FFQs in children, which are related to child cognitive development and capacity to concentrate, and may influence their ability to both recall foods and estimate portion sizes⁶. For these reasons child dietary intake is commonly reported by a proxy, usually parents⁶, and most commonly by the mother⁷ who is regarded as the gatekeeper of food provision within the family environment. In a review of validation studies for the assessment of dietary intake in children, parents were proxies or parental assistance was used in more than 50% of studies¹. The ability of a child to self report food and drink consumed increases with age⁶. It has been suggested that to complete an FFQ, children need to be ≥ 12 years old⁸. However, uncertainty exists when a child is between the ages of eight and 12 years as to who (i.e. parent or child) should be asked to report child intake, due to factors including

increasing child independence, cognitive abilities and increased consumption of food and drinks outside the home outside of parental control.

The Australian Child and Adolescent Eating Survey (ACAES) is a child-specific FFQ that has been developed and validated in youth aged 9-16 years for fruit and vegetable intake, nutrient and fat intake⁹⁻¹¹. While the ACAES has been shown to be valid for energy intakes in the younger age groups (8-12 years) for both child and maternal reports¹², it was not clear who was the more accurate reporter, mother or child and accuracy of father report is unknown.

The gold standard method for validation of energy intake is by comparison with total energy expenditure determined using the doubly labeled water (DLW) technique in weight stable individuals. Unfortunately, this technique cannot be used widely due to its high cost and the need for specialized laboratory facilities and staff expertise for analysis⁷. As an alternative, weighed food records (WFRs) are commonly used as the reference method in dietary intake validation studies as the errors associated with WFRs and FFQs are considered to be largely independent¹³.

Therefore this study aimed to determine and compare the accuracy of the reporting of child daily energy intake determined by parent-completed 4-day weighed food records and the ACAES FFQ completed independently by the mother, father and child, in comparison to total energy expenditure (TEE) measured by the DLW method.

Materials and Methods

Participants

Children aged 8-11 y with two eligible care givers (defined as residing predominantly with the child) were recruited from the Hunter region, NSW Australia during February 2009 predominantly through university emails and community noticeboards. Children were eligible to participate if they were a healthy weight (defined by age and sex-specific Body Mass index (BMI) 18.35 – 20.74)¹⁴; had two caregivers who were willing to attend all required sessions; no known medical conditions affecting body weight, metabolic rate or appetite; and not taking any medications associated with weight change. These inclusion criteria were specific to reduce heterogeneity among participants given the high costs associated with the DLW method. Parents provided written informed consent, and children assent, prior to baseline assessments. Ethics approval was obtained from the University of Newcastle Human Research Ethics Committee.

Study design and data collection

All participants attended the university laboratory on day one (baseline) and day 10 of a 10-day data collection period. On day one, child participants received an oral loading dose of DLW. Urine samples were collected before and after DLW on day one and once daily on days 2-10. Child EI was additionally assessed by a 4-day WFR completed by a parent(s) during the 10 days and by completion of the ACAES FFQ by the child and both parents on day one. Child participants fasted overnight prior to the baseline visit. Height and weight of the child participant were measured at baseline and day 10 to assess weight stability. Parents/caregivers were advised to maintain usual dietary patterns and physical activity habits for their children to facilitate weight stability and therefore usual total energy expenditure (TEE). Participants were phoned

once during the data collection period by a member of the research team (TB) to check progress and adherence to the study protocol.

Outcome measures

Dietary intake: All participants in each family (child and two caregivers) independently completed the ACAES FFQ under supervised conditions to estimate usual child intake. ACAES is a semi-quantitative FFQ and asks about intake frequency of 120 food items over the previous six months. It was developed and initially validated for use with Australian children^{9 11 10}. The ACAES was used to derive estimated total energy intake (EI) from the reported frequency of the child's consumption of a defined list of foods over the previous six months⁹. Portion sizes for individual food items were accessed from the Australian Bureau of Statistics (ABS) and data from the 1995 Australian National Nutrition Survey or the "natural" serving size for common items such as a slice of bread. The frequency options ranged from 'never' up to '4 or more times per day for foods and up to '7 or more glasses per day' for some beverages. Data from the ACAES FFQ was scanned and nutrient intakes computed via FoodWorks (Professional Version 3.02.581) using the following databases: Australian AusNut 1999 database (All Foods) Revision 14 and AusFoods (Brands) Revision 5 (Xyris Software (Australia) Pty Ltd, 2004: Brisbane Australia).

Child EI was additionally assessed from a 4-day WFR kept by the parents (primarily the mother), which included weekdays and at least one weekend day. At baseline, parents were provided with detailed instructions from an Accredited Practicing Dietitian (TB) on how to complete the WFR. Parents were provided with a set of SOEHNLE Venezia electronic kitchen scales (Soehnle-Waagen GmbH & Co, Murrhardt, Germany) that weigh in one gram (± 1 g) increments up to two kilograms, as well as a record book to record intake. WFRs were checked for completeness on

day 10 with clarifications made with participants. The same nutrient analysis programs described above were used to generate daily energy intake.

Doubly labeled water (DLW)

TEE was measured using the DLW method as described in detail elsewhere¹⁵. Briefly, background isotope levels were determined at baseline with a urine sample collected in the laboratory prior to dosing with the DLW. Child participants were then given an oral loading dose of DLW ($^2\text{H}_2\text{O}$ and H_2^{18}O) corresponding to 0.083g $^2\text{H}_2$ (99.8 atom % excess; Sigma Aldrich, Milwaukee, WI) and 1.3g ^{18}O (10 atom % excess; Taiyo Nippon Sanso, Yokogawa, Japan) per kg of measured body weight. The isotope dose was measured in grams to three decimal places. A second urine sample was obtained approximately five hours post dose, and then daily urine samples were collected for 9-consecutive days with participants recording the time each sample was collected. Urine samples were stored frozen (at -20C) until analyzed on an Isoprime Dual Inlet Stable Isotope Ratio Mass Spectrometer (DI-SIRMS). The multipoint approach was used to calculate TEE as previously described [14]. All samples were analyzed in duplicate with laboratory standards calibrated against an international suite of waters including Vienna Standard Mean Ocean Water (VSMOW)¹⁶. ^2H and ^{18}O being reported in % relative to VSMOW with an analytical uncertainty better than $\pm 3\text{‰}$ (1SD) and $\pm 0.5\text{‰}$ (1SD), respectively. CO_2 production was derived from ^2H and ^{18}O disappearance rate constants (22) calculated by least squares regression analysis. TEE was then calculated by the DeWier equation using the rates of CO_2 production and the respiratory quotient (RQ) (23).

Anthropometric measures

Height was measured using a Harpenden portable stadiometer (Holtain Limited, Dyfed, Britain)

to 0.1 cm using the stretch stature method at baseline. Weight was measured to 0.01kg on a digital scale (CH-150kp, A&D Mercury Pty Ltd, Australia), in light clothing and without shoes, at baseline and on day 10. Weight change over the 10 day period was calculated. BMI on day one was calculated using the standard equation ($\text{weight [kg]} / \text{height[m]}^2$) with BMI z scores determined using the least mean square (LMS) method ¹⁷.

Data analysis

Data are presented as mean $\pm$ standard deviation (SD) and were analysed with SPSS version 19 (SPSS Inc, Chicago, Illinois, USA). The accuracy of energy intake derived from all the FFQ reports and the WFR were assessed by calculating the absolute (ie (EI-TEE) and percentage difference (EI/TEE x 100) from the method of DLW.

The strength of any associations between EI derived from the FFQs and WFR with TEE were assessed using Pearson Correlation analyses. Bland-Altman plots were produced according to standardised methods ¹⁸. The plots indicate the direction of bias and whether it is consistent across levels of intake. The limits of agreement (criterion: mean difference $\pm$ 2SD for the difference between the measures) determine whether the agreement between the two methods is acceptable ¹⁹. Interpretation of the Bland-Altman plots were based on categories defined by Tang ²⁰ and used previously in validation studies ⁹. ‘Good agreement’ is when the difference between the two measures is approximately equal to or less than one SD, ‘Fairly good (acceptable) agreement’ is when the difference is equal to or less than 2SD and ‘bad or poor’ agreement is when the differences are equal to or greater than 3SD.

Pearson correlations were tested between the averages and differences of the each of the two measures (ie FFQchild vs DLW, FFQmother vs DLW, FFQfather vs DLW and WFR vsDLW) in order to determine if the difference between the two measures is dependent on initial value.

Participants were identified as under-reporters of EI based on the 95% confidence limits of the expected EI: TEE of 1²¹. The 95% confidence limits were calculated, as follows:

$$\pm 2 \times \sqrt{[(CV_{EI}^2/D) + (CV_{TEE}^2)]}$$

where CV_{EI} is the within subject coefficient of variation (CV) for EI from a FFQ (23%)²², and

CV_{TEE} is the within subject CV for TEE (8.8%). D is the number of days of dietary assessment,

however as FFQs are used to capture habitual intake, D is defined as infinity²¹. Therefore,

participants with EI: TEE <0.82 were classified as under-reporters of EI, those with EI:

TEE>1.18 were classified as over-reporters, and those within the range were considered adequate

reporters.

Results

Eleven child participants were recruited to the study. One child became ill during the study and one child did not adhere to the study protocol; therefore data suitable for analysis were obtained from nine children. These children were all weight stable (± 1 kg) during the data collection period. The mean weight variation during the 10-day collection period was 0.15 ± 0.17 kg (range -0.2 to +0.3kg). The children ($n=9$) were mostly female ($n=6$) and had a mean $\pm$ SD age 9.8 ± 1.3 years, BMI 17.6 ± 2.9 kg/m² and BMI z score 0.35 ± 0.94 . Adult participants were all biological parents with equal numbers of mothers ($n=9$) and fathers ($n = 9$).

Descriptive statistics for the children's EI derived from the WFR, the FFQ reported separately by the child, mother and father, and TEE from the DLW method are presented in **Table 1**. **Figures 1a-1d** display the Bland-Altman plots for the average versus mean difference in EI between FFQ or WFR and TEE by DLW. **Figure 2** summarizes the level of bias and extent of variation between methods. The bias for the WFR was small with the bias favoring slight underreporting of child EI but substantial variation indicated by the wide limits of agreement. The child FFQ reports showed only small over-reporting bias but substantial variation. Both parents FFQ reports indicated substantial over-reporting bias, with greater over reporting by mothers compared to fathers. The extent of variation was lowest for father FFQs with narrow limits of agreement; mothers limits of agreement were also wide.

The limits of agreement (LOA) were wide for all dietary assessment methods except the fathers' FFQs indicating a lack of complete agreement between any of the measures at the individual level. At the group level, all values for the WFRs, child reports and father reports fell within the LOA (2SD) indicating fairly good agreement²⁰ with the DLW method. For the mothers, the LOA were the widest with one value falling outside the LOA, indicating a (slightly) lower level of

agreement compared with the child and father reports. In descending order, the mean difference (LOA) when compared to DLW for each reporter were 130 (-1518, 1258) kcal for child or (113±35% of TEE), 398 (0,796) kcal for father or the father (121 ± 13%), 807 (-213, 1824) kcal or (144±26%) for mother and -153(1089, -1395) kcal or 95 ±32% for the WFR (Figure 2). The limits of agreement were narrowest for the father report.

From the Bland Altman plots the level of bias for the FFQ and WFR were consistent across varying levels of energy intakes. Thus, no meaningful correlations were found between the means of and differences between dietary assessment methods and the DLW estimation of TEE, indicating that the difference between the two measures is not dependent on the magnitude of the mean EI value. Pearson correlation coefficients between EI, as measured by the FFQ and TEE, was statistically significant when reported by fathers only $r = 0.92$, $P < 0.001$, but not for mother report (0.53, $P = 0.15$), or child report (0.35, $P = 0.37$). The Pearson correlation for the WFR with DLW was also not significant (0.30, $P = 0.44$).

Classification of mis-reporters for energy intake using cut points for the FFQ were as follows: two children (22%) were under-reporters, three (33%) were accurate and four (44%) were over-reporters; for mothers, one (11%) was categorized as accurate and eight (89%) as over-reporters; for fathers, three (33%) were categorized as accurate and six (67%) as over-reporters.

Discussion:

This study evaluated the accuracy of child total energy intake reporting by comparing the ACAES FFQs completed independently by the mother, father and child in comparison to total energy expenditure (TEE) measured using DLW. The child-reported FFQ evaluation was the closest to gold standard measure of DLW, indicating that the children were the most accurate reporters ($113 \pm 35\%$) using the ACAES FFQ, followed by fathers ($121 \pm 13\%$), with mothers ($144 \pm 26\%$) the least accurate.

The 4-day WFR assessment of total energy intake was also compared with the DLW method with the discrepancy between the WFR and TEE only 5% of daily kcal, indicating very good accuracy. Although the WFR on average under-reported child EI whereas the child FFQs over-reported intake by approximately 13% of daily kcal, the child FFQs were only slightly less accurate than the assessment of child EI obtained from the WFR. This is surprising given that the WFR provides much greater detail about foods and portions sizes than an FFQ¹³. The practicality of using WFRs is commonly questioned given the participant and analytical burden. The current study suggests that WFRs can provide an accurate estimation of child energy intake, but also indicates that the semi-quantitative FFQ specifically designed for Australian children and using contemporary portions sizes is approximately equal for estimating child energy intake. Variations of < 10% energy intake between methods in validation studies are uncommon. In a systematic review of DLW studies in children²³ the multiple pass 24-hour recall data was found to demonstrate the smallest difference between TEE and EI, with over-reporting in the range of 7-11%. For other dietary methods under-reporting was in the range of 19-41% for estimated food record and 11-27% for weighed food records, while FFQs overestimated TEE by up to 59%²³.

To the authors knowledge, this is the first study to investigate who is the most accurate reporter of dietary intake for children 8-11 years old within a family group in comparison to the gold standard method of DLW. It is also only one of few studies to assess the validity of EI using a child-specific FFQ compared to DLW²³. In a recent systematic review of child validation studies that included use of the DLW method, it was identified that parents are most commonly used as the proxy to report dietary intake on behalf of their children for those under nine years, or when the dietary assessment method requires a greater literacy or cognitive ability. In all studies where the parent/s were used, it was mothers who reported dietary intake with fathers used in only two of 15 studies included in the review⁷. In the current study, fathers were more accurate reporters of their child's intake compared to mothers. This was not expected as mothers are assumed to be more involved in meal planning, food preparation and influencing a child's intake in the family environment, and therefore better informed of child intake. These results suggests that fathers are just as aware, if not more so, than mothers of their children's food and beverage intakes. Fathers' roles and their importance in childhood nutrition is an emerging area of research^{24 25} and may be changing given the changing roles of fathers²⁶. Given the current study indicates that fathers are more able to accurately report child intake than mothers, this means they can be used more actively within studies that measure child dietary intake in the future. However our results suggest that for a child between the ages of 8-11 years their level of dietary reporting is closer to the 'true' value, than either the mother or father.

An additional unexpected finding was that mothers were not as accurate estimators of child intake compared to the children. This may be because mother's are prone to a Hawthorne effect or social desirability of reporting what they believe the researchers want to hear, or may be influenced by the foods they 'serve' their children rather than that consumed, or it may merely be

the common over-reporting bias associated with FFQs. However, it appears from the results of the current study that fathers are less prone to mis-reporting bias.²⁷ Comparison to children who may remember differently to adults and by recalling usual habits and more recent intake²⁸. The amount of time the parent spent observing the child during the recall period may also have influenced in their answers.

In this study FFQs were associated with an over-reporting bias, in agreement with previous literature⁵. However, some children were categorized as under-reporters using the FFQ. Perks et al²⁹ compared an FFQ adapted from an adult version to DLW in 50, 9-16 year olds and found that dietary reports from children and adults were equally likely to under- or over-report energy intakes when compared to TEE as assessed by DLW. Similarly to the current study, mothers were found on average to significantly over-report, rather than under-report child intake when using an FFQ³⁰. Collectively, the limited findings across current child DLW validation studies indicate that differences do exist when using child versus maternal or paternal parents and thus it is important to report who the proxy reporter was and this issue should be considered when interpreting results.

The calculation of the LOA provide information about the direction and magnitude of bias and whether bias is constant across levels of intake. In this study, the LOA are considered wide, indicating the lack of precision of the FFQ method at the individual level. However the LOAs shown are not as wide as previous reports in children using an FFQ^{29,30} and the bias is constant across varying levels of energy intake. This may indicate that development of a semi-quantitative FFQ specifically designed for Australian children that uses appropriate portions sizes is a more accurate method than simply adapting a valid FFQ from adult populations, which is a more

common approach in research studies, due to the ease of this and the limited number of valid dietary measures available for pediatric populations.

The main limitations of this study are the small sample size although this sample size is comparable to other studies using DLW, which tend to have a limited number of subjects due to the high cost and subject burden involved.⁷ Results of the current study may not be applicable to other population groups and ethnicities. Demographic details of the parents and child educational ability was not collected as part of the study. Hence, future studies should recruit a larger, more culturally diverse population to assess validity of FFQs. Also, the DLW method assessed a 10 day energy expenditure period which may not represent 'habitual' energy expenditure, nor reflect the six month reporting period of the FFQ. While a random convenience sample of children was chosen, it is likely that for some participants this was be a period of lower activity and for some a period of relatively higher activity, the two measures do not cover the same periods. It is possible that participants completed the WFR more accurately because this was an obvious reinforcement that they were participating in a dietary study, and this may have influenced results. The strengths of the current study is that it did assess body weight pre- and post-DLW dosage, used a strong statistical approach to validation and utilised two dietary assessment methods in comparison with DLW.

Conclusion

The accuracy of FFQs in estimating child EI compared to the DLW method appears consistent with other published literature. Children were the most accurate reporters when compared to their parents, with fathers more accurate than mothers. The child FFQ report was approximately equal to the 4-day weighed food record in estimating EI in children aged 8-12 years. The ACAES FFQ

336 may be used in studies to estimate TEE in 8-11 year old children but consideration should be
337 given to who reports child energy intake.

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