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Background/Objectives: To assess the validity of a 7-day pre-coded food record (PFR) method in 9-month-old infants against metabolisable energy intake (ME_{DLW}) measured by doubly labelled water (DLW); additionally to compare PFR with a 7-day weighed food record (WFR) in 9-month-old infants and 36–month-old children.

Subjects/Methods: The study population consisted of 36 infants (age: 9.03±0.2 months) and 36 young children (age: 36.1±0.3 months) enrolled in a cross-over design of 7 consecutive days PFR vs. 7 consecutive days WFR. Children were randomly assigned to one method during Week 1, crossing over to the alternative method in Week 2. Total energy expenditure (TEE) and ME_{DLW} was obtained in the 9-month-old infants using the DLW technique for 7 days while recording with PFR.

Results: For the 9-month-old group, PFR showed a mean bias of +726 kJ/day, equivalent to 24 %, (P<0.0001) compared to ME_{DLW} (n=29). Using WFR as the reference in this group no between-method differences were found for energy, fat and carbohydrate. Energy intake in the 36-month-old children was 12% higher in the PFR vs. WFR (P<0.0001) and protein plus total fat intake were overestimated with the PFR (P=0.008, P<0.0001, respectively).

Conclusions: The study indicates that the PFR may be a valuable tool for measuring energy, energy-yielding nutrients and foods in groups of 9-month-olds infants and 36-month-olds young children.

Keywords: Pre-coded food record; validation; energy intake; doubly labelled water; energy expenditure; dietary assessment

Introduction

Detailed information regarding energy and nutrient requirements during infancy and early childhood is critical to the provision of sound nutritional advice consistent with growth and development plus the prevention of diet-related disease (Berenson, 2002; Guo *et al.*, 2002). Dietary intake assessment is integral to research as well as in the clinical setting. However, assessment of dietary intake in infants and young children is extremely challenging, requires special methodology and is further complicated by the rapid growth changes that occur during a relatively short period of time. In addition, not all food served to an infant or young child is necessarily consumed, some may be wasted, and if the child attends daycare, adults other than the parents may be involved in dietary assessment. Several studies of estimated food records in children and adolescents have shown an underestimation of food intake by up to 35% (Bandini *et al.*, 1997; Champagne *et al.*, 1998; Singh *et al.*, 2009). However, only little research on the validation of dietary intake methodology in infants and young children exist (Burrows *et al.*, 2010; Davies *et al.*, 1994; Lanigan *et al.*, 2004).

The weighed intake record has long been recognized as the most precise method available for estimating usual intakes (Gibson, 1990). However, the method is costly and time consuming for both researchers and participants, and alternate methods are necessary in larger studies. A pre-coded food record (PFR) method was developed to assess the diet of infants and young children between 6 months and 4 years of age (Trolle *et al.*, 2002). We chose a 7-day record rather than a 4-day, because 7 days is more representative of habitual diet, percent consumers of different foods decrease with fewer days of recording (Biltoft-Jensen *et al.*, 2009), and we wanted to be able to compare the results with The Danish National Survey of Dietary Habits using a similar method (Pedersen *et al.*, 2010). In contrast to the traditional estimated food record method, the PFR uses household measures and photographs for portion size estimation, and is useful for both infants and toddlers. Furthermore, it is less expensive, simpler for parents to administer and is able to be scanned which makes it ideal for use in a range of studies.

The objective of the present study was to assess the validity of a 7-day pre-coded food record (PFR) method in 9-month-old infants against metabolisable energy intake (ME_{DLW}) measured by doubly labelled water (DLW); additionally to compare PFR with a 7-day weighed food record (WFR) in 9-month-old infants and 36–month-old children.

Materials and methods

Subjects

Nine-month-old infants and thirty-six-month-old children living in the Copenhagen area were recruited through the central governmental register. Children were identified according to their date of birth and included those born between September 2004 and February 2005 and from July 2007 – March 2008. An invitation letter was sent to 3400 families two weeks before the children turned 9 and 36 months of age, respectively. Inclusion criteria were: age either 9 months ± 2 weeks or 36 months ± 3 months, cared for by parents (9-months only), eating a Western diet, kindergarten agreed to participate (36 months only), and parents read/speak Danish. Exclusion criteria were: breastfed, a chronic illness that may impact the energy metabolism, and if regurgitating of milk after ingestion was frequent. One hundred and twenty-two families were interested in participating in the study and 76 were eligible.

The study protocol was approved by the ethical committee of the *Capital region* of Denmark and written informed parental consent was obtained (journal no. H-B-2007-022).

Study design

Parents were randomly assigned – with stratification for age (9 or 36 months) - to record their child's diet during the first week with PFR or WFR and instructed by the responsible investigator during the first home visit. After the first week, parents were instructed in the other method during a second home visit. We aimed for a one-week period between the two recording periods however up to 10 days was acceptable for the infants and one month for the children. A third home visit was made after the last recording, and the weight and height of the 36-month-olds were recorded. Children were weighed in their underwear and barefoot to the nearest 0.1 kg on a digital scale (Soehnle Verona 63686, www.MEDShop.dk). Height was measured to the nearest 0.5 cm with a stadiometer.

If the child was not at home during the last home visit (3 children), the weight and height of the child were collected from the child's health cards, measured by healthcare personnel at the scheduled third year examination. For length and body weight of the infants see DLW section.

Pre-coded food record (PFR)

The diet was recorded for 7 consecutive days in booklets with pre-coded response categories which included open-answer options and covered meals and snacks. Quantities were estimated from either predefined household measures or from a series of 12 food photographs (Trolle et al., unpublished), depending on the specific food or drink. For food items not included in PFR, parents recorded type of food and portion size eaten in open-answer categories. If the child attended daycare, food and drink was recorded in household measures by the daycare staff on a separate sheet, and then transferred to the pre-coded food record by the parents.

All intakes of energy, nutrients and food items recorded in the precoded food record were calculated for each individual using the software system GIES (version 1.000 d), a system developed at National Food Institute, Technical University of Denmark, and the Danish Food Composition Databank (version 7; Søborg; Denmark; www.Foodcomp.dk). The intake model in GIES operates with three separate data layers: the recorded food intake, recipes, and food composition data. Prior to this study the Danish Food composition Databank and the recipes were amended to include products and recipes common for infants and young children.

Weighed food record (reference method) (WFR)

Parents were provided with structured recording sheets and a digital scale (Soehnle, attaché, A-L Isenkram En Gros AS) with a precision of ±1 g (0-1000 g) and ±2 g (1000-2000 g), and a maximum of 2 kg. Practical and written instructions were provided on how to weigh and describe in detail the consumption of food and beverages, how to record food items individually and cumulatively using the scales, and estimate waste by recording all food or beverage not consumed. Parents were asked to provide brand names, detailed descriptions of ingredients used in home-prepared meals and cooking methods. If the child attended daycare the main scientist instructed the daycare staff and provided them with a digital scale and recording sheets. All intakes recorded in the WFR were manually coded in duplicate and calculations were completed in GIES as described above.

Doubly labelled water (DLW)

In the 9-month-old group, total energy expenditure (TEE) was measured during the PFR recording period using the DLW technique. DLW is acknowledged as the gold standard measure of TEE in free-living individuals (Ainslie *et al.*, 2003) and has been widely used in infants (Butte *et al*., 2000). The isotopes were administrated orally either as water or added to approximately 10 ml infant formula. Close to the expected time of a feed the pre-weighed dose was brought to the home of the infant in a small feeding bottle, sealed in a polythene bag. Most infants drank the dose easily and quickly. Pre-weighed tissues were used to mop up any loss that occasionally occurred while the infant was drinking the dose. When infant formula was added to the dose, the portion of DLW was calculated and subsequently, any dose loss. Prior to administration of the DLW dose, the infant was weighed naked at an extra home visit for the 9-month-olds on a baby scale with a precision of 0.001 g (0-15 kg) (Sartorius IP 65, Bie & Berntsen AS). The dose was calculated according to the body weight of the infant as 0.10 g $^{2}H_2O$/kg body weight and 2.8 g ^{18}O/kg body weight prepared from 99.8% $^{2}H_2O$ and 10.0% $H_2{}^{18}O$, respectively (Cambridge Isotopes Laboratories, Inc., Andover, Massachusetts, USA) and accurately weighed off to the nearest 0.001 g (Mettler PL 200, Mettler-Toledo AS).

A pre-dose urine sample was collected from each infant before administering the DLW, and subsequently on days 1 and 7 according to the method described in detail elsewhere (IAEA, 2009). In brief, cotton wool balls were left inside the infants' nappy, which the parents checked frequently for urination. When the infant had urinated the urine sample was obtained by inserting the cotton wool into a 50 ml syringe. The time for voiding was taken as the midpoint between the time for leaving the cotton balls in the nappy and the time for collection of the wet cotton balls. The isotopic enrichment of the prepared samples and references were measured by isotope ratio mass spectrometry (20:20 Hydra Model, PDZ Europa, Crewe, UK).

Anthropometric measurements were entered into the software program WHO Anthro 2005 (World Health Organization, 2010).

Statistics

As the SD of the expected mean difference between energy intake estimated from PFR and WFR was not available, the SD for energy intake for children between one and three years of age (1333 kJ) was used from The Danish National survey of Dietary habits (Lyhne *et al.*, 1996). With a significance level of 0.05, and a power of 90%, 35 participants were needed in each group to be certain of detecting a mean difference between PFR and WFR of 650 kJ (Lenth, 2006).

Data were analyzed with SAS (version 9.1 for windows, SAS institute Inc., Cary, NC, USA) with a level of significance of $P<0.05$. Data are presented as means and SD. Differences between methods were analysed using paired *t*-tests. Visual agreement between methods was analysed using the Bland and Altman approach (Bland *et al.*, 1986).

Results

For the 9-month group 37 children were recruited, and one dropped out because of persistent illness. Data from one infant were excluded due to illness of the child during the recording period. Measurement of TEE was successful in 29 infants with data lost due to either poor parental compliance in collecting urine samples, illness during the study, or regurgitating within 2 h of the dose being given. 42 children were recruited to the 36-month-old group however 6 were lost due to failure of kindergartens to participate and personal problems for families. Data from two young children were excluded due to illness during the recording period. Thus the final study sample included 35 infants and 34 young children. Characteristics of the children are shown in Table 1.

TEE results are presented in Table 2. Comparisons with estimated energy intake are possible by including a factor equivalent to the energy cost of growth to derive ME_{DLW}. In absolute terms, the energy cost of growth is 115 kJ/day by 9 months of age (Butte *et al.*, 2000).

For the 9-month-old group, no significant between-method differences were found for the absolute values except for mean protein intake (g/day) where the WFR was significantly higher (Table 3). For the 36-month-old group, mean energy intake and mean intake of energy-yielding nutrients were significantly higher with the PFR. No significant difference was found for mean intake of total carbohydrate (Table 4). When nutrient density was compared, the percentage of energy provided by each macronutrient differed significantly for all nutrients, except protein for the 36-month-old group.

PFR data showed that infants' intake was significantly higher with regard to bread, fruit and berries and showed significantly higher consumption of milk products (not potable) and fatty spread for the 36-month-old group, than with the WFR (data not shown).

The difference between energy intake from the PFR and ME_{DLW} plotted against the mean of the two methods is presented in Fig. 1. As the observed differences are primarily positive, parents mostly overestimated energy intake using the PFR. The width of 95 % limits of agreement varied from -589 kJ to 2072 kJ (± 2 s.d.). Mean difference between the two methods as percentage of ME_{DLW} was 24 %. The plot demonstrates an increase in differences with increasing energy intake. However, log transforming the data did not change the plot considerable (plot not shown). Energy intake differences between WFR and PFR for the 36-month-old group are shown in Fig. 2 which illustrates that overestimation of energy intake with the PFR is pronounced compared to WFR. The width of 95 % limits of agreement varied from -787 kJ to 1959 kJ (± 2 s.d.). Both plots indicate wide discrepancies between the two methods for individual subjects.

Discussion

The present study showed that in 9-month-old infants, PFR substantially overestimated energy intake in the infants compared to ME_{DLW}. Using WFR as the reference, in the 9-month-olds, energy intake and energy-yielding nutrients were similar for the infants with the exception of protein. In contrast, for 36-month-old children, PFR overestimated energy intake and most energy-yielding nutrients compared to WFR.

The DLW technique is non-invasive, completely safe, and involves minimal subject burden. The technique enables a precise estimation of metabolisable energy intake among free-living individuals, including infants and young children (Jones *et al.*, 1987; Roberts *et al.*, 1986). The mean TEE in the current study was 309±46 kJ/kg/day for the 9-month-old infants. This is similar to earlier reported figures of between 306-343 kJ/kg/day for 9-month-old infants (Tennefors *et al.*, 2003; Davies *et al.*, 1997; Butte *et al.*, 2000). Slightly higher TEE figures of up to 393 kJ/kg/day for infants between 9 and 12 months of age have been reported (Davies *et al.*, 1991; Vasquez-Velasquez, 1988). Discrepancies in reported TEE findings may be due to differences in the proportion of breast- and formula-fed infants (Butte *et al.*, 2000; Jiang *et al.*, 1998) and differences in the estimated energy deposition for growth and the wide spectrum of nutritional status. We are not aware of any validation studies to have compared PFR with ME_{DLW} in infants and young children. However, validation studies undertaken with older children (aged 10-15 y) estimating food records, have reported an underestimation of habitual energy intake compared with TEE measured by DLW of up to 35 % (Bandini *et al.*, 1997; Champagne *et al.*, 1998; Singh *et al.*, 2009). For comparison, the present study found an overestimation of mean energy intake of 24 % compared to ME_{DLW} for the 9-month group.

The plot demonstrating the difference between energy intake from the PFR and ME_{DLW} plotted against the mean of the two methods showed a tendency of an increase in the difference with increasing energy intake (Fig. 1), indicating larger difference between the two methods with increasing energy intake for the 9-months-olds.

The higher mean protein intake from the PFR, compared to the WFR, for the infants cannot be explained by significant differences in any of the food groups. Summation of minute differences may have contributed to the observed differences. The nutrient densities showed more significant differences between the two methods than the absolute figures. However, this may be of less importance since the figures are still within the nutrient recommendations for this age group (Nordic Council of Ministers, 2004).

In the 36-month-olds, energy intake estimated from the PFR was 12% higher than from the WFR with relatively overestimation of total fat, saturated fat, and added sugars. A highly significant difference was found for intake of fatty spread, a 56% higher intake, and milk products ($P<0.0003$ and $P<0.0003$, respectively) (data not shown). Differences in these two food groups could explain the overall difference in fat and saturated fat in this age group. The overestimation could be due to difficulties in recording the correct portion size, or the use of too large portion sizes in the PFR. Clearly, one possibility is also that some of the differences simply are caused by the fact that the children had different intakes in the different weeks where the diet was recorded either with the PFR or WFR.

A study validating a semi-quantitative food-frequency questionnaire against a weighed record among 2-year-old children showed a tendency of underreporting unhealthy foods like cake, soft drinks and sweets, while more healthy foods like bread, fruit and potatoes were overreported (Andersen *et al.*, 2004). This tendency was not found in the present study for the 36-month group. However, for the 9-month group bread, fruit and berries were overestimated with the PFR. This overestimation may be caused by too large portion sizes and could be reduced by changing the units of measurement for these food items.

Based on body weight, the mean energy intake for the 36-month-old group was 5370 kJ/day, only 2 kJ/day lower than estimated from PFR. This may indicate that there was a degree of underestimation with the WFR while the PFR could be closer to the actual intake. However, estimated values for energy expenditure using the DLW method plus energy stored for growth (2 %) in this age group are around 5000 kJ/day (Torun *et al.*, 1996). For the 9-month-old infants, the recommended energy intake expressed per kilogram body weight was between ME_{DLW} and EI_{PFR}. This may be due to the infants in the current study being less active than would be expected for their age. The boys participating in the study were relatively big, having a weight-for-age z-score of 0.9 and a BMI-for-age of 0.5 (data not shown), indicating that they were larger and heavier than the WHO child growth standards, and must have had a period of surplus energy intake. It is conceivable that their high body weight discouraged physical activity and that they were in a state of positive energy balance, making the bias between ME_{DLW} and EI_{PFR} smaller than presented.

It is notoriously difficult to measure food intake accurately for all age groups. Food records, weighed records or recall methods each have their strengths and weaknesses. Measuring food intake for infants and young children has an obvious dependency on the parents or proxy person of the child studied. As the parents normally control the dietary intake of the infant and this age-group primarily eats at home, this provides potential for an accurate recording. However, when the children are at day-care, other caregivers must be involved, who might approach the task of recording with varying levels of motivation and interest. Other factors could include conscious or unconscious modification of usual dietary habits in an attempt to present a more wholesome picture, and omissions or additions, especially if the record was not filled out immediately. Lastly, it is very difficult for the parents to estimate the exact amount of food eaten by the child even while trying. Food may be wasted, perhaps not only on the plate but around and on the child. Sometimes the child may even take the food into his/her mouth, chew it, and subsequently spit it out. Even when using a scale as in recording with WFR registering the waste and estimating the actual amount consumed can be very difficult.

A limitation of the present study was the relatively small sample size with lack of finance influencing the use of the DLW technique in only the younger cohort. However, the sample size is consistent with numbers in other validation studies using the technique.

In conclusion, the study indicates that the PFR, produces acceptable estimates for energy, energy-yielding nutrients and foods in groups of 9-months-old infants and 36-month-olds young children, and may be a valuable tool for future dietary assessments in infants and young children.

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Conflict of interest: None to declare

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Table 1 Characteristics of subjects

	9-month-old	36-month-old
	(n=35)	(n=34)
Age (months)	9.03±0.2	36.1±0.3
Body weight (kg)	9.4±1.0	15.5±2.0
Height (cm)	73.2± 3.2	97.9±3.7
Body weight for age z score[1]	0.7±0.8	0.6±1.0
Energy requirement[2] (kJ/child)	3330±355	5369±720
Duration of exclusive breastfeeding (months)	2.9	-
Duration of partial breastfeeding (months)	5.5	-

1) Body weight for age z score was derived from the software program WHO Anthro (World Health Organization, 2010)
2) Energy requirement is calculated as kJ/kg body weight of the child (Nordic Council of Ministers, 2004)
Values are means ± s.d.
Percentage male = 56% in both groups

Table 2 Energy expenditure (TEE_{DLW}), metabolisable energy intake (ME_{DLW}), energy intake determined by the pre-coded food record (EI_{PFR}) and the weighed food record (EI_{WFR}), and the difference between EI_{PFR} and ME_{DLW} for 9-month-old group (n=29)

	Mean	s.d.
TEE_{DLW} (kJ/day)	2881	118
TEE_{DLW} (kJ/kg/day)	309	46
ME_{DLW} (kJ/day)	2996	493
EI_{PFR} (kJ/day)	3722	901
EI_{WFR}(kJ/day)	3640	846
Difference (EI_{PFR}-ME_{DLW})(kJ/day)	726	673

Table 3 Total energy and energy-yielding nutrients obtained from the pre-coded food record or the weighed food record method in 9-month-old children (n=35)

	Pre-coded food record		Weighed food record		
Dietary component					*P-value*
Energy (kJ/day)	3677	884	3825	1036	0.47
Protein (g/day)	27.3	6.3	31.1	9.6	**0.03**
Protein (E%)	12.7	1.7	13.8	1.8	**0.005**
Fat (g/day)	37.9	11.3	34.5	7.4	0.13
Fat (E%)	38.0	6.0	34.0	4.8	**0.0005**
Saturated fat (g/day)	14.7	6.8	13.3	3.2	0.29
Saturated fat (E%)	14.5	5.1	13.3	2.4	0.18
Carbohydrate[1] (g/day)	111.4	28.9	124.3	42.6	0.08
Carbohydrate[2] (E%)	49.3	6.0	52.2	5.1	**0.01**
Added sugars (g/day)	3.5	3.8	2.2	2.4	0.05
Added sugars (E%)	1.6	1.0	0.6	0.6	**0.036**

Values are means ± s.d.

1) Available carbohydrates plus fibres

2) For carbohydrates E% is the percentage of energy provided by available carbohydrates (17 kJ/g) and fibres (8 kJ/g).

Table 4 Total energy and energy-yielding nutrients obtained from the pre-coded food record or the weighed food record method in 36-month-old children (n=34)

Dietary component	Pre-coded food record		Weighed food record		*P-value*
Energy (kJ/day)	5372	760	4786	810	**<0.0001**
Protein (g/day)	47.0	9.7	43.0	9.1	**0.008**
Protein (E%)	14.8	1.5	15.2	1.7	0.065
Fat (g/day)	50.9	9.6	39.7	8.1	**<0.0001**
Fat (E%)	35.2	5.2	30.8	4.3	**<0.0001**
Saturated fat (g/day)	21.6	4.7	16.5	3.7	**<0.0001**
Saturated fat (E%)	14.9	2.8	12.8	2.3	**<0.0001**
Carbohydrate (g/day)[1]	165.6	28.4	159.7	31.2	0.116
Carbohydrate (E%)[2]	50.0	4.8	54.0	4.4	**<0.0001**
Added sugars (g/day)	22.1	11.1	15.9	7.7	**0.0001**
Added sugars (E%)	7.0	3.4	5.8	3.1	**0.004**

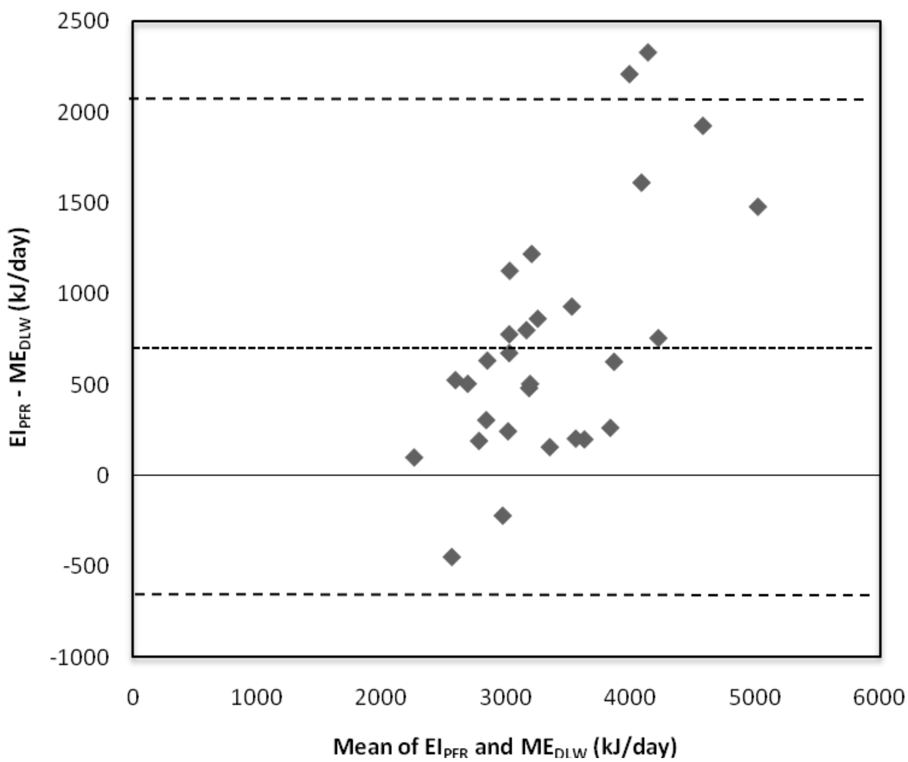
Values are means ± s.d.

1) Available carbohydrates plus fibres

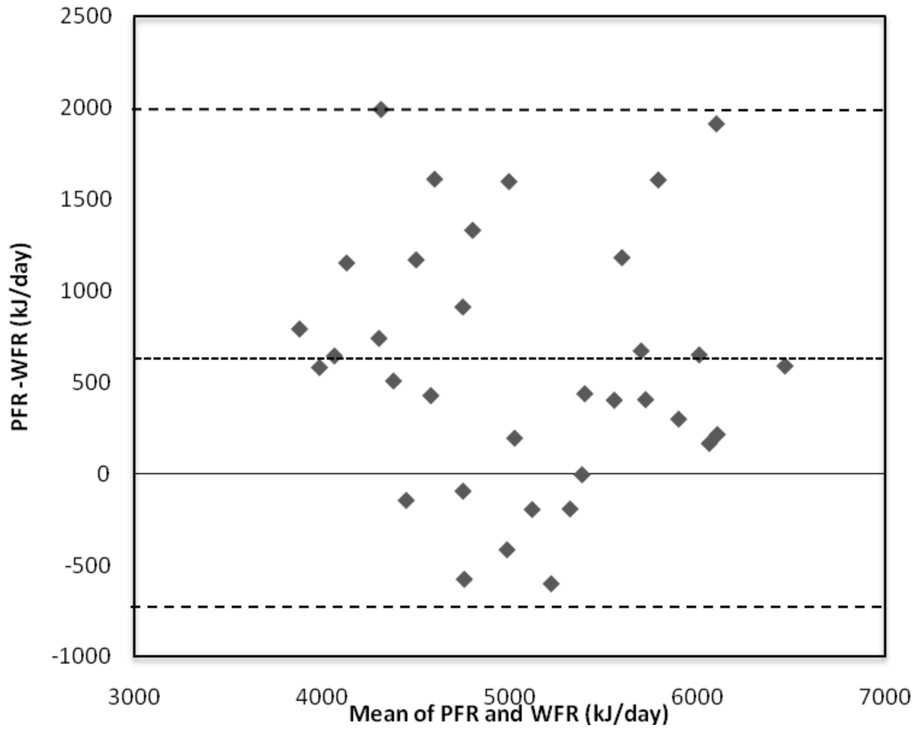
2) For carbohydrates E% is the percentage of energy provided by available carbohydrates (17 kJ/g) and fibres (8 kJ/g).

Fig. 1 Difference between energy intake estimated from pre-coded food record (EI_{PFR}) and metabolisable energy intake as measured by doubly labelled water (ME_{DLW}) plotted against the mean of EI_{PFR} and ME_{DLW} for the 9-month-old group. ··········, Mean difference; - - - -, ±2SD (n=29)

Fig. 2 Difference between weighed food record (WFR) and pre-coded food record (PFR) plotted against the mean of WFR and PFR for the 36-month-old group. , Mean difference; , ±2SD (n=34)



2500
2000
1500
1000
500
0
-500
-1000
0
1000
2000
3000
4000
5000
6000
EI$_{PFR}$ - ME$_{DLW}$ (kJ/day)
Mean of EI$_{PFR}$ and ME$_{DLW}$ (kJ/day)


2500
2000
1500
1000
500
0
-500
-1000
PFR -WFR (kJ/day)
3000
4000
5000
6000
7000
Mean of PFR and WFR (kJ/day)