Abstract

Measuring dietary intake in children enables the assessment of nutritional adequacy of individuals and groups and can provide information about nutrients, including energy, food and eating habits. The aim of this review was to determine which dietary assessment method(s) provide a valid and accurate estimate of energy intake by comparison with the gold standard measure, doubly labeled water (DLW). English language articles published between 1973 and 2009 and available from common nutrition databases were retrieved. Studies were included if they were conducted in children 0-18yrs and used the DLW technique to validate reported energy intake (EI) by any other dietary assessment method. The review identified fifteen cross-sectional studies, with a variety of comparative dietary assessment methods. These included a total of 664 children, with the majority having less than 30 participants. The majority of dietary assessment method validation studies indicated a degree of misreporting with only eight studies identifying this to a significant level ($p<0.05$) compared to DLW estimated EI. Under-reporting by food records varied from 19-41% (n= 5 studies) with over reporting most often associated with 24 hr recalls (7-11%, n= 4), diet history (9-14%, n= 3) and food frequency questionnaires (2 - 59%, n=2).

This review suggested that the 24 hour multiple pass recall conducted over, at least, a three day period that includes week and weekend days and uses parents as proxy reporters is the most accurate method to estimate total energy intake in children aged 4-11y, compared to TEE measured by DLW. Weighed food records provided the best estimate for younger children aged 0.5-4y while the diet history provided better estimates

for adolescents ≥16y. Further research is needed in this area to substantiate findings and improve estimates of TEE in children and adolescents.

Introduction

Accurate assessment of child and adolescent food intake is an important factor in determining the nutritional adequacy of an individual's diet. Previous research suggests that collecting reliable and accurate dietary data from this population group can be difficult (1).

Parents are often used as proxy reporters of their children's dietary intake in research studies (2). This is largely due to children at younger ages having lower literacy levels, limited cognitive abilities and difficulties in estimating portion size (2). It has been previously acknowledged that children below the age of approximately eight years cannot accurately recall foods, estimate portion size and cannot conceptualize frequency of food consumption (2). However, as the child grows older and develops cognitively, their ability to self-report their own food intake improves (1). The age at which a child becomes an accurate self-reporter of their own dietary intake has been estimated to be approximately 12 years of age, though debatable as per the dietary assessment method (1).

The literature suggests that there is a transition period between the ages of eight to 12 years, during which the child becomes a more accurate reporter of their own dietary intake. There is no consistency in terms of whether the parent or child were the reporter of child intake in previous studies, nor have recommendations been based on the

literature as to who is the most appropriate reporter of dietary intake for children in this age range. These issues have been discussed in a recent review (3).

Validity refers to the ability of a dietary assessment tool to measure food consumption data that represents the true dietary intake of the individual (1). A method is described as valid if reported dietary intake is not significantly different to actual dietary intake consumed (1). Valid dietary assessment methods are needed to firstly measure, and then compare the data reported by parent and child in order to determine who the most accurate reporter is. There are limited validated dietary assessment tools for use with pediatric populations (1) and no published studies to date were identified that had investigated parent and child report against an objective measure of dietary intake within in the same study.

It is common for dietary assessment tools to be compared or validated against another similar method (1) or by direct observation of meal consumption (4-6). This technique is limited in that the comparative method is subject to similar limitations as the tool being assessed. The majority of dietary assessment methods are subject to recall bias, as they rely on a participant's memory (7). To overcome this, an objective measure that is independent of error in the method being evaluated is desirable to assess the validity of a dietary assessment tool so that correlation does not occur on the basis of statistical errors that are common to both approaches.

Doubly labeled water (DLW) is considered to be the 'gold standard' reference method for validation of measurements of EI. DLW estimates total energy expenditure (TEE) and is typically measured over a period of 7-14 days and incorporates short term day to day variation in physical activity (8) (9). However, even a 14 day period cannot account for

seasonal variation in physical activity levels or other situations that impact on EE with time. A review that included both children and adults from 6-74y has demonstrated the coefficient of variation for repeated measurements of EE by DLW is 8-10% (9). In free-living, weight-stable individuals TEE as measured by the DLW is reflective of actual EI (10). This makes it possible to determine the accuracy of reported EI. The DLW method is seldom used due to the high costs, moderate participant research burden and the high technical skills and facilities required for analysis.

In this review, studies intending to validate dietary assessment tools for the measurement of energy intake (EI) in children were considered. The aim of this review was to evaluate the accuracy of dietary assessment methods used to estimate the daily EI of children by comparing reported intake with TEE measured by DLW.

Methods

The review was conducted in 3 stages;

Stage 1: Articles were retrieved via online database searching; hand-searching reference lists and cited reference searches (Figure 1).

The online databases of Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane, MEDLINE, ProQuest, PubMed and EMBASE (Excerpta Medica Database) were searched. Keywords and combinations of these were used to search the databases comprehensively. The keywords included child, adolescent, paediatric (pediatric), dietary assessment, food frequency questionnaire, dietary recall, diet record, energy intake, energy expenditure, doubly labeled (labeled) water and validation. Articles were limited to those printed in English language journals between 1973 and January 2009. The reference lists of articles retrieved for inclusion in the review were hand-searched to identify other relevant articles. Key articles retrieved via online databases and hand-searching reference lists were also used for further searches using the Web of Science database *Cited Reference* function. The results of *Cited Reference* searches were narrowed using the key words *child, adolescent and paediatric (pediatric), doubly labeled (labeled) water and validation.* This was undertaken to capture the most relevant articles for further evaluation and critical appraisal.

Stage 2: The titles and abstracts of articles were reviewed to assess eligibility for inclusion in this review. Articles were identified as relevant to the review if they were: experimental studies aiming to compare reported dietary intake with TEE, if they included child and/or adolescent participants (aged <18 years), reported EI as measured by a dietary assessment tool, used DLW to estimate TEE, and the primary purpose of the

study was validation of the dietary assessment method. Studies were included regardless of the reporter of the child's dietary intake (parent or child reported data). If it was not clear if an article should be included from the review of the abstract, the full article was retrieved.

Stage 3: All retrieved articles were independently assessed for quality, using a standardized quality assessment checklist (11) and one reviewer (RM) critically appraised the articles using the Joanna Briggs Institute critical appraisal tool to identify sources of bias, performance, attrition and detection (12). Data relevant to this review included the study design, characteristics of participants, dietary method/s used and results.

Methods to determine accuracy: The reporting status of the dietary intakes in each of the included studies was determined from either that listed within the results section of the included article or for those studies where this was not listed was calculated as (EI/TEE). The 'reporting status' of each study was determined using three pre-defined categories consistent with previous definitions (13). The categories are dependent on the level of accuracy of reported EI compared to measured TEE. These 3 categories included: adequate reporters (AR; EI/TEE within the 95% confidence limits 0.84-1.16), under-reporters (UR; EI/TEE <0.84), or over-reporters (OR; EI/TEE >1.16). Further where available from included studies, results were extracted if the reporting status of participants was correlated to various characteristics of the group. These characteristics include demographic statistics (age and gender), anthropometric characteristics (height, weight and body mass index (BMI)) and body composition statistics (percentage body fat and fat-free mass). Limitations of each study and the evidence level (14) were also recorded.

Limits of agreement (LOA) were commonly reported using the Bland Altman approach (11 studies). With this method, a pair-wise comparison is used to assess the relative bias (mean difference ± 2 standard deviations) between the estimated EI and the reference measure of TEE. The calculation of the mean difference provides information about the direction and magnitude of bias and whether the bias is constant across levels of intake. When the limits of agreement are approximately equal to two standard deviations of the mean difference then the two methods are considered to be in fairly good agreement. Consequently LOA are reported as MJ / day or KJ / day. The LOA is often used to provide additional data to characterize the validity, or otherwise, of the comparative EI estimate assessment (15). For example the level of agreement between energy intake reported by 24 hour recall and total energy expenditure by DLW would be determined by plotting the individual differences between each of the methods for each participant then calculating the mean difference and standard deviation. If the values fall outside the 2SD limit of agreement then, this would indicate a poor level of agreement, on an individual level.

Results

A total of 975 articles were identified using the search strategy outlined in Figure 1. Of these, 23 were retrieved for quality checking and critical appraisal. The critical appraisal process resulted in the inclusion of 15 articles, for this review, all with a positive study quality when assessed against pre-specified criteria (11). The main reasons for exclusion included adult studies, EI not reported and DLW not used to measure TEE. All studies included were cross-sectional in design and were classified as Level IV evidence (14).

Table 1 outlines a summary of the participants, dietary assessment methods, DLW reporting period, dosage amounts, number of collection days of urine samples and provides indication of if body weight assessment for each study. In terms of reporting body weight, eight of the15 studies reported that participant body weights were measured at baseline only, six studies measured both pre- and post- body weights with one study reporting a significant increase in weight over the collection period. Only one study did not report whether body weight had been measured. All studies included a urine collection pre dose of DLW.

A total of 780 children and adolescents participated across the 15 studies, however only 664 of these had data recorded for TEE measured by DLW, in addition to reported EI. This review only includes the data for participants with both TEE and EI data recorded.

All studies included participants who were reported to be free-living individuals. The age of participants ranged between 0.5 to 18 years with the majority (n= 9) of studies being carried out in children aged 4-11 y with limited studies at the lower (n=3) and upper ends of the range (n=3). Studies were largely carried out using Caucasian children. Of the 15 studies, three studies included children from a range of ethnicities including African-American children (16-18) and two studies were identified that were carried out with overweight/obese participants (19, 20). The majority of studies (11 of 15) used a single dietary assessment method to estimate dietary energy intake, three studies used two separate dietary intake methods (18, 21, 22).

Table 2 provides a detailed description of the included studies and their limits of agreement, where reported. Table 3 displays the characteristics of participants identified as misreporters, as per the criteria detailed in methods section.

Twenty-four hour multiple pass recalls (24h MPR, n= 4 studies) (18, 23-25) and estimated food records (EFR) (n=5) (18, 19, 21, 23-28) were the single most commonly used dietary assessment tools. Diet history methods (13, 20, 22) used in three studies and weighed food records (WFR) (21, 22, 29) and food frequency questionnaires (each FFQ with a reporting period of the previous 12 months) were used to estimate EI in two studies each (17, 30). One study measured energy intake using a combination of both weighed and estimated food records (31) and dietary intake was verbally recorded on tape in one study (18). In each of the studies the 24hr MPR was conducted using a three pass method which included a quick list, detailed description review and use of either food models/portion photographs or household measures for each of three separate days. The average value of the recalls was used to compare with TEE by the DLW method.

All studies assessed energy intake using a particular dietary method assessed within the same time period as the DLW collection. In all studies participants were instructed to report usual dietary intakes for WFR, EFR and 24 MPR in an attempt to capture intake representative of both weekdays and weekends.

Dietary intake was most commonly reported by both the child and one or two parents/carers (7 out of 15 studies) (17, 20, 22, 23, 26, 27, 30). Five studies reported obtaining dietary intake data from parents only (21, 22, 24, 25, 29) and four studies used child reported data alone (13, 18, 19, 31). Parents were more likely to report the child's intake for them when the child was young (less than 7 years of age in four studies (21, 24, 25, 29), and less than 9 years in one study (22)) or when the dietary assessment method required a greater level of skill or was an increased burden on participants (for example, parents recorded weighed foods for children up to nine years of age (22)). In all studies

where parents were used to report their child's intake, mothers were utilized as the main reporters. Fathers were reportedly used occasionally in only two studies (23, 32). Older children and adolescents were more likely to report their own intake (participants 12 years or older in three studies (13, 19, 31), aged 6- 11 years in one study (18)) and a combination of parent-child reports were used over a range of ages (see Table 1).

Energy intake was estimated from reported dietary intake in all 15 studies using food composition tables and nutrient analysis software in 11 studies (18, 20-27, 29, 31). Four studies did not report the methods used for analysis and calculation of EI (13, 17, 19, 30).

Across the 15 studies reviewed, all dietary methods produced some degree of misreporting. Significant under-reporting of energy intake was found for dietary methods of estimated food records (19-41% of estimated energy intake, n=3 of 5 studies), weighed food records (11-27% n= 1 of 2 studies) and over reporting for multiple 24 hr MPR recall (7-11%, n= 2 of 4 studies), and food frequency questionnaires (up to 59%, n= 1 of 2 studies).

Gender, weight status and ethnicity are indicated where reported in included studies. Reporting status was categorized by gender in five studies. Underreporting was found in both girls (3 out of 5 studies; (13, 20, 31)), and boys (2 out of 3 studies; (20, 31)). Misreporting associated with gender was not related specifically to any dietary assessment method or the reporter of intake. Two studies examined the relationship between weight status and misreporting (19, 20). Both studies found that energy intake was underreported in overweight and obese children. Waling et al reported that obese children were twice as likely to under-report compared to overweight children (32), while Bandini et al found that they twice as likely to under-report compared to non-obese

children (19). Interestingly in four other studies included, the likelihood of under-reporting was most strongly predicted by higher percent body fat (28, 30), reported total grams of dietary fat (26)or by individuals in the highest tertile of body fat (33). In one study, African American participants under-reported their intake by 37% less than measured TEE, which was significantly different to Caucasian participants (reported EI 13% less than TEE as measured by DLW).

The majority of studies reported that the dietary assessment method used had provided a good estimate of EI at the group level. However, at the individual level, the accuracy was reduced. The mean reported EI and mean TEE as measured by the DLW at the group level were not significantly different in many studies, however the wide LOA indicate that large variations occurred at the individual level. Five studies concluded that the method used for dietary assessment could not be used for assessment of group or individual energy intakes, (17-20, 27).

Discussion:

Analysis and Discussion of Results

This review identified only 15 studies that have evaluated the accuracy of dietary assessment methods used to estimate the daily EI of children by comparing reported intake with TEE measured by DLW.

While all studies were associated with a degree of mis-reporting, the diet history method demonstrated variation with two of the three studies identifying under-reporting (14-18%) and the third study finding over-report (6-14%). Eight studies identified misreporting of intake to be statistically significant to TEE as measured by DLW (17-20,

22, 24, 25, 31). The misreporting of dietary intake by dietary assessment method showed that only participants who reported using the diet history (plus interview) method did not misreport intake significantly. However it should be noted that this was only a single study with a small sample size (n= 35 participants), thus limiting the generalizability of this finding (13).

Approximately half of all child participants who had their energy intake recorded using 24 hour multiple pass recall and diet history (interview only), were found to significantly over-report their intake. However both 24h MPR and DHI produced more modest over-reports of dietary intake than other methods (9% and 12.6% over-report respectively). Over-reporting using 24h MPR and DHI was found to be significant when dietary intake was reported by parents (three out of five studies used parents only (22, 24, 25), another two used parent-child reports (20, 22) as shown in Table 1).

Estimated food records (EFR) produced a significant underestimation of EI (30.4% less than TEE), however two other studies that used EFR to measure dietary intake did not demonstrate significant misreporting, one carried out in young children 0.5-1 yrs with n=10 participants and the other with n= 47 children aged 6-9 yrs (21, 26). In addition to these, one study did not report statistical findings from their results (27). Bandini et al (19) collected dietary data from older children aged 12-18yrs over a 14 day collection period which may have contributed to misreporting of intake due to the high burden placed on participants. O'Connor et al (26) and Lanigan et al (21) obtained data from parents, and parents and children, over a period of 3 and 5 days respectively. The assisted parental reporting and the shorter reporting period may have improved the accuracy of reports in these two studies.

Tape record of dietary intake, although not a common diet assessment method has been previously suggested as a future means for assessing dietary intake of children because of convenience, ease of use, the efficiency and the minimal cognitive ability required to use the device (34). However tape record and combination weighed food records/estimated food records were found to be the most inaccurate methods for assessing EI (100% of participants recording intake using these methods significantly misreported intake; *n*= 30). It is important to note that both studies using these methods (18, 31) used data self-reported by children (6.5 – 11 years; (18)) and adolescents (15 years; (31)). Of the included studies that identified significant misreporting of EI, the food frequency questionnaire method which commonly asks respondents to report their usual frequency of consumption of each food from a list of foods for a specific time period was shown to have a level of misreporting. The FFQ method was used in the study by Kaskoun et al (17) which utilized parents as a proxy to report dietary intake of children aged 4.2-6.9 years produced the most significant discrepancy between reported EI and measured TEE (OR intake by 59%). Over-reporting using a FFQ was found to be significant in 47% of total child participants (17). FFQs and are known to commonly over report dietary intake (35), in this study the over-estimation of EI for children may be attributable to the use of adult portion sizes in the FFQ to estimate each child's intake and the FFQ tool being used was not developed specifically for use with pediatric populations (17). In this review, only two studies were identified that compared DLW to an FFQ and these demonstrated a large degree variability in their estimation of energy intake, highlighting just how inaccurate it is. This is consistent with previous reports in adults. For example the Women's Health Initiative have provided compelling evidence using DLW to

demonstrate the inadequacy of the FFQs in capturing energy intake. In general, the FFQ by it's design, cannot quantify energy intake reliably (36).

The age of participants was reported for all studies, however only Livingstone et al (22) directly correlated reporting status to age, where EI reported using diet history (interview only) method significantly over-reported intake of children aged 3-12 years. This method of assessment produced an accurate measurement of EI for participants aged 15-18 years. These findings demonstrate that reporting accuracy using the diet history method in older children and adolescents, increases as the child has more input into the data reported and recorded by researchers (22). However, the opposite is true for the weighed food record method; children aged 12-18 years were more likely to under-report dietary intake. This agrees with other studies in older children where food records unanimously underreport by 20% with greater bias in older children (37). This may be related to the increased burden associated with weighing all foods for consumption, the participant requiring literacy and numeracy skills and usual consumption pattern may change due to inconvenience of recording, choice of foods which are easy to record, beliefs about which foods are healthy or unhealthy (7).

The characteristics of participants found to have misreported intakes suggests that reporting status could be related to ethnicity and weight status which is consistent with other literature (18, 38). However due to the limited number of studies published in this area and available for reviewed, further evidence and research is required in this area.

At the group level, most studies found that the dietary assessment method used in the study was a valid measure of estimating energy intake, however not as accurate at the individual level. The wide limits of agreement (LOA) indicate that large variations occur in dietary intakes between individuals. This highlights the need to report energy and dietary intakes using a standardized method to account for variation such as by kilogram of weight status or a standardized energy intake.

The DLW technique involves dosing individuals with an accurately measured quantity of DLW at baseline and collecting urine samples over a designated period of time which are subsequently analyzed to calculate TEE (39). The dose of DLW given to each individual is calculated by multiplying a certain quantity of DLW by an individual's body weight or total body water (40) and varies depending on the age of the individual (41). The dosage of DLW administered to the children in the included studies varied in addition to the collection period which limits the direct comparison between studies difficult. The majority of studies in this review used the method of 24 hour recall which may have contributed to the findings.

The findings of this review are influenced by the limitations commonly associated with the dietary assessment methods. Weighed food records, estimated food records, 24h multiple pass recall and tape recorded intake data all rely on the period of assessment being 'typical' of usual intake and are also associated with recall bias. A further limitation in DLW studies is that the periods of time asessed to capture intake and TEE do not necessarily cover the same time frame. While the prospective assessment methods

such as food records and prospective recalls do capture the typical two week DLW time period, this is not the case when retrospective methods such as diet histories or food frequencies are administered prior to the DLW assessment. If subjects have an atypical food consumption pattern, either much greater or lesser, during the DLW urine collection period, this will increase the degree of inaccuracy greatly. Although different studies used the same dietary assessment methods, there are inconsistencies between studies in their implementation. The majority of the studies included a small sample size (<30 participants).

The accuracy of the method may also rely on the reporter of the data. It is difficult to determine from the studies included in this review who is the most accurate reporter of a child's dietary intake, and which method is most accurate and reliable. Each study in this review varied in the age of the participants, reporter (parent-reporters, child-reporters and parent-child reporters were identified in the 15 studies included) and dietary assessment used. It was not possible to accurately determine the relationship of age to reporting status as only one study (22) divided participants according to their ages. However the results show that when dietary energy intake is of interest parents should be used as a proxy for young children, lees than 8 years or at least to compliment diet information obtained from the child alone especially when diet methods require more advanced cognitive abilities or the reporting period is a longer time frame, greater than a few days to improve accuracy of estimated results.

It is important to note that mere participation in a research study may have biased the data reported for each child or adolescent as participants may have selectively reported foods due to their involvement in the study. Reporting methods which required more

involvement and thus more participant burden (such as weighed food records and estimated food records) may also result in changes to eating habits or reporting inaccuracies due to the time required and level of difficulty associated with these methods of reporting.

Conclusions

The review identified 15 studies that have assessed the validity of reported dietary intake against the method of doubly labeled water. The limited findings suggest that the 24 hour multiple pass recall conducted over at least a three day period which includes weekdays and weekend days, using parents as reporters is the most accurate method for reporting energy intake in children 4-11 years when compared to TEE measured by DLW. This review indicated that compared to DLW, weighed food records provided the best estimates of EI for younger children aged 0.5-4y while the diet history method provided better estimates for adolescents ≥16 years. Further research is needed in this area to substantiate findings.

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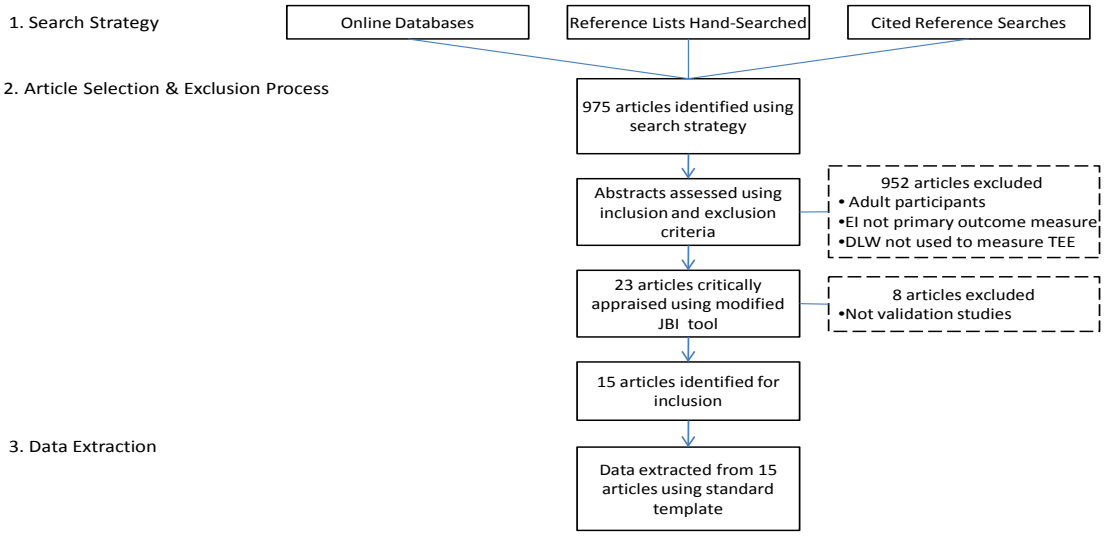

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495 Figure 1. Studies for Inclusion in the review of evaluating dietary methods against doubly
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Table 1. Cross sectional studies identified in a systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labelled water

Source Country	n	Gender	Age (years)	Subjects	Dietary Method + Reporting Period	Reporter	Length of DLW collection (days)	Number of Urine samples	Dosage	Weight Collected pre and post study
Multiple Pass 24 hour recall (MPR)										
Johnson et al (23) USA	24	Boys 12 Girls 12	Range 4-7 Boys 6.4 ±1.0 Girls 5.5 ±0.7	Caucasian BMI Boys 18 ± 3.1 Girls 17.9 ± 2.7	24h MPR 3 days	P+C	14	5	0.12g ^2H_2O and 0.15g $H_2{}^{18}O$/ kg BW	Yes
Reilly et al (25) Scotland	41	Boys 18 Girls 23	Range 3 - 4 3.7 ± 0.4	BMI 16.1 ± 1.8	24h MPR 3 days	P	7	3	0.06mL ^2H_2O and 1.6mL $H_2{}^{18}O$/ kg BW	Baseline only
Lindquist et al (18) USA	30	Boys 17 Girls 13	Range 6.5-11.6 9.5 ± 1.4	African American n=13 Caucasian n=17 BMI 20.9 ± 5.8	24h MPR 3 days + Tape recorder 3 days	C	14	5	0.12g ^2H_2O and 0.15g $H_2{}^{18}O$/ kg BW	Baseline only
Montgomery et al (24) Scotland	63	Boys 32 Girls 31	Range 4.5-7 Boys Median 6.0 (4.8-6.7) Girls 5.7 (4.5-6.9)	BMI Boys median 16.25 (13.5-21.5) Girls 15.4 (14-20.5)	24h MPR 3 days	P	10	3	0.24mL ^2H_2O and 1.6mL $H_2{}^{18}O$/ kg BW	Baseline only
Diet History (DH)										
Sjoberg et al (13) Sweden	35	Boys 18 Girls 17	Range 15-17 15.7 ± 0.4	BMI 20.7 (2.5)	DH+ (questionnaire + interview)	C	15	8	0.05g ^2H_2O and 0.10g $H_2{}^{18}O$/ kg BW	Yes
Waling et al	21	Boys 10	Range 8.3 -	Overweight 16	DHI	P+C	14	6	0.12g ^2H_2O and 0.25g	Yes

(31) Sweden		Girls 11	12.4 10.5 ± 1.1	Obese 5 BMI 23.1 ± 2.6					$H_2{}^{18}O$/ kg est. TBW	
Livingstone et al (22)UK	78	Boys 41 Girls 37	Range 3-18	3yrs n= 8 5ys n= 12 7yrs n= 12 9yrs n= 12 12yrs n= 12 15yrs n= 12 18yrs n= 10	DHI	P for children 3-5yrs P+C 7-18yrs	10-14 days depending on age	11-15 depending on age	0.05g ^2H_2O and 0.125g $H_2{}^{18}O$/ kg BW	Baseline only
Estimated Food Records (EFR)										
O'Connor et al (26)Australia	47	Boys 22 Girls 25	Range 6 – 9 7.4 ± 0.8	BMI 16.8 ± 2.3	EFR	P+C	10	12	0.05g ^2H_2O and 0.125g $H_2{}^{18}O$/ kg BW	Baseline only
Lanigan et al (21) UK	21	Boys Girls n/s	Range 6-12 months 8.1±1.6	Wt 9.2 ± 1.2kg	EFR 5 days WFR 5 days Cross over design	P	7	7	n/s	Baseline only
Bandini et al(19) USA	55	Boys 28 Girls 27	Range 12 – 18 14.4 ±2.0	**Obese** n= 28 Weight 95 ±25.1 Height 163.9±7.6 **Non obese** n=27 Weight 56 ± 9.6 Height 164.4 ± 8.5	EFR 14 days	C	14	4	0.1g ^2H_2O and 0.25g $H_2{}^{18}O$/ kg est TBW	Yes
Champagne et al (33) USA	23	Boys 12 Girls 11	Range 11.1 - 11.7	African American n= 11 BMI 21.3 ± 2.2 Caucasian n= 12 BMI 19.3 ±2.0	EFR 8 days	P+C	9	4	0.14g ^2H_2O and 0.25g $H_2{}^{18}O$/ kg TBW	Baseline only
Bratteby et al (32) Sweden	50	Boys 25 Girls 25	15 yrs	Boys BMI 20.2 ± 2.8 Girls 20.9 ±2.5	EFR 7 days	C	14	17	0.15g ^2H_2O and 0.3g $H_2{}^{18}O$/ kg TBW	Yes

Food Frequency Questionnaire (FFQ)

Perks et al (29)USA	50	Boys 23 Girls 27	Range 8.6 - 16.2	BMI 19.5 ± 3.3	FFQ Reporting period 1 year	C	12	6	0.05g $^{2}H_2O$ and 1.5g $H_2{}^{18}O$/ kg BW	Baseline only
Kaskoun et al (17)USA	45	Boys 22 Girls 23	Range 4.2 - 6.9	Caucasian .n= 36 Native American n= 9 Boys Wt 19.5 ±4.1 Ht 1.11 ± 0.1 Girls Wt 20.7 ±4.1 Ht 1.12 ± 0.1	FFQ Reporting period 1 year	P	14	5	≈ 0.12g $^{2}H_2O$ and 0.15g $H_2{}^{18}O$/ kg BW	Yes

Weighed Food Records (WFR)

Davies et al (28) UK	81	Boys 40 Girls[#] 40	Range 1.5 - 4.5	Age groups 1.50-2.49 n= 23 2.50-3.49 n= 31 3.5-4.49 n= 27	WFR 4 days	P	10	11	0.05g $^{2}H_2O$ and 0.125g $H_2{}^{18}O$/ kg BW	n/s
Livingstone et al (22)UK	58	M + F	Range 7 - 18yrs	3yrs n= 8 5ys n= 12 7yrs n= 12 9yrs n= 12 12yrs n= 12 15yrs n= 12 18yrs n= 10	WFR 7 days	P of children 7-9 yrs C 12-18yrs	10-14 days depending on age	11-15 dependin g on age	0.05g $^{2}H_2O$ and 0.125g $H_2{}^{18}O$/ kg BW	Baseline only

Data shown is Mean (SD) unless otherwise specified, DLW- doubly labeled water, [#] exact numbers not reported articles indicates 'approx equal numbers of boys and girls, DH+-diet history plus additional interview;; n/s not specified ; P, parent only; C, child only; P+C, parent and child. BW – body weight; TBW total body water

502 Table 2: Results of validation studies included in a systematic review of the validity of dietary assessment methods in children when
503 compared with doubly labeled water

Source	Diet method (number of days)	Results	Significance of results	Limit of Agreement (LOA)	Limitations
Multiple Pass 24 hour recall (MPR)					
Johnson et al (23)	24 MPR 3 days	NS between mean 24hr MPR and mean TEE Mean difference EI UR by 3% NS between sexes No correlation between EI and TEE thus 24 MPR	The 24hr MPR is useful for estimating group intake of EI of children 4-7yrs reported by parents	1.10, 807 kcal / day	• Recall bias • Wide LOA • Only 3 days data collection • Small sample size
Reilly et al (25)	24 MPR 3 days	EI significantly (P<0.001) OR by 11% mean 660kJ 95% CI (183 – 1137) NS between sexes No relationship to weight status	The 24hr MPR produced a significant over estimate of children 3-4yrs	660 ± 3018 kJ/ day	• Recall bias • Wide LOA • Only 3 days data collection • Portion sizes used based on adult serve sizes
Lindquist et al (18)	24 MPR 3 days + tape recorded	24MPR NS between TEE and recall for group or ethnicity No gender difference (Mean 0.04MJ / day) Taped significantly (P<0.05) UR by 14% (-1.13 MJ/ day) and remained significant for African American children (-2.44MJ / day). Misreporting association with older age and greater adiposity.	Traditional recall method more accurate for reported EI than tape recorded	LOA not reported	• No LOA reported • Participants weight at the end of the study unknown • Diet intake were completed at various times throughout yr to capture seasonality
Montgomery et al (24)	24 MPR 3 days	NS between mean EI and mean TEE for boys EI significantly (P<0.05) OR by 7% for girls median difference 440kJ / day	The 24hr MPR OR EI in children 4-7yrs.	-2.88, 2.38 MJ/day	• Results not reported for total group • Recall bias • Adult portion sizes used • Wide LOA

Diet History (DH)					
Sjoberg et al (13)	DH+	NS between mean EI and mean TEE for total group (4% UR) Girls 18% UR (P< 0.001) but not for boys (8% UR) Weight changed significantly (P0.02) between start and finish time of study for boys (+ 0.82 ±1.39kg) but not girls	DH+ method used is valid to assess habitual intake or ranking of individuals for adolescents with reporting accuracy related to gender.	-5.63, – 6.45MJ	• Wide LOA • Weight change of participants may confound the TEE calculated from the DLW • Relies on participants memory
Waling et al (20)	DHI	EI UR by 14% (1.66 ± 1.76 MJ / day when compared to TEE by DLW Both boys + girls significantly (P<0.05) UR 17% & 11%respectively. The level of underestimation did not differ between sexes NS between weight categories EI UR by 22% by obese which is twice the rate for overweight. UR negatively correlated with BMI (-0.38, P<0.01)	The DH method UR dietary intake compared with measured TEE. The reported EI of children with a higher BMI and were older UR more than children with lower BMI and younger	-0.1, 3.42MJ/ day	• Small sample size • Wide LOA
Livingstone et al (22)	DHI	EI significantly (P<0.05) OR by 13.9% for children 3yrs, 6.1% 9yrs, 13.7% 12yrs, mean difference 0.45MJ /day In 15yrs good agreement 18yrs small bias to UR -2±21% (NS)	Better agreement than the comparable WDR in this study DHI are biased towards over estimation and lacked precision at individual assessments	-3.07, 3.98 MJ / day	• Weight of participants over duration of study not measured small sample when divided into age groups
Estimated Food Records (EFR)					

O'connor et al (26)	EFR 3 days	NS between mean EI and TEE, difference approx 4% (118 ± 1706kJ / day) Biggest predictor of mis reporting was reported fat grams.	EFR suitable for nutrition assessment of EI children 6-9 yrs	-3.23, 3.46 MJ / day	• Wide LOA • EFR may not be representative only 3 day recorded data • Relies on participants memory
Lanigan et al (21)	EFR and WFR each 5 days	No significant diff between mean EI and metabolizable energy from either dietary method. EFR and WFR OR energy intake by ≈7.3% (238kJ/day) and (243kJ/day) respectively	EFR are a reasonable measure of young childrens intake (6-24months)	243 ± 1690kJ / day	• Wide LOA • DLW used to calculate metabolizable energy and not TEE so not directly comparable with other studies
Bandini et al (19)	EFR 14 days	Mean reported energy was significantly (P<0.001) UR by the whole group with obese individuals UR more, 41.3% compared to TEE. Non obese UR by 19.4% No differences between sexes Mean weight change over the study was 0.15 ±1.29% in non obese group and 0.31 ±1.02% in obese (not sig)	EFR over a 2 week period did not reliably predict EE in obese and non obese individuals. Recording errors may increase with body size	LOA not reported	• Participants showed small amount of weight change • Participants paid for research • LOA not reported
Champagne et al (16)	EFR 8 days	African American children sig (P 0.002) UR 37% (950±200kcal) Caucasian UR 13% (P0.06) (320 ± 160kcal) Children in the highest tertiles of body fat were more likely to UR	Energy intake is under reported when using dietary records to establish nutrient intake. African American children may be more likely to UR	LOA not reported	• Participants weight at the completion of the study not reported

Bratteby et al (30)	EFR 7 days	Both boys (18.1%) and girls (21.7%) significantly (P<0.05) UR EI UR was associated with increased %BF and weight	Energy Intakes UR in adolescents using the 7 day diet record particularly those with a tendency towards over weight and increased body fat content	LOA not reported	• LOA not reported • Results not reported as whole group only by gender
Food Frequency Questionnaire (FFQ)					
Perks et al (29)	FFQ Previous 12 months	Equal numbers of participants OR (6.65 MJ / day) and UR (6.39MJ/ day) when EI compared to TEE however differences were not significant Boys and girls were sig more likely (r=-0.25) to UR as % BF increased	FFQ good means of estimating energy intakes however wide LOA indicate not good at individual level	-6.30, 6.67 MJ/ day	• FFQ has reporting period of 1 yr so not directly reflecting the DLW collection period • FFQ reliant on memory
Kaskoun et al (17)	FFQ Previous 12 months	Significant (P<0.001) difference between mean EI and TEE, OR 59% (3.39 ± 2.45 MJ/ day). Girls sig OR 62%, Boys sig OR 56% NS between sex or ethnicity	FFQ overestimates EI in children 4-6 yrs in white and native American children	-1.58, 9.57MJ / day	• FFQ has reporting period of 1 yr so not directly reflecting the DLW collection period • FFQ uses adult portion size
Weighed Food Records (WFR)					
Davies et al (28)	WFR 4 days	No sig diff between EI and TEE, the average difference was 3% (154kJ/ day). Older children 3.5-4.5yrs mean difference 37kJ/day	Weighed food intake methodology can provide accurate population based data for children 1.5-4.5yrs	-3.5, 1.8 MJ/day	• Eating habits may be influenced due to burden of WFR • Participants weight at the end of the study unknown

Livingstone et al (22)	WFR 7 days	WFR good agreement for children 7-9yrs EI significantly (P<0.001) UR by 11% in 12yrs, 22% 15yr 27% in 18yr Mean difference -1.47 (-2.24, 0.70MJ/ day	The WDR has a bias towards underestimating EI in adolescents	-7.31, 4.37 MJ / day	• Wide LOA • As above
Source	**Diet method**	**Results**	**Significance of**	**Limit of Agreement**	**Limitations**

504 The limits of agreement presented indicate the mean difference between the estimated EI and the reference measure of TEE by DLW
505 ± 2 standard deviations. DH+ - Diet history plus an interview, NS – no significant difference, EI – energy intake, TEE – energy
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516 **Table 3. Characteristics of significant mis-reporters of energy intake of included studies**

Characteristic of Child	Reporter	Age (years)	n	Dietary Method	Status	EI/TEE	p value	Reference
Gender			11		AR			
Female	P+C	8.3– 12.4		DHI		0.89	<0.05	(31)
	C	15 -17	17	DH+	UR	0.82	<0.001	(13)
	P	5 - 7	31	24h MPR	AR	1.07	<0.05	(24)
	P	4.2 -6.9	23	FFQ	OR	1.62	<0.00	(17)
	C	15	25	WFR/EFR	UR	0.78	<0.05	(32)
Male	P+C	8.3 – 12.4	10	DHI	UR	0.83	<0.05	(31)
	P	4.2 – 6.9	22	FFQ	OR	1.56	<0.05	(17)
	C	15	25	WFR/EFR	UR	0.82	<0.05	(32)
Weight Status								
Overweight	P+C	8.3– 12.4	16	DHI	AR	0.89	< 0.05	(31)
Obese	P+C	8.3– 12.4	5	DHI	UR	0.78	< 0.05	(31)
	C	12 - 18	28	EFR	UR	0.59	< 0.001	(19)
Ethnicity			12		AR			
Caucasian	P+C	11.1– 1.7		EFR		0.87	0.06	(27)

African-American	P+C	11.1–11.7	11	EFR	UR	0.63	0.002	(27)
			8		AR			
Age (years)								
3	P	3		DHI		1.13	<0.05	(22)
9	P+C	9	12	DHI	AR	1.06	<0.05	(22)
12	P+C	12	12	DHI	AR	1.13	<0.05	(22)
12	P+C	12	12	WFR	AR	0.89	<0.01	(22)
15	P+C	15	12	WFR	UR	0.78	<0.01	(22)
18	P+C	18	10	WFR	UR	0.73	<0.01	(22)

EI- Energy Intake, TEE – Total energy Expenditure, 24h MPR-24 hour multiple pass recall; DHI,-diet history interview; DH+, diet history plus additional interview; EFR, estimated food record; FFQ, food frequency questionnaire; WFR, weighed food records; EFR – estimated food records, UR, under report <0.84 EI/TEE; OR, over report >1.16 EI/TEE, AR Adequate report 0.84-1.16) (13) P, parent only; C, child only; P+C, parent and child.

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