

ORIGINAL ARTICLE

Dietary intakes assessed by 24-h recalls in peri-urban African adolescents: validity of energy intake compared with estimated energy expenditure

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Background/Objective: The objective of this study is to determine the relative validity of reported energy intake (EI) derived from multiple 24-h recalls against estimated energy expenditure (EE_{est}). Basal metabolic rate (BMR) equations and physical activity factors were incorporated to calculate EE_{est} .

Subjects/Methods: This analysis was nested in the multidisciplinary Physical Activity in the Young study with a prospective study design. Peri-urban black South African adolescents were investigated in a subsample of 131 learners (87 girls and 44 boys) from the parent study sample of 369 (211 girls and 158 boys) who had all measurements taken. Pearson correlation coefficients and Bland–Altman plots were calculated to identify the most accurate published equations to estimate BMR ($P < 0.05$ statistically significant). EE_{est} was estimated using BMR equations and estimated physical activity factors derived from Previous Day Physical Activity Recall questionnaires. After calculation of EE_{est} , the relative validity of reported energy intake (EI_{rep}) derived from multiple 24-h recalls was tested for three data subsets using Pearson correlation coefficients. Goldberg's formula identified cut points (CPs) for under and over reporting of EI.

Results: Pearson correlation coefficients between calculated BMRs ranged from 0.97 to 0.99. Bland–Altman analyses showed acceptable agreement (two equations for each gender). One equation for each gender was used to calculate EE_{est} . Pearson correlation coefficients between EI_{rep} and EE_{est} for three data sets were weak, indicating poor agreement. CPs for physical activity groups showed under reporting in 87% boys and 95% girls.

Conclusion: The 24-h recalls measured at five measurements over 2 years offered poor validity between EI_{rep} and EE_{est} .
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Keywords: adolescents; dietary assessment; energy cutoff points; 24-h recalls; validity

Introduction

In multicultural societies, such as South Africa, testing of validity of dietary methodology is vital as differences in food habits, cultures and languages may affect both the ways in which participants report on food intake and researchers' understanding of the food intake data. In adolescents, lack of knowledge regarding food preparation, low literacy levels

and short attention span further complicate dietary assessment (DA) (Flood et al., 2004).

In South Africa, the 24-h recall is a commonly used method of DA, particularly among children and adolescents (Steyn et al., 1986; Labadarios et al., 2005; Kruger et al., 2006; MacIntyre and Du Plessis, 2006). Despite the well-known limitation that dietary intake data from single 24-h recalls are not representative of usual diet (Gibson, 2005; Ma et al., 2009), only one study has reported on the relative validity of the 24-h recall used among South African adolescents (Kruger et al., 2006).

A reason for the lack of validation data may be the challenges faced by researchers in resource poor settings when undertaking validation studies. One approach to

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testing validity is to compare the dietary intake derived from a 'test' DA method to the dietary intake derived from a 'reference' method. This comparative approach may, however, merely show similar errors in both methods rather than relative validity. Another approach uses biomarkers such as plasma or serum levels of vitamins B6 and C and folate (Flood et al., 2004), 24-h urinary nitrogen excretion and EE (Gibson, 2005) to determine the validity of reported intakes, using specialised and expensive equipment (Henry et al., 1999). Although the determination of basal metabolic rate (BMR) and EE to calculate total daily EE by doubly labelled water is considered the most accurate method of validating reported EI (Schoeller, 1995), this method is costly and not always available in a field setting, especially in a resource-poor country such as South Africa. Methods of determining EE, such as the compendium of physical activities, that uses direct observation, participant recall or recording of physical activities in a diary (Ainsworth et al., 2000) are costly and require a high level of literacy and commitment from the participants and rely on memory. Therefore, these methods may not be an option to use among adolescents and especially those from developing countries.

The estimation of EE using published equations to calculate BMR (Henry et al., 1999) and physical activity factors (PAFs; Brooks et al., 2004) derived from simple physical activity questionnaires such as the Previous Day Physical Activity Recall (PDPAR; Trost et al., 1999) offers a feasible approach to validate reported EI in populations in resource-poor settings. The use of BMR estimation equations, however, is limited by the fact that equations derived for one population may not be applicable to a target population in a different environment (Tverskaya et al., 1998; Rodriguez et al., 2000). Furthermore, as there are a number of published equations, each using different combinations of variables, the researcher has to decide which is the most appropriate for the study sample.

The Physical Activity in the Young study was a prospective study to determine the physical activity patterns, dietary intakes, anthropometric measurements and physical maturity of free-living, peri-urban adolescents (grade 8) in the North West province, South Africa over 2 years. This paper reports a sub-study which aimed to determine the relative validity of reported EI of the study sample derived from 24-h recalls taken at each measurement point in comparison with estimated EE derived from calculated BMR and estimated physical activity levels (PALs).

Subjects and methods

Study population

This prospective sub-study was nested in the multidisciplinary Physical Activity in the Young study (parent study). All available adolescents ($n = 369$) (158 boys and 211 girls) between the ages of 13 and 18 years at two secondary schools in Ikageng, North West province, were included in this study.

All learners were in grade 8 at the onset of the study in 2004. Only those subjects for whom all measurements were available were included in the sub-study (87 girls and 44 boys). As the equations for the calculation of BMR are applicable only for subjects ≥ 17 years, an additional criterion for the sub-study was that subjects must be 16 years or younger at all measurement points. This resulted in a sample size of 81 (55 girls and 26 boys) for data subsets 2 and 3 (see Figure 1). The Physical Activity in the Young study was approved by the North-West University Ethics Committee (Ethics number 04M01). Written authorisation was obtained from the school principal to conduct the study. Recruited participants and parents/guardians gave written informed consent before inclusion in the study.

Study outline

The outline of the study is presented in Figure 1. Subjects were assessed at seven measurement points: March (baseline), June, August and September 2004 and March, June and September 2005. Specific months were selected to assess seasonal dietary intakes (March, autumn; June and August, winter; September, spring).

Demographic assessment

Demographic data including age, gender and ethnic group were obtained using a structured questionnaire.

Procedure for conducting the 24-h recall

Dietary intakes were assessed by standardised 24-h recall interviews at each measurement point. Two trained and experienced interviewers, supervised by a registered dietitian, conducted the interviews. Participants recalled food and beverage intakes of the previous 24 h (midnight to midnight), starting with the first food/beverage consumed on waking. Prompting was used to identify important food items not mentioned and to obtain detailed information on preparation methods, brand names and portion sizes. Portion sizes were estimated using a food portion photograph book validated for the north-west province adult population, which included adolescents (Venter et al., 2000). To ensure standardisation of interview and recording techniques, procedures were reviewed before each DA occasion, 24-h recalls were scrutinised on completion for visible errors such as omissions of preparation methods and portion sizes, errors were then discussed and corrections were addressed immediately.

Anthropometric and physical activity measurements

Physical activity assessments were carried out at all seven measurement points. Anthropometric measurements were taken at five points (March, September 2004 and March, June, September 2005; Figure 1). Body weight (in underwear)

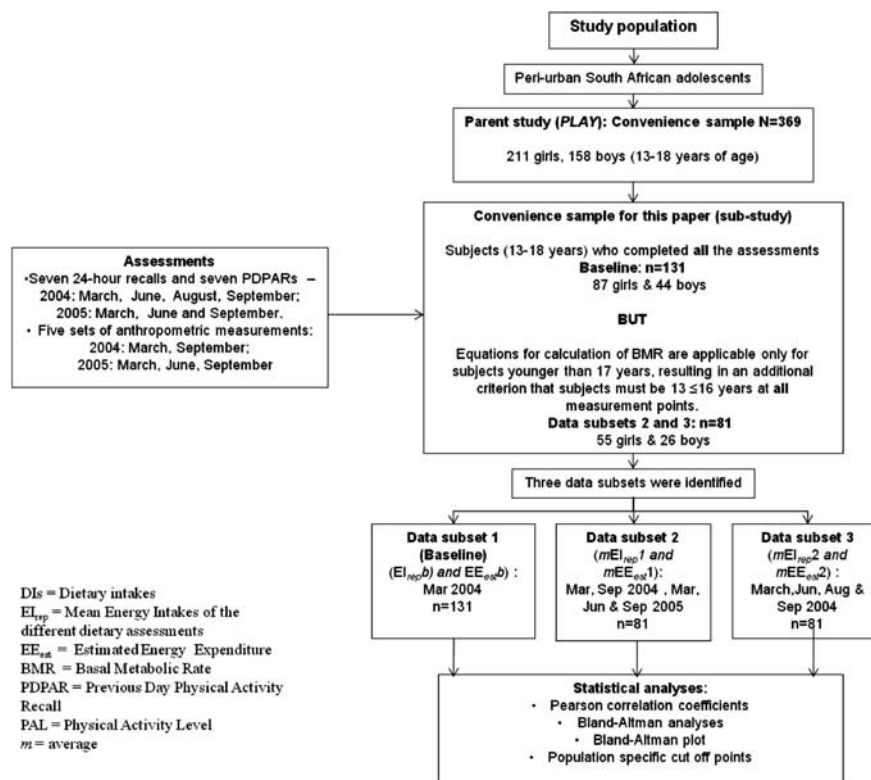


Figure 1 Study design. PLAY, Physical Activity in the Young.

and height were measured by qualified anthropometrists using standardised procedures (International Society for the Advancement of Kinanthropometry (ISAK), 2001). Participant age was calculated as the difference between the date of measurement and the date of birth using Excel XP (2004).

Accordingly to Sirard and Pate (2001), the PDPAR questionnaire (Trost et al., 1999) is a widely used reliable and valid method for the assessment of habitual physical activity of children and adolescents and was therefore used in our study to determine the PAL. The PDPAR questionnaire is a self-reported questionnaire, which is vulnerable to recall errors, deliberate misrepresentation, social desirability and other biases. Nevertheless, researchers have deemed that of all self-report questionnaires, the 1-day recall is the most reliable and valid for adolescents (McMurray et al., 2004). One of the limitations of the PDPAR questionnaire is that it may not be sensitive enough to detect changes of the intensity of the activities in the 30-min blocks used in the questionnaires (Anderson, 2005). Reported activities were coded and assigned a metabolic equivalent min/week value (Ainsworth et al., 1993). Participants were then classified into one of three PAL categories (see statistical analyses for detail).

Statistical analysis

Reported energy intake. The reported EI (EI_{rep}) of each subject at each measurement point was derived from the analysis of

the 24-h recall data using the FoodFinder dietary analysis software programme (Medical Research Council Inc., 2007). EI data were exported to Statistica 4 for further analysis (StatSoft, 2004).

Estimation of basal metabolic rate. Ideally BMR and EE equations should be developed for specific populations (Tverskaya et al., 1998). In the absence of specific equations for our target population, we attempted to identify the most appropriate published equations to use by calculating the Pearson correlation coefficients between BMRs estimated by the equations shown in Table 1. The nature of the agreement between estimated BMRs was further explored using Bland and Altman (1986) analyses.

The means and standard deviations for the BMR estimated by the various equations are shown in Table 1. The Pearson correlation coefficients between estimated BMRs ranged from 0.89 to 1.0 for the girls and from 0.97 to 1.0 for the boys (Table 2). Further investigation of the agreement between estimated BMRs using Bland–Altman analyses, showed acceptable limits of agreement and constant differences across averages of estimated BMR for equations (2) and (5) for the girls (Figure 2) and equations (9) and (12) for the boys (Figure 3). Each variable introduces an additional source of error into an equation. Thus, from a statistical viewpoint, equations requiring only weight are more likely to give

Table 1 Equations used to determine the most appropriate one for the estimation of BMR for the study sample and the mean and standard deviation baseline BMR calculated by each equation

| References | Equations | Estimated BMR (kJ) (baseline) | |
|-------------------------|---|-------------------------------|-------|
| | | Mean | s.d. |
| Girls (n ¼ 87) | | | |
| Henry et al. (1999) | (1) BMR (kJ) ¼ weight (kg) 47.9 þ 3230 | 5331.6 | 400.8 |
| | (2) BMR (kJ) ¼ weight (kg) 21.0–height (cm) 11.0 þ FFM (kg) 80.7–age (years) 154.6 þ 5319 | 4944.5 | 480.4 |
| FAO/WHO/UNU (1985) | (3) BMR (kJ) ¼ 51 weight (kg) þ 3120 | 5358.0 | 426.8 |
| | (4) BMR (kJ) ¼ 30.9 weight (kg) þ 2016.6 height (m) þ 907 | 5318.3 | 314.0 |
| Schofield et al. (1985) | (5) BMR (kJ) ¼ 56 weight (kg) þ 2898 ^a | 5355.0 | 468.6 |
| | (6) BMR (kJ) ¼ 35 weight (kg) þ 19.48 height (m) þ 837 | 5324.2 | 344.3 |
| Boys (n ¼ 44) | | | |
| Henry et al. (1999) | (7) BMR (kJ) ¼ weight (kg) 66.9 þ 2876 | 5655.0 | 536.1 |
| | (8) BMR (kJ) ¼ weight (kg) 78.5 þ suprailiac (mm) 45.3–triceps (mm) 54.99–subscapular (mm) 38.3 þ 294 | 3087.2 | 594.8 |
| (FAO/WHO/UNU (1985) | (9) BMR (kJ) ¼ 73.2 weight (kg) þ 2720 ^a | 5760.7 | 586.6 |
| | (10) BMR (kJ) ¼ 69.4 weight (kg) þ 322.2 height (m) þ 2392 | 5772.3 | 580.0 |
| Schofield et al. (1985) | (11) BMR (kJ) ¼ 74 weight (kg) þ 2754 | 5828.0 | 593.0 |
| | (12) BMR (kJ) ¼ 68 weight (kg) þ 5.74 height (m) þ 2157 | 5867.8 | 586.7 |

Abbreviations: BMR, basal metabolic rate; FFM, fat-free mass.

^aEquations identified as the most appropriate for the estimation of BMR in the study sample.

Table 2 Pearson correlation coefficients between basal metabolic rate estimated by the different equations at baseline

| Girls (n ¼ 87) | | | | | | | |
|-------------------------|------------------------------|---------------------|------|--------------------|------|-------------------------|------|
| References | Equation number ^a | Henry et al. (1999) | | FAO/WHO/UNU (1985) | | Schofield et al. (1985) | |
| | | (1) | (2) | (3) | (4) | (5) ^b | (6) |
| Henry et al. (1999) | (1) | 1.00 | 0.90 | 1.00 | 0.94 | 1.00 | 0.96 |
| | (2) | | 1.00 | 0.90 | 0.89 | 0.90 | 0.90 |
| (FAO/WHO/UNU (1985) | (3) | | | 1.00 | 0.94 | 1.00 | 0.96 |
| | (4) | | | | 1.00 | 0.94 | 0.99 |
| Schofield et al. (1985) | (5) ^b | | | | | 1.00 | 0.96 |
| | (6) | | | | | | 1.00 |
| Boys (n ¼ 44) | | | | | | | |
| | Equation number ^a | Henry et al. (1999) | | FAO/WHO/UNU (1985) | | Schofield et al. (1985) | |
| | | (7) | (8) | (9) ^b | (10) | (11) | (12) |
| Henry et al. (1999) | (7) | 1.00 | 0.97 | 1.00 | 0.99 | 1.00 | 0.99 |
| | (8) | | 1.00 | 0.97 | 0.97 | 0.97 | 0.97 |
| FAO/WHO/UNU (1985) | (9) ^b | | | 1.00 | 0.99 | 1.00 | 0.99 |
| | (10) | | | | 1.00 | 0.99 | 0.99 |
| Schofield et al. (1985) | (11) | | | | | 1.00 | 0.99 |
| | (12) | | | | | | 1.00 |

^aSee Table 1 for the equations.

^bEquations identified as the most appropriate for the estimation of basal metabolic rate in the study sample.

accurate estimations of BMR than those including height and fat free mass. The following equations were identified as the most appropriate and were used in all subsequent calculations.

Girls:

BMR (kJ) ¼ 56 weight (kg) þ 2898 (Schofield et al., 1985; Table 1, equation (5));
and

Boys:

BMR (kJ) ¼ 73.2 weight (kg) þ 2720 (FAO/WHO/UNU (1985); Table 1, equation (9));

where weight was the weight measured at the corresponding measurement point. For the estimation of BMR for June and August 2004 (when weights were not measured, Figure 1), the average of the weights measured in March and September was used.

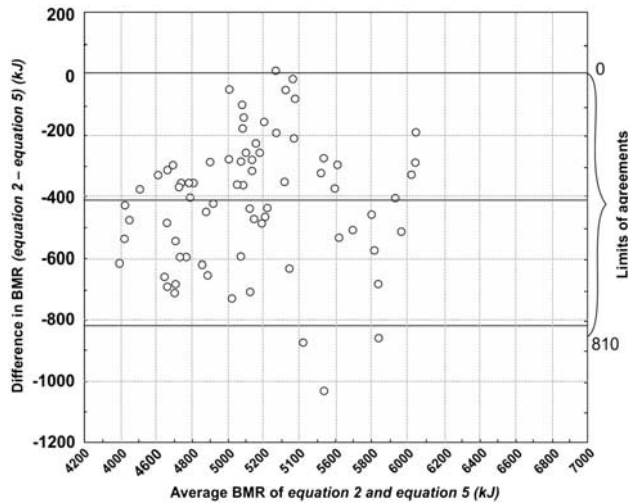


Figure 2 Bland–Altman plot for difference between BMR calculated by equations (2) and (5) and the average of BMR calculated by equations (2) and (5), girls.

Estimation of EE. Estimated EE (EE_{est}) was calculated per subject for each of the seven measurement points using the following equation (Black, 2000):

$$EE_{est} = \frac{1}{4} BMR \times PAF$$

where BMR was estimated using equations (5) and (9) (Table 1) for the girls and the boys, respectively. The following PAF values proposed by Brooks et al. (2004) were assigned to the PAL categories determined from the PDPAR questionnaire (Trost et al., 1999): PAL 1 (low activity) $\frac{1}{4}$ 1.55, PAL 2 (medium activity) $\frac{1}{4}$ 1.7 and PAL 3 (high activity) $\frac{1}{4}$ 2. The average EE_{est} of multiple calculated EE is represented in this paper as mEE_{est} .

Validity analyses. To determine the relative validity of EIs derived from different numbers and periods of 24-h recalls, three data subsets were identified as follows (Figure 1):

- Data subset 1: Baseline reported EI (EI_{repb}) and baseline estimated EE (EE_{estb}).
- Data subset 2: The average EI_{rep} (mEI_{rep1}) derived from five 24-h recalls (March and September 2004 and March, June and September 2005) and the average EE_{est} (mEE_{est1}) of the same five measurement points, representing the average reported EI and the average estimated EE over 18 months.
- Data subset 3: The average EI_{rep} (mEI_{rep2}) derived from four 24-h recalls (March, June, August and September 2004) and the average EE_{est} of March and September 2004 (mEE_{est2}) representing the average reported EI and estimated EE over 7 months.

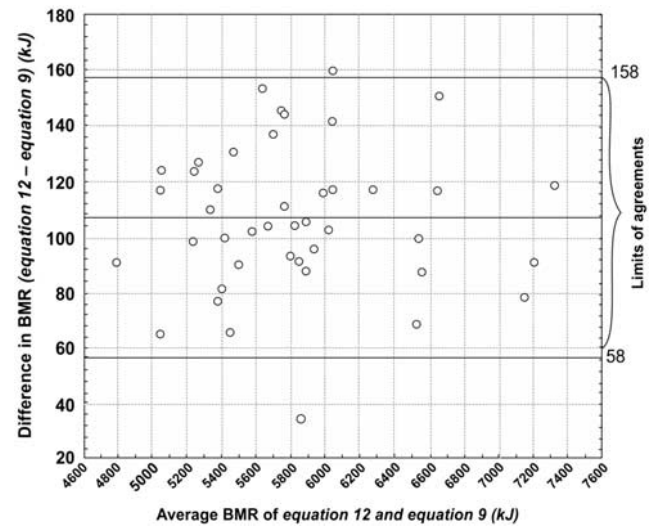


Figure 3 Bland–Altman plot for difference between BMR calculated by equations (9) and (12) and the average of BMR calculated by equations (9) and (12), boys.

The distributions of all the above data subsets were normal. Means and standard deviations were calculated for EI_{repb} , mEI_{rep1} and mEI_{rep2} , and mEE_{estb} , mEE_{est1} and mEE_{est2} . Relative validity was determined by calculation of Pearson correlation coefficients between EI_{repb} and mEE_{estb} , mEI_{rep1} and mEE_{est1} , and mEI_{rep2} and mEE_{est2} . The nature of the relationship between the reported EI and EE expenditure variables in each of the data subsets was further analysed using Bland–Altman plots (Bland and Altman, 1999), where the agreement (difference between EI_{rep} and EE_{est}) was plotted against the average of EI_{rep} and EE_{est} . This plot indicates if there is a relationship between the agreement and the average of EI_{rep} and EE_{est} . If no relationship exists, validity can be established if the difference between EI_{rep} and EE_{est} is not clinically significant. The limits of agreement were calculated as 1.96 times the standard deviation of the differences around the mean difference.

Identification of under/over reporting

To identify possible under and over reporting of EI, population specific cut points (CPs) for plausible EI_{rep} : EE_{est} ratios were calculated for each data set using Goldberg's equations (Black et al., 1997; Black, 2000):

$$CP \text{ for } EI_{rep} : EE_{est} = \frac{1}{4} PAL \times \exp \left(z_{\alpha/2} \times \frac{\delta S = 100b}{\sqrt{n}} \right)$$

where PAL is assumed to be the average PAL of a group, $z_{\alpha/2}$ is taken as ± 2 , the approximate critical values for a $\frac{1}{4}$ 0.05, n is the number of participants and S is the overall coefficient of variation for PAL, taking into account the variability in EI and EE_{est} . S is given by $S = \frac{1}{4} \sqrt{\frac{CV_W^2 + k^2 CV_B^2 + CV_P^2}{k^2}}$ where

CV_w is the within-participant (subject) coefficient of variation as determined by a one-way analysis of variance, k is the average number of days of DA (Rieper et al., 1993), CV_B is the coefficient of variation in repeated EE measurements (taken as 8%; Schofield et al., 1985) and CV_p is the coefficient of variation in PAL, taken as 0 for a specific PAL group. Specific CPs for each PAL group were calculated to determine under and over reporting (Livingstone et al., 2003).

Results

Sample size and anthropometric measurements

Data for all measurement points were available for 131 (52%; 87 girls and 44 boys) of the total parent study sample of 369 subjects (211 girls and 158 boys). Because of the criterion of including data only of subjects younger than 17 years, the number of subjects eligible for inclusion in data subsets 2 and 3 for the validation analysis decreased to 81 (55 girls and 26 boys). The means (standard deviations) for age, weight and height at baseline and at the end of the study are shown in Table 3.

Validation of EI of baseline and multiple 24-h recalls

The mean (s.d.) EI_{rep} and EE_{est} for each data subset are given for the girls and the boys in Table 4. The mean EE_{est} was higher than the mean EI_{rep} for all data subsets with the exception of the boys data subset 1 for medium active boys.

Table 5 shows weak Pearson correlation coefficients between EI_{rep} and EE_{est} for all data subsets. For the girls, all Pearson correlations were weak. The baseline data ($EI_{rep,b}$ and $EE_{est,b}$) gave a slightly stronger coefficient than the average of five measurements over 18 months ($mEI_{rep,2}$ and $mEE_{est,2}$), with the average of four measurements over 7 months ($mEI_{rep,1}$ and $mEE_{est,1}$) yielding a weak inverse correlation. For the boys, the average of five measurements over 18 months ($mEI_{rep,2}$ and $mEE_{est,2}$) gave the strongest and the baseline data ($EI_{rep,b}$ and $EE_{est,b}$) the weakest Pearson correlation coefficients. When Pearson correlation coefficients were calculated for the baseline data according to PAL category,

coefficients seemed stronger for the more active participants (PAL 2 and 3) but remained weak.

The weak agreement shown by the Pearson correlation coefficients was confirmed by the Bland–Altman analyses which showed wide limits of agreement and proportional bias between the differences and averages of EI_{rep} and EE_{est} for all the data subsets (data not shown).

Cut points and reporting of energy intake

Table 6 shows the calculated Goldberg CPs according to Black (2000) for each PAL group. The highest calculated CP for PAL 1 group for boys was similar to the lowest CP for PAL 3 group. In other words, an $EI_{rep}:EE_{est}$ of a boy in PAL 1 group who over reported would have the same $EI_{rep}:EE_{est}$ as a boy in the PAL 3 group who under reported. The majority of the participants in both genders was in the PAL 3 group.

When the $EI_{rep}:EE_{est}$ ratio of each adolescent in a PAL group was compared with the sub-study's calculated CPs, it became clear that most of the boys (87%, $n = 39$) and girls (95%, $n = 83$) under reported their EI, whereas 2% ($n = 1$) of boys and 2% ($n = 1$) girls over reported.

Discussion

The aim of the parent study of this sub-study was to describe the usual physical activity and dietary intakes of the target group over 2 years. It was, therefore, necessary to evaluate the validity of the average reported energy intakes over the 7- and 18-month periods of the study. The 24 h recalls are easily administered, accommodate participants of low literacy levels, are inexpensive and offer a low respondent burden and a good response rate (Goodwin et al., 2001; Deakin, 2006). These benefits make the 24-h recall a suitable DA method for peri-urban South African adolescents. The literature (Ma et al., 2009), however, indicates that a single 24-h recall does not offer a true reflection of usual dietary intake. Furthermore, unless the specific 24 h-recall instrument and the number and period of administrations

Table 3 Anthropometric characteristics for adolescents at baseline and end assessments

| Descriptive Measurement | Age (years) | Weight (kg) | Height (cm) | Age (years) | Weight (kg) | Height (cm) |
|-------------------------|-------------|----------------------------|-------------|-------------|-----------------------|-------------|
| | | Baseline (n ¼ 87) of girls | | | End (n ¼ 55) of girls | |
| Mean | 13.6 | 43.1 | 151.7 | 15.1 | 48.33 | 154.5 |
| ±s.d. | 0.55 | 8.29 | 5.72 | 0.55 | 7.51 | 5.4 |
| –95% CI | 13.47 | 40.88 | 150.1 | 15 | 45.62 | 152.5 |
| p 95% CI | 13.76 | 45.32 | 153.2 | 15.3 | 51.04 | 156.5 |
| | | | | | | |
| | | Baseline (n ¼ 44) of Boys | | | End (n ¼ 26) of Boys | |
| Mean | 13.5 | 39.33 | 151.3 | 15 | 47.34 | 159.8 |
| ±s.d. | 0.59 | 7.07 | 7.39 | 0.59 | 9.02 | 7.59 |
| –95% CI | 13.30 | 36.41 | 148.5 | 14.8 | 43.12 | 156.3 |
| p 95% CI | 13.77 | 42.25 | 154.1 | 15.3 | 51.56 | 163.4 |

Abbreviation: CI, confidence interval.

Table 4 Mean and standard deviation of reported energy intake (E_{rep}) and estimated total energy expenditure (EE_{est}) for each of the three data subsets tested for girls and boys

| Data subset | n | Reported energy intake (kJ) | | Estimated total energy expenditure (kJ) | |
|----------------------------------|----|-----------------------------|------|---|------|
| | | Mean | s.d. | Mean | s.d. |
| Girls | | | | | |
| Data subset 1 ^{a 1,2,3} | 87 | 8081 | 3078 | 9439 | 1239 |
| Data subset 2 ^{a 1,2,3} | 55 | 9224 | 2346 | 10 965 | 858 |
| Data subset 3 ^{a 1,2,3} | 55 | 9224 | 2346 | 9509 | 1125 |
| Data subset 1 ^{a 1} | 35 | 8795 | 3033 | 8499 | 726 |
| Data subset 1 ^{a 2} | 19 | 6630 | 3015 | 9197 | 819 |
| Data subset 1 ^{a 3} | 33 | 8158 | 2959 | 10 575 | 927 |
| Boys | | | | | |
| Data subset 1 ^{a 1,2,3} | 44 | 9587 | 4923 | 10 777 | 1554 |
| Data subset 2 ^{a 1,2,3} | 26 | 9599 | 2536 | 11 745 | 1124 |
| Data subset 3 ^{a 1,2,3} | 26 | 9599 | 2536 | 10 738 | 1509 |
| Data subset 1 ^{a 1} | 8 | 8691 | 2557 | 9314 | 1283 |
| Data subset 1 ^{a 2} | 7 | 9703 | 5403 | 8952 | 672 |
| Data subset 1 ^{a 3} | 29 | 9817 | 5468 | 11 621 | 1009 |

^aPAL, physical activity level; PAL 1, light active; PAL 2, medium active; PAL 3, high active.

Data subset 1 ¼ baseline reported energy intake (E_{rep} ; March 2004) and baseline estimated energy expenditure (EE_{est} ; March 2004);

Data subset 2 ¼ the average E_{rep} (mE_{rep1}) derived from five 24-hour recalls (March, September 2004 and March, June and September 2005) and the average EE_{est} (mEE_{est1}) of the same five measurement points representing the average reported energy intake and the average estimated energy expenditure over 18 months. Data subset 3 ¼ the average E_{rep} (mE_{rep2}) derived from four 24-hour recalls (March, June, August and September 2004) and the average EE_{est} (mEE_{est2}) of March and September 2004 representing the average reported energy intake and the average estimated energy expenditure over 7 months.

Table 5 Pearson correlation coefficients of E_{rep} and mEE_{est} of the different data subsets and of data subset 1 with participants grouped into different PAL categories

| Data subset | Boys | | Girls | |
|----------------------------------|------|---------------------------------|-------|---------------------------------|
| | n | Pearson correlation coefficient | n | Pearson correlation coefficient |
| Data subset 1 ^{a 1,2,3} | 44 | 0.04 | 87 | 0.20 |
| Data subset 2 ^{a 1,2,3} | 26 | 0.32 | 55 | 0.17 |
| Data subset 3 ^{a 1,2,3} | 26 | 0.18 | 55 | -0.12 |
| Data subset 1 ^{a 1} | 8 | -0.14 | 35 | -0.15 |
| Data subset 1 ^{a 2} | 7 | 0.38 | 19 | 0.14 |
| Data subset 1 ^{a 3} | 29 | 0.31 | 33 | 0.37 |

^aPAL, physical activity level; PAL 1, light active; PAL 2, medium active; PAL 3, high active.

Data subset 1 ¼ baseline reported energy intake (E_{rep} ; March 2004) and baseline estimated energy expenditure (EE_{est} ; March 2004);

Data subset 2 ¼ the average E_{rep} (mE_{rep1}) derived from five 24-hour recalls (March, September 2004 and March, June and September 2005) and the average EE_{est} (mEE_{est1}) of the same five measurement points representing the average reported energy intake and the average estimated energy expenditure over 18 months. Data subset 3 ¼ the average E_{rep} (mE_{rep2}) derived from four 24-hour recalls (March, June, August and September 2004) and the average EE_{est} (mEE_{est2}) of March and September 2004 representing the average reported energy intake and the average estimated energy expenditure over 7 months.

required by the study design have been tested for validity, the usefulness of the resultant dietary intake data may be questionable. Unfortunately, validation of reported energy intakes by comparison with objectively measured EE requires high resource and expertise inputs, which are not available to researchers in developing countries such as South Africa.

Relative validity of reported energy intakes

Our study showed poor relative validity in comparison with estimated EE of reported EI derived from both a single 24-h recall and the average of four or five 24-h recalls repeated over 7 and 18 months, respectively. The term ‘multiple 24-h

recall’ usually implies two or more 24-h recalls taken from the same individuals over a 1 to 4 week period (Johnson et al., 1996; Montgomery et al., 2005; Cullen et al., 2008; Castetbon et al., 2009; Hong et al., 2009). The term, however, may also be applied to 24-h recalls repeated over periods from 2 months to a year (Jonnalagadda et al., 2000; Slater et al., 2003; Hong et al., 2009; Nelson and Lytle, 2009; Jaceldo-Siegl et al., 2010) to represent usual intake (Gibson, 2005).

Our results suggested that for boys, use of the average of four or five recalls improved the Pearson correlation coefficient over a single recall, although the Pearson correlation coefficients remained weak. In contrast, the Pearson correlation coefficients for girls for the baseline data

Table 6 Peri-urban South African adolescents' specific calculated Goldberg CPs for different estimated PAL categories

| Descriptive | PAL 1 (PAF $\frac{1}{4}$ 1.55) | | PAL 2 (PAF $\frac{1}{4}$ 1.7) | | PAL 3 (PAF $\frac{1}{4}$ 2) | |
|-------------|--------------------------------|----------|-------------------------------|----------|-----------------------------|----------|
| | Lower CP | Upper CP | Lower CP | Upper CP | Lower CP | Upper CP |
| Boys | 1.30 | 1.85 | 1.41 | 1.90 | 1.82 | 2.19 |
| Girls | 1.43 | 1.68 | 1.52 | 2.05 | 1.84 | 2.17 |

Abbreviations: CP, cut point; PAF, physical activity factor; PAL, physical activity level.

subset and data subset 2 were similar, but decreased when the average of four recalls was used. The Pearson correlation coefficient of 0.2 obtained for the average of five recalls for boys is similar to correlation coefficients obtained between EI and EE measured by doubly labelled water in young children (0.25; Johnson et al., 1996) and adults (0.22; Johnson et al., 1998). From the literature it appears that correlation coefficients between reported EI and measured or estimated EE tended to be lower than those between EI determined by different DA measuring points. For example, correlation coefficients of 0.53 (Hong et al., 2009) and 0.87 (Slater et al., 2003) have been reported between EIs derived from 24-h recalls and FFQs. Some studies (Johnson et al., 1996; Jonnalagadda et al., 2000) have found that the overall validity might improve by using multiple pass 24-h recall techniques. In a recent systematic review of the validity of DA methods with the doubly labelled water method, Burrows et al. (2010) suggested that the accuracy of 24-h recalls may decline with age and that the diet history method might improve the quality of dietary data in adolescents older than 16 years.

The possibility that the estimation of the BMR of our subjects may not have been appropriate cannot be overlooked. The equations selected used only weight and age for the calculation of BMR, in contrast to the more complex equations, which include height and arm anthropometry variables. The decision to use the simpler equations was based on the well-recognised fact that each variable in an equation introduces additional possible errors. On the other hand, adolescence is a period characterised by growth and changes in body composition (Story and Neumark-Sztainer, 2002; Jones et al., 2009), which could impact on BMR. In 1985, Schofield et al. noted that the inclusion of height had little effect on the estimation of BMR. This conclusion has been confirmed more recently and specifically for normal weight adolescents (Tverskaya et al., 1998; Henry et al., 1999; Rodriguez et al., 2000) and supports the use of the simpler BMR estimation equations, as has been carried out in other studies among adolescents (Vance et al., 2008). One known factor to affect BMR, but which is not accounted for by any of the published equations, is that of climate (Rodriguez et al., 2000). The BMR of populations living in tropical climates has been shown to be lower than that of populations from colder climates (Froehle, 2008). This may have resulted in an overestimation of BMR and total EE in our

study sample (the North West province is a semi-arid region with summer temperatures of up to 40 °C (Tourism North West Province, 2010)). Although this may have affected the numbers of participants identified as under reporters, the effect of climate would be constant across all participants and the Pearson correlation coefficients therefore would not have been affected.

Cut points of EI

The literature suggests that $EI_{rep}:EE_{est}$ CPs can be used to identify possible under and over reporting. CPs should be group specific and calculated consistently with each participant's PAL (Black, 2000). Misreporting of EI is a common finding of validation studies of 24-h recalls. Vance et al. (2008) found that 68% of males and 79% of females in their adolescent study sample under reported in comparison with BMR estimated using the equations of the FAO/WHO/UNU (1985). Similar to our study, under reporting was more apparent among the girls than boys. In this study, 485% of participants were classified as under reporters and no relationships between EI and body mass index, age or gender could be identified. Although Baxter and colleagues (2006) also found no relationship between reported EI and body mass index or age, they found a correlation between under and over reporting and gender. In contrast, Lytle et al. (1993), Jonnalagadda et al. (2000) and Kruger et al. (2006) found nonsignificant differences between the reported EI and EE among children, adults and peri-urban black South African adolescents, respectively.

Under reporting in our study could have resulted from failure of the subjects to report all food items or ingredients in mixed dishes, under estimation of food portion sizes or a combination of these reasons. Although a validated food portion photograph book (Venter et al., 2000) was used to assist portion size estimation, subjects might have had difficulty in relating the amount of food they consumed to the photographs, and possibly tended to select the first (smallest) portion size. Alternatively, EE may have been over estimated. The PAF used may have overestimated the activity level, or the information gained from the adolescents when completing the PDPAR questionnaires could have been inaccurate. Furthermore, the appropriateness of the BMR equations, as already discussed, for our study population should not be overlooked.

Even though this study administered five 24-h recalls over 18 months, in reality only one 24-h recall was administered over 2 to 6 months. The results of this study also showed that EI derived from the single 24-h recall at baseline had a similar poor validity to EI derived from five 24-h recalls over 18 months or from four 24-h recalls over 7 months. Therefore, the period in which the multiple 24-h recalls are administered needs to be narrowed.

The results of our study raise serious concern about the accuracy of the dietary data and the validity of any conclusions based on the DI data in the parent study. Under

reporting of EI implies that intakes of nutrients associated with energy (macronutrients, most minerals and the B-complex vitamins) would also be under reported, and using these data may inflate the numbers of participants identified as at risk of deficient intakes. Furthermore, any associations between DI and weight status, physical activity or seasons may be distorted. Nevertheless, the dietary data collected in this study may provide useful insights into the food patterns of the target population of peri-urban adolescents in South Africa, a population for which little dietary information exists. One approach to the dietary data analyses would be to adjust nutrient intakes for energy using nutrient densities or nutrient residuals (Kipnis et al., 2003). Alternatively, the analysis of the reported dietary intakes in terms of dietary scores such as the Dietary Diversity and Food Variety Scores (Steyn et al., 2006), which consider the number of food groups and food items consumed, could provide useful information on the dietary adequacy and food intake patterns of the target population.

Future studies should explore the validity of four 24-h recalls per data sampling period by using a calorimeter or doubly labelled water as reference method for EE. In addition, analysing blood samples for vitamin B₁₂ or folate, or urinary nitrogen excretion per participant at each data sampling measurement could aid in validating the 24-h recall questionnaire. A reference dietary intake such as weighed food records in addition to the determination of EE, would allow for the application of the 'method of triads', (Ocke and Kaaks, 1997) to strengthen validation data. Further studies need to focus on the time frame between the multiple 24-h recalls.

Conclusion

Valuable lessons can be learnt from this study. First, even though the 24-h recall is a popular DA method in South Africa, its validity in all populations cannot be assumed. Second, the time period over which 24-h recalls are conducted needs to be carefully considered. Although multiple 24-h recalls are known to improve validity over a single 24-recall, this was not the case in the sub-study, possibly due to the interval between recalls. Whether shorter intervals between recalls would improve validity warrants further testing. Third, the study highlights the need for the developing and testing of population-specific BMR prediction equations as recommended by Frankenfield et al. (2005) and Burrows et al. (2010).

Conflict of interest

The authors declare no conflict of interest.

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