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Methodological considerations and future insights for twenty-four hour dietary recall assessment in children

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Abbreviations

MP24hr; Multiple pass 24-hr recall

NHANES; National Health and Nutrition Examination Surveys

LIDNS; Low Income Diet and Nutrition Survey

DLW; Doubly-labelled water

EI; Energy intake

BMR; Basal metabolic rate

Abstract

Dietary assessment has come under much criticism of late to the extent that it has been questioned whether self-reported methods of dietary assessment are worth doing at all. Widespread under-reporting of energy intake, limitations due to memory, changes to intake due to the burden of recording and social desirability bias all impact significantly on the accuracy of the dietary information collected. Under-reporting of energy intakes has long been recognised as a problem in dietary research with doubly labelled water measures of energy expenditure uncovering significant under-reporting of energy intakes across different populations and different dietary assessment methods. In this review we focus on dietary assessment with children with particular attention on the 24-hr dietary recall method. We look at the level of under-reporting of energy intakes and how this tends to change with age, gender and body mass index. We discuss potential alternatives to self-reported (or proxy-reported) dietary assessment methods with children, such as biomarkers, and how these do not enable the collection of information important to public health nutrition such as the cooking method, the mixture of foods eaten together or the context in which the food is consumed. We conclude that despite all of the challenges and flaws, the data collected using self-reported dietary assessment methods are extremely valuable. Research into dietary assessment methodology has resulted in significant increases in our understanding of the limitations of self-reported methods and progressive improvements in the accuracy of the data collected. Hence, future investment in dietary surveillance and in improving self-reported methods of intake can make vital contributions to our understanding of dietary intakes and are thus warranted.

Keywords

Dietary assessment; 24-hour recall, Biomarkers; Diet; Children; Methodology

1. Introduction

The aim of dietary assessment is to collect an accurate record of the dietary intake of an individual or population group. Dietary intake is a very complex health behaviour with large day-to-day and seasonal variation in the foods and drinks an individual consumes. In assessing associations between dietary variables and disease risk it is important to consider habitual dietary intake, however, due to the burden of assessing diet, studies tend to collect information on intake over a short period of time only (usually days). Most methods of assessing diet rely on self-reported intake and this is complicated by the complex socio-cultural relationships individuals may have with food.

In 1992 Faggiano et al. described measuring dietary habits as "one of the most challenging activities in epidemiology"[1]. When children are the subjects of dietary assessment the challenges are increased due to their limited literacy, writing skills, food knowledge and often interest in taking part in dietary surveys coupled with the range of people responsible for their care and food provision [2, 3].

In this review, we discuss dietary assessment methods with particular focus on the 24-hr dietary recall method with children. We look at the level of under-reporting of energy intakes and how this tends to change with age, gender and body mass index. We look at alternatives to self-reported (or proxy-reported) dietary intakes with children and discuss why, despite all of the challenges and flaws, the data collected are valuable and continued investment in dietary surveillance and in improving self-reported methods of intake are warranted.

2. 24-hr dietary recalls

The dietary 24-hr recall involves an in-depth interview where the previous day's intake is described. The interviewer may assign average weights to the foods or the subject may estimate portion sizes using food models or photographs. It is quick to administer but does require a trained interviewer. The method relies on the subject's memory and is therefore prone to omissions. Single observations provide a poor measure of individual intake [4, 5] and many studies therefore use a series of repeated 24-hr recalls [6]. The 24-hr recall is widely used in dietary surveys and research as it is a relatively low burden method for the subject, as respondents don't need to be literate and the interview can be tailored to the individual's food knowledge.

A variation of the 24-hr recall method termed the 'Multiple Pass 24-hr recall' (MP24hr) was developed by the United States Department of Agriculture for use in the National Health and Nutrition Examination Surveys (NHANES) [7] with a view to reducing the degree of under-reporting in dietary surveys. The method is quick and inexpensive and the burden on the subject is low [8]. Recent studies using doubly-labelled water (DLW) to assess energy expenditure across the NHANES surveys found the levels of under-reporting have been reduced by 2-4% in males and 4-8% in females, following introduction of the MP24hr recall [9].

The NHANES survey examines the health and nutritional status of a nationally representative sample of approximately 5000 people each year [10]. Dietary recalls are conducted in-person by a trained interviewer and a second dietary recall is conducted by phone. In addition to NHANES, the MP24hr method has been successfully adapted in other large-scale national surveys, including the Australian Health Survey [11].

A similar, triple pass 24-hr recall method was adopted in the Low Income Diet and Nutrition Survey (LIDNS) which took place between 2003 and 2005 in the UK [6]. The principal aims of LIDNS were to provide quantitative data on the food and nutrient intakes, sources of nutrients and nutritional status of the low income population. Data was collected on over 3700 people aged 2 years and over.

The standardised nature of the MP24hr recall method ensures consistency in the interview process, and the flow of questions is designed to keep respondents interested and engaged [7]. The method can be adapted for telephone interviews, thus reducing the costs, time and logistical constraints often associated with nutritional surveys [12-14].

3. Under-reporting of energy intakes

Biochemical markers have been used to assess the validity of dietary reports. Urinary nitrogen excretion and doubly-labelled water (DLW) measures of energy expenditure have been used to validate reported intakes of nitrogen and energy respectively [15, 16]. Use of these biomarkers, particularly DLW, resulted in the identification of underestimation of food intakes as a common problem in dietary surveys [17, 18]. Similar to other dietary assessment methods [19], energy intake has been under-estimated by between 6% and 40% [9, 20, 21] using 24-hr dietary recalls from adult surveys, with females tending to under-report to a greater extent than males [9, 21].

Under-reporting is caused by a combination of under-recording and under-eating. Under-recording means the subject reports lower food intakes than those actually consumed. This may be due to omissions of whole foods or underestimation of portion sizes. Whereas, undereating is where the subject either consciously or sub-consciously reduces the amount of food they consume during the recording period. Underestimation of energy intake may be due to under-reporting, or a reduction of energy intake during the recording period or a combination of the two. The extent to which underestimation was due to under-recording or under-eating was assessed by Goris et al. (2000) [22]. They used DLW to measure energy expenditure and asked subjects to complete a 7-day dietary record. Subjects were deemed to have under-recorded energy intake if energy intake was lower than energy expenditure but weight remained stable. Subjects were deemed to have under-eaten if energy intake was lower than energy expenditure and weight decreased. Goris et al. found 37% of subjects under-reported their habitual energy intakes of which 26% was due to a decrease in food intake during the study period and 12% was due to under-recording of food intakes. No selective omission of snacks was seen, but fat was selectively under-reported. Stubbs et al (2014) used covert observation to identify the extent to which mis-reporting was due to under-eating because of the knowledge that they were being observed (the "observation effect") and how much was due to the discrepancy between the amount consumed and the amount reported "reporting effect" [23]. They found the observation effect to be greater for women compared to men (-8% compared to -3%) and the reporting effect to be -11.5% for men and -8.7% for women using the 24-hr dietary recall method. Total under-reporting (observation effect plus reporting effect) combined was found to give an under-estimate of energy intake of around 15%.

Obese individuals have been identified as a group who have a tendency to under-report energy intakes [24]. Goris et al. (2000) found only one out of 30 obese subjects reported energy intake to within 10% of their energy expenditure measured by DLW [22] and Lissner et al. (2007) found obesity-related under-reporting in both men and women [25]. The degree of under-reporting increased as BMI increased but under-reporting occurred in subjects from all weight categories [19]. Identifying obese individuals as a group who tend to under-report various aspects of their food intake is an important finding which throws question on the appropriateness of excluding under reporters from dietary analyses. It may be that by applying these exclusion criteria to data we exclude one of the very populations whose dietary intakes we need to understand.

Although differences in the populations studied and the dietary methods applied have resulted in a range of estimates of the extent to which subjects under-report, an overall tendency to under-report energy intake is a fairly consistent finding [19, 26].

4. Elements to dietary misreporting

One of the key challenges in assessing dietary intake is that 'what people eat is not what people say they eat' [27]. According to Heisenberg's uncertainty principle, once you begin to measure something you change its properties by the process of the measuring and this statement holds true in measuring diet. 'Recording of food intake, the knowledge that they will be interviewed about their food intake or being aware that their food intake is being observed may all lead to subjects altering their eating habits' [28]. Almost half of subjects asked to keep a 7-day weighed record and be interviewed about their experiences admitted to changing their eating habits during the recording period [29]. Of those 53% reported changing their eating habits as they were more conscious of what they were eating. Subjects may also alter their diet to facilitate reporting. Vuckovic et al. (2000) found subjects altered their food intake by eating simpler foods, foods with pre-determined portion sizes and packaged foods, fewer snacks and not eating out, in order to make the task simpler [30]. People may alter dietary intake to provide what they perceive to be a better or correct response, this may be particularly true of parents responding for their children who want to be seen to be providing healthy foods for their child. Subjects may eat more healthily during recording periods either consciously or sub-consciously and may forget food items or misjudge the quantities of foods consumed [31]. Women may be more prone to social desirability bias compared with men [32]. During focus group discussions, subjects admitted to being concerned about the researcher's perceptions of their diet and to altering their diet to be healthier [30]. Such changes in diet may not be detected by the usual procedure for excluding dietary intakes deemed invalid, such as EI:BMR cut-offs for under-reporting [33]. Participants admitting to altering their diet to make the task of recording foods easier, had a higher EI:BMR than those claiming to have reported their intake accurately [30].

Archer et al. (2013) investigated the validity of energy intakes reported in the U.S. National Health and Nutrition Examination Survey (NHANES) from 1971 to 2010, and reported social desirability and systematic biases (the translation of food consumption data into nutrient values) to be large sources of error in nutrition surveillance [34]. They concluded that ‘throughout its history, NHANES dietary measurement protocols have failed to provide accurate estimates of habitual caloric consumption of the U.S. population’.

Following a review of studies where reported energy intake was validated against energy expenditure measured by DLW, Livingstone and Black (2003) concluded that 'under-reporting is a selective rather than a general phenomenon'. Protein and starch were found to be under-reported to a lesser degree than fat and sugar and participants who were classified as low energy reporters recorded diets with higher nutrient density[19]. Stubbs et al (2014) found women reduced their fat intakes when they were aware their food intake was being observed whereas men reduced their intake of alcohol [23]. Protein intake was found to be under-reported by 2% on average whereas energy intake was under-reported by 14%. However, since all foods contain energy, under-reporting of energy is often greater than for other nutrients. Subjects reporting low energy intakes have been found to report a higher percentage energy from protein and starch and a lower percentage energy from fats and sugars [19]. These findings confirmed those of Black et al. (1997) who found individuals identified as likely to have under-reported their intake reported significantly lower intakes of fat and sugars compared with the rest of the study group [35]. Schoeller (1990) discussed the fact that selective omission of snack foods would result in reported intakes of micronutrients being close to that of actual intakes whilst reported intakes of fat, salt and sugar would be under-reported to a greater extent than energy [36]. Any attempt to adjust the data for low reported energy intake was found to increase such discrepancies [37-39].

For methods such as the 24-hr dietary recall which rely on an individual's memory, foods may not be reported because they are simply forgotten. Research has shown that snack foods tend to be forgotten more often than meals along with additions such as sugar, salt and sauces and drinks [7, 40].

5. Challenges assessing dietary intake of children

Motivational issues, subject recording bias and subject selection bias are all common problems encountered with dietary assessment of people of all ages [30, 41]. In addition to these, literacy and writing skills, limited food recognition skills, memory constraints and concentration span are of added concern when children are the subjects.

Measuring food intake in children aged 4-10 years is particularly problematic and there are few tools designed specifically for measuring diet in this age group [2]. Parental accounts of what their children consume are often relied upon for children under the age of 10 years [3]. However, whilst parents may provide accurate accounts of what their children eat at home they are less able to provide detailed information on what their children consume when in the care of others [42]. It is unlikely parents would be able to report on the significant number of snacks that are consumed both inside and outside of the home as children may help themselves to these foods. The accuracy with which parents can report a child's diet may depend on a number of factors including their working hours and number of children [43]. The alternative, collecting dietary information from the many adults responsible for the day to day care of each child is difficult, expensive and time-consuming [41]. For these reasons the food intake of young children (children under the age of 10 years) is difficult to measure. In order to acquire the most accurate information possible from young children it is necessary to develop methods of measuring food intake designed specifically for completion by this age group [2]. The accurate self-recording of food intake requires a child to have an adequate concept of time and the ability to identify and quantify foods, along with sufficient concentration and memory spans [41]. The accuracy of dietary assessment depends on the communication and understanding between the subject and researcher [44]. This extends to the language and terms used in instructing and/or questioning which needs to be adapted to be appropriate to the target group.

Livingstone and Robson (2000) report that from 8 years of age there is a rapid increase in children's ability to provide accurate reports of their own dietary intake [41]. Burrows et al (2010) are in agreement, however other researchers suggest 10 years old as the youngest age at which children can provide a reasonably accurate account of their food intake stating that by this age children's cognitive abilities are similar to those of adults [45, 46].

A variety of ages are quoted in the literature as the youngest age at which children are capable of accurately reporting dietary information. This is to be expected since the minimum age for self-completion of a dietary assessment method will depend on the cognitive demands and food knowledge required for the specific dietary assessment tool selected. A young child able to recall the foods and drinks consumed the previous day in order to respond to a 24-hr recall for example, may struggle with a more demanding cognitive task such as averaging their intake of foods over time, as required in the food frequency questionnaire. The levels of accuracy of dietary reporting which can be expected will undoubtedly be lower with children of a younger age. It is important to acknowledge the limitations that age and consequent conceptual ability may impose on studies with young children. The consensus indicates that children below the age of 8-10 years are unlikely to be able to accurately reporting their dietary intake, however they may nevertheless provide a more accurate account of their intake than their parents or other adults [47].

A validation study using direct observation was conducted with 24 US children ages 7 to 11 years [48]. The children recorded frequency of food consumption, over 2 days, on a diet diary. This was validated against simultaneous direct observation. The children completed the diet diary at the end of each day therefore the method relied heavily on the child's memory. Interestingly parental assistance was not found to increase the accuracy of the reports. It is suggested this may have been due to the large number of eating occasions which took place outside the home. The percentage agreement between the observer and the child across all food categories was 82.9%, a level they describe as 'acceptably high'. They commented that the 2 day recording period may have been sufficiently short to maintain enthusiasm for form completion and concluded that children in this age range are capable of accurately reporting frequency of consumption of foods. This study recorded only types of foods consumed without any measure of amount consumed.

Children who have school dinners provide a unique opportunity to examine the validity of children's dietary reports as children's choices can be observed and food portions and leftovers can be weighed. Domel et al. (1994) compared 9-10 year old children's recorded intake from school dinners with actual intake as recorded by direct observation [49]. They found a tendency towards under-reporting of food intake but concluded that children in this age group were capable of keeping reasonably accurate food records.

As children grow older they spend increasing amounts of time in the care of others and whilst parents may provide accurate accounts of what their children eat at home they are often unaware of the foods and drinks their children consume at school [42]. Children of school age therefore may be asked to respond to a dietary recall themselves. Twenty-four hour dietary recalls have been used to collect data on children's dietary intakes using parents as proxy reporters [8, 50, 51], and with children reporting their own food intake [52-55].

6 Misreporting of energy intakes in children

6.1 Parental reports

Johnson (1996) examined the validity of the Multiple Pass 24-hr recall method in assessing energy intakes in children aged 4-7 years by comparison with energy expenditure measured by DLW [8]. They measured energy expenditure over 14 days and conducted 3 multiple pass 24-hr recalls (with the parents) during this period. The multiple pass method was found to give a valid estimate of energy intake at the group level but at the individual level the limits of agreement, as determined by Bland Altman plots [56], were poor indicating a large range of under- and over-estimation of intakes. When Bornhorst et al. (2014) compared energy intakes reported by parents of children aged 4 to 10 years old with objectively measured energy expenditure using DLW, they found good agreement at the group level, for children who were classified as thin or normal weight but with a large range of under and over-estimation amongst individuals [50]. With younger children of 3-4 years old, Reilly et al. (2002) found energy intakes to be significantly overestimated by parents, using the multiple pass method, even at the group level compared with energy expenditure measured by DLW [51]. Burrows et al. (2010) conducted a systematic review of studies which assessed the validity of energy intakes reported using a variety of dietary assessment methods with children from birth to 18 years, in comparison to DLW [26]. They found that for 24hr recalls over-reporting was most common in this age group with mean over-estimates of between 7% and 11% of energy expenditure. This suggests reporting of energy intake may be more accurate when children are the subjects of dietary assessment than when adults diets are measured where under-reporting tends to be around 15% [20].

6.2 Child reports

Fewer studies have assessed the validity of the 24-hr dietary recall method when children report their own intake. In a study with children aged 8 to 9 years, children responded to dietary recalls themselves and foods reported during a multiple pass 24-hr recall were compared against observations of school breakfast and school lunch [57]. The accuracy of the children's recalls was found to be poor with 51% of the foods eaten being omitted from the recall and 39% of the foods recalled not having been consumed.

In an earlier study, children aged 8 to 9 years completed a 24-hr recall assisted by a food record [52]. The children's reported consumption of foods eaten was compared with an observer's record of the foods actually consumed. A researcher observed the children eating at school and parents were recruited to make observations at home. They found significant differences between observed and recalled energy intake with energy intakes being over-estimated by this age group, but no significant difference in nutrient densities. There was 77.9% agreement across all meals and snacks.

Livingstone and Black (2003) reviewed studies where children's reported energy intake had been compared with energy expenditure measured by DLW [19]. They found a trend for under-reporting to increase with age. Children up to the age of 12 years old were found to give reasonably accurate reports of energy intake however in older children the level of accuracy was poor. Champagne et al. (1998) also found levels of under-reporting to increase with age [58]. Young children may feel pressure to eat up their meal and parents may feel pressure to report providing an adequate diet for their child, whereas adolescents, especially girls, may have aspirations towards thinness which may lead to an increase in tendency to under-report as age increases. In addition, as children get older, they acquire and eat more foods away from home and this may be carried out either subconsciously or without parental approval. Such items may therefore be omitted from a self-report of food intake.

Livingstone and Black (2003) found under-reporting to be more prevalent amongst girls and children with a higher BMI [19]. Investigation into misreporting of energy intake in the 2007 Australian Children's Survey also found under-reporting to be more likely in participants who were female and over-weight or obese [59]. Ventura et al. (2008) found the BMI of 11 year olds who under-reported their dietary intake by 24-hr dietary recall was significantly higher than that of over-reporters or plausible energy reporters [60]. This trend was also seen in a cross European study of 1512 12 to 18 year olds. Adolescents reported their food intake using an online dietary recall, 33% of the adolescents were found to under-report their energy intake with higher levels of under-reporting seen in those classified as over-weight or obese [61].

7 Justification for continued use of self-reported dietary measures

Given the well-documented issues around the accuracy and precision of self-reported energy intakes it is reasonable to question whether continued investment of research money in dietary assessment is warranted. However,there are a number of reasons why it is imperative that we collect information on the food and nutrient intakes of children and young people. These include the increasing prevalence of diet related diseases, the importance of dietary intake in early life and the tracking of eating behaviours and obesity from childhood into adulthood. Currently there is no viable alternative to self-reported methods for collecting this data.

7.1 Prevalence of diet related diseases

The prevalence of diet related non-communicable diseases is increasing [62] and non-insulin dependent diabetes and obesity are major global health concerns [63-65]. Sugar intakes are of particular concern due to increasing levels of dental caries, a progressive and cumulative disease which is a major public health issue [66, 67].

An inadequate diet in childhood may lay the foundations of many adult medical conditions [68, 69]. Poor childhood diet has been associated with an increase in coronary heart disease [70] cancer and stroke, [71] and atherogenesis may begin in early life where children display some of the traditional risk factors for cardiovascular disease, including obesity and elevated plasma lipids [72].

7.2 Importance of dietary intake in childhood

It is suggested that childhood is a time when modifications of food choice may be more readily accepted [73] and the earlier healthy lifestyles are established the more likely they may be to persist or track into adulthood [68].

Tracking has been described as the consistency of biological variables through time [74]. Craigie et al (2003) followed up over 200 people at age 32 to 33 years who had participated in a dietary survey at age 11 to 12 years [75]. They examined tracking of the balance of good health food groups and found intakes of fruit and vegetables; bread, cereals and potatoes; and meat, fish and alternatives to track significantly.

Perhaps the most consistent finding is for tracking of obesity from childhood into adulthood. There is an increased risk of adult obesity associated with childhood obesity after the third year of life [76]. Whitaker et al (1997) found that children who were obese after the age of 6 years had a 50% probability of being obese as an adult compared with only a 10% probability for children of normal weight [77]. More recently Craigie et al (2003) found significant tracking of BMI from childhood (11 to 12 years) into adulthood (32 to 33 years), moreover 95% of children in the highest quartile of BMI at age 11 to 12 years were overweight or obese at age 32 to 33 years [75]. Ambrosini et al (2014) found moderate tracking of dietary patterns associated with adiposity from 7 to 13 years of age in a large cohort of UK children [78].

In a study following children from birth to 15 years of age, birth weight was not found to be predictive of later BMI, however they found significant tracking of BMI during the first 15 years particularly after the age of 7 years [79]. In 2000, Zwiauer estimated that 15-20% of obese adults became obese in childhood and a further 10-15% during adolescence [80]. Therefore, the evidence indicates that although the majority of adult obesity does not originate in childhood a large proportion of obese children go on to become obese adults. A systematic review on dietary energy density and body weight found strong evidence of a positive relationship between dietary energy density and increased body weight in both children and adolescents [81]. Understanding the dietary patterns and food choices of this age group is therefore vitally important.

7.3 Lack of viable alternatives to self-reported dietary intakes

Biomarkers offer an objective measure of capturing information on dietary intakes. Assessment of food intake using biomarkers depends on the collection and analysis of biological samples such as blood, urine, stool or tissue biopsies. It may be challenging to recruit children (and their parents) to take part in such studies. Examples include serum lipids, fatty acid composition, plasma carotenoids and fat-soluble vitamins [77, 78, 82, 83].

Serum C15:0 has been found to be a useful biomarker of diary fat intake [84]. Concentrations of carotenoids in the blood have been identified as the best biomarkers for consumption of fruits and vegetables [85] however, less invasive methods such as resonance Raman spectroscopy measures of skin carotenoid status show promise [86]. Urinary hippuric acid may be another useful biomarker for intakes of fruit, vegetables and juice in children and adolescents. The marker was found to correlate with intake better in younger children possibly due to an increased intake of other foods and drinks rich in polyphenols in the older group such as coffee and tea [87]. Such less invasive methods may be more acceptable and practicable with children.

In addition to biomarkers of nutrients, untargetted metabolomics has been used in the discovery of biomarkers of specific foods. This has been achieved by feeding individuals particular foods and using spectrometric and spectroscopic techniques to recognise patterns of metabolites associated with consumption of specific foods in blood or urine [88] e.g. putative markers for intake of raspberries and broccoli have been discovered using this technique [89] along with proline betaine as a marker of citrus intake [90].

Although an objective measure and therefore free from many of the sources of bias found in self-reports of intake, there are errors associated with the measurement of intakes using biomarkers. There may be high inter-individual variation in absorption, metabolism and excretion of metabolites [91] and concentrations of biomarkers can be affected by a number of factors such as ethnic background, weight status and other elements of the diet [92]. Watkins et al 2016 [93] found variability in subjects' response to supplementation with n-3

PUFA in post-menopausal women with a general upward trend in key metabolites in most participants but with some individuals showing little or no response.

Objective measures such as biomarkers are available only for a limited number of nutrients (such as energy and protein) and do not provide information on the mixture of foods and drinks consumed to provide that level of intake, nor do they give us the contextual information around food intake such as where the food was purchased or who the food was eaten with which may be important in understanding dietary habits.

Image capture methods such as Sensecam [94] and the e-button [95] have been used to objectively monitor food intake through the automatic capture of images. There are however, issues around food identification using these methods particularly for mixed dishes or meals where not all of the food items are visible [96] as would be the case for sandwiches. There are also some concerns around privacy issues and many schools and nurseries will not allow images to be captured on their premises.

8 Maximising accuracy of dietary recalls with children

Burrows et al. (2010) concluded 24-hr multiple pass recalls conducted over at least a 3-day period that includes weekdays and weekend days and uses parents as proxy reporters to be the most accurate method to estimate total energy intake in children aged 4 to 11 years, compared to total energy expenditure measured by DLW [26].

Self-reported measures of assessing intake with children are more complex and subject to greater errors due to children's limited food knowledge, memory, concept of time and also potentially motivation; these limitations and possible methods to overcome them are presented in Table 1. Baxter and colleagues have investigated various methods to minimise error in 24-hr recalls with children. The timing and content of the recall and the retention interval (elapsed time between consumption of meals and the interview) can all contribute to accuracy [97-99]. Reporting accuracy was found to be greater with a shorter retention interval and when the recording period was for the previous 24 hours (i.e. if interviewed at 4pm, the target period would be from 4pm the previous day) as opposed to the previous day (from midnight to midnight) [97, 99]. Accuracy was improved when the recall interview was on the same day as both school meals in the target period rather than the subsequent day [98]. Furthermore, a recent systematic review suggested that the timing of the recall was the most important factor in determining the accuracy [100]. The researchers recommended that dietary interviews with children are conducted as soon as possible after the eating occasion and ask about diet alone, rather than an integrated recall of diet and physical activity. As mentioned previously, age and cognitive ability are important factors affecting the accuracy of recalls [57]. It is believed that children aged over 8 years are able to accurately recall their food intake [26]. However it has been reported that children as young as 6 years may be more accurate than teachers or parents when recalling what they ate for school lunch [47]. One option could be a 'consensus' recall method, which enables the child and parent to be interviewed together. The method has been shown to give more accurate information compared to interviews with the child or parent alone [101, 102]. For young children, in-nursery or in-school, meal observations can also be conducted and the information combined with parental reports.

In order to capture the most accurate data from young children, specific questions can be tailored to their overall food knowledge. For instance, asking children to describe the colour and texture of foods can help the researcher determine which foods were consumed [2]. Examples may include asking what colour the milk bottle lid was to determine the type of milk (whole, semi-skimmed, or skimmed), and for bread, asking whether the bread had bits in (for multigrain or granary). For cooking methods, researchers may ask where the food was cooked, for example was it cooked in a pan on top of the cooker or in the oven? Visual aids may also be used, such as photographs of popular food brands. The types of questions or aids used need to reflect the research objectives and the level of detail required.

Table 1: Limitations of the 24-hr recall method with children, and methods to improve accuracy of the data captured

Limitations of 24-hr recall with children	Methods to improve accuracy of recalls
Literacy and writing skills	Research suggests that children over the age of 8-10 years are likely to be able to report their dietary intake more accurately than their parents. Online methods also provide an alternative to paper-based methods. Use proxy reporting, in school observation and/or in-person interviews.
Limited food recognition skills	Asking children to describe the colour and texture of foods can help the researcher determine which foods were consumed. E.g. asking what the colour the milk bottle lid was.
Memory constraints Concept of time	A 'consensus' recall method, which enables the child and parent to be interviewed together, may overcome some of the difficulties children experience when recalling their diet.
Concentration span	Online tools to capture dietary intakes are often more engaging than the traditional, paper-based methods, thus keeping the child focused on the task.
Parents unable to provide detailed information on what their children consume when in the care of others	For young children, in-nursery or in-school, meal observations can be combined with parental reports.

9 Conclusions

Although assessment of dietary habits, particularly those of children, is challenging and self-reports of food intake are flawed, methods such as the 24-hr recall are still useful in capturing important information on individual intakes of foods and drinks. Given the increasing burden of diet related disease it is imperative that we keep working towards improved methods of measuring intakes of foods and nutrients. In recent decades there has been a significant increase in the understanding of the errors in dietary assessment and how these differ between different population groups. This includes both the errors inherent in the assessment method itself along with perturbation of the diet due to the act of measuring food intake (including the observation effect, social desirability bias and changes to diet to facilitate recording).

As Subar et al. (2014) discuss in their excellent response to the recent criticism of self-reported dietary assessment, social desirability bias would mean intakes of healthy foods such as fruits and vegetables would be under-reported to a lesser degree [103]. Yet still, in the UK, children's intakes of fruits and vegetables are reported to be around half of the recommended 5-a-day [104]. There is currently no objective method for assessing dietary patterns and despite the reporting bias and lack of precision associated with self-report methods, consistent links between dietary variables and prevalence of disease have been detected.

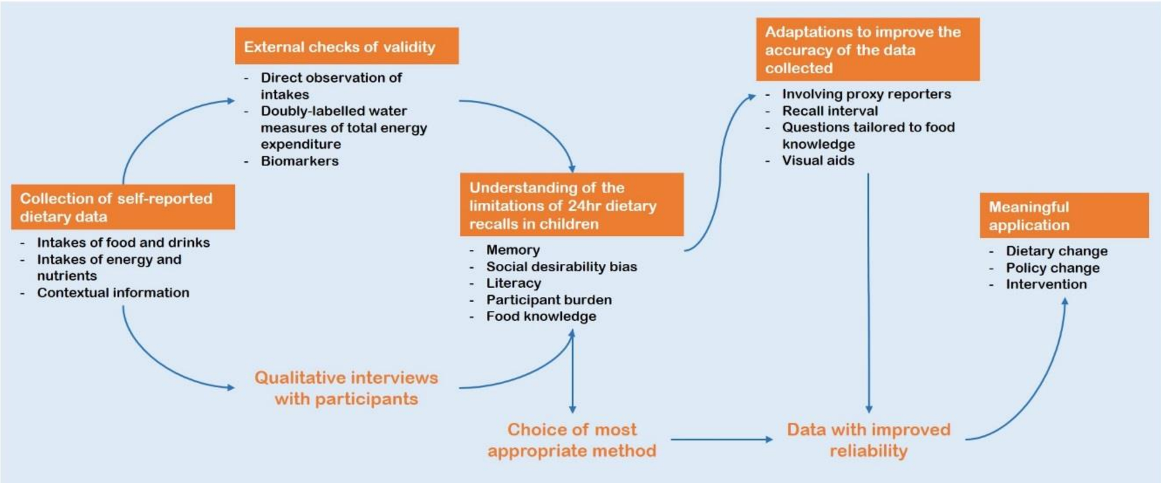
10 Future Research

Further work should focus on improving self-reported methods of dietary assessment and combining these with biomarkers and/or technology based methods of capturing intake to improve accuracy whilst reducing the participant burden. Subar et al. (2014) state "*thoughtfully interpreting the data we do have, given our knowledge of measurement error, is critical*".

Fundamental to understanding peoples' diets more accurately is improved knowledge of the error inherent in a particular method. Better understanding of how measurement error differs across dietary assessment methods and amongst specific population groups will assist researchers in choosing the most appropriate method or combination of methods for the population and research question in order to understand dietary relationships further. Livingstone and Black (2003) highlight that the reasons for mis-reporting are complex and likely operate in different people in different ways. They emphasize the importance of collaborating with behavioral scientists in order to examine the social, cultural and psychological influences on the accuracy of dietary reporting [19]. Figure 1 shows the iterative cycle by which the learnings at various stages of dietary data collection can feed into the continued improvement of our understanding and application of dietary assessment methods.

To suggest that collection of dietary data using self-reported measures should be discontinued is to ignore the significant progress that has been made. Dietary assessment is never going to be an exact science but as methods become more accurate and applied more carefully to the population groups our understanding of dietary habits will progressively improve.

Figure 1 - Iterative cycle of improvement of dietary assessment methodologies.



Footnote - Figure 1 illustrates the mechanisms by which the various elements of dietary data collection can feed into the iterative improvement of dietary assessment methodologies.

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