The Validity and Reproducibility of the 24-Hour Recall Dietary Assessment Method amongst Adolescents in North West Province, South Africa

By

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Thesis submitted for the degree

DOCTOR OF PHILOSOPHY

In

NUTRITION

At the

POTCHEFSTROOM CAMPUS

Of the

NORTH-WEST UNIVERSITY

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November 2008

For my beloved husband,

Riaan Rankin who kept me going

when I couldn't.

-Driekie

ACKNOWLEDGEMENTS

It is a privilege for me to acknowledge the following persons which made every obstacle worthwhile.

- *Prof Salome Kruger who was the designer of the PLAY-study and who gave me the opportunity to accomplish my PhD.*
- *The researchers team of North-West University who assisted with the data capturing*
- *Dr Hattie Wright who assisted me in writing my Thesis*
- *Dr Suria Ellis who done the statistical analysis of the validity article and you became a good friend*
- *My promoter Prof Una MacIntyre who shared her validity knowledge and passion to me*
- *Dr Hanekom who was a star during the last 8 months and who also assist me with the writing of my Thesis*
- *Elizabeth the lady working at my home, who kept our house standing*
- *Alida for her organization at my private practice and for general support*
- *My parents in-law for their ongoing support and love*
- *My sisters, Adéle and Lindi for their patiences, love, prayers and encouragement*

In memory of my father and mother: My heart aches for you, but I known the pearls of memory hang proudly around my heart. Thank you for the wisdom en devotion throughout the years

To my Lord, JESUS CHRIST: Thank you for eagle wings, Your Wisdom and Your Love

Driekie

ABSTRACT

TITLE:	THE VALIDITY AND REPRODUCIBILITY OF THE 24-HOUR RECALL DIETARY ASSESSMENT METHOD AMONGST ADOLESCENTS IN NORTH WEST PROVINCE, SOUTH AFRICA
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KEYWORDS:	REPRODUCIBILITY, VALIDITY, ADOLESCENTS, 24-HOUR RECALL, DIETARY ASSESSMENT

Adolescence proves to be one of the most vulnerable development stages in the life of humans and therefore dietary assessment of this group is important, but complex. This is due to rapid growth during puberty and the development of new eating patterns that influence dietary intake. Adequate dietary intake in this age group is crucial, since adverse effects such as iron deficiency anaemia, inadequate growth and dental caries can occur. Furthermore, dietary imbalance is a significant risk factor that can lay the groundwork for developing preventable complications in late adolescence and adult life such as non-communicable chronic diseases including obesity and diabetes mellitus type II and certain cancers, all leading causes of morbidity and mortality.

Given the vulnerability of adolescents in terms of dietary intake, understanding their dietary intake is crucial. Dietary assessment of adolescents is influenced by social, physiological and psychological changes making accurate measurement of this group difficult. Hence, it is of fundamental importance to find a golden standard in terms of a dietary assessment method to use in this group.

Several international studies investigated validity and reproducibility of the dietary intake of adolescents, measured with different dietary assessment methods. However, in South Africa only three validity and reproducibility studies have been published and none of them focused exclusively on adolescents. Since the validity of the results of dietary assessment methods of international studies cannot be extrapolated to South African black adolescents, this study emanated from the need to investigate whether multiple 24-hour recalls are valid and reproducible when used to assess the dietary intakes of black adolescents in a convenience sample of grade eight learners from a high school in a township in the North West Province. The study was nested in the multidisciplinary "*PhysicaL Activity in the Young*" (PLAY) study. Firstly, the optimal number of 24-hour recalls was determined by calculation of reproducibility coefficients for energy, selected nutrients and food groups. Results showed that four repeated 24-hour recalls provided the optimal reproducibility for black peri-urban South African adolescents.

Secondly, the search for a reference method to compare energy intake against energy expenditure led to an investigation into basal metabolic rate equations and physical activity factors with the intention of estimating the energy expenditure. Validity of reported energy intake assessed by multiple 24-hour recalls and estimated energy expenditure was tested using the Pearson correlation coefficient and the dependent t-test. The Pearson correlation test revealed low associations between energy intake and energy expenditure for boys (0.32) and girls (0.17), while the dependent t-test of the energy intake between the different measured occasions showed little difference, which could be explained by the high *within* participant variation and lower variation *between* the different participants. The low correlation coefficients showed that there was no association between reported energy intake and mean estimated energy expenditure; thus also no agreement. As a result, multiple 24-hour recalls measured over two years with only five 24-hour recalls did not give a valid measurement of the energy intake of black peri-urban adolescents.

Lastly, the ratio of reported energy intake over energy expenditure was evaluated against the energy cut-off points, specifically calculated for age and ethnic group. It indicated that 85% of the participants underreported their energy intake.

These results could have been influenced by the estimated basal metabolic rate equations that could have estimated the basal metabolic rate of this group incorrectly or could be due to the inability of the group to recall their physical activity levels correctly. Therefore it is recommended that further validity studies regarding dietary intake need to be performed on adolescents. It is suggested that energy expenditure as a reference method should be measured by using a calorimeter or the doubly labeled water method and then compared with the reported energy intake. Analysing different biochemical determinants of nutritional intake could also be used as an objective reference method to assess the validity of dietary data obtained from questionnaires.

UITTREKSEL

TITEL:	DIE GELDIGHEID EN BETROUBAARHEID VAN DIE 24-UUR HERROEPMETODE VAN DIEETOPNAME ONDER ADOLESSENTE IN DIE NOORDWES PROVINSIE, SUID-AFRIKA
OUTEUR:	DRIEKIE RANKIN
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GRAAD:	PHILOSOPHIAE DOCTOR IN DIEETKUNDE
SLEUTEL WOORDE:	BETROUBAARHEID, GELDIGHEID; ADOLESSENTE, 24 UUR HERROEP, DIEETOPNAME

Daar is bewys dat adolessensie een van die kwesbaarste stadia in die mens se lewe is; daarom is die dieetopname van die groep belangrik, maar ook kompleks. Hierdie kompleksiteit word toegeskryf aan die vinnige groei tydens puberteit en die ontwikkeling van nuwe eetpatrone wat dieetinname beïnvloed. Toereikende dieetinname in die ouderdomsgroep is van kritieke belang aangesien ongunstige effekte soos ystertekortanemie, ingeperkte groei en tandbederf kan voorkom. Verder is'n ongebalanseerde dieet 'n belangrike risikofaktor wat die fondasie lê vir die ontwikkeling van voorkomende komplikasies in die laat adolessente en volwasse lewe, soos nie-oordraagbare kroniese siektes insluitende obesiteit en diabetes mellitus tipe II en sekere kankers, wat aanleiding kan gee tot morbiditeit en mortaliteit .

Gegewe die kwesbaarheid van adolessente ten opsigte van dieetinname is dit van kardinale belang om hulle dieetiname te verstaan. Die groep se dieetassessering word beïnvloed deur sosiale, fisiologiese en psigologiese veranderinge, en akkurate meting van hierdie groep is moeilik. Dit is dus van fundamentele belang om 'n goue standaard met betrekking tot 'n dieetassesseringsmetode te vind vir hierdie groep.

Verskeie internasionale studies het die geldigheid en betroubaarheid van dieetinname van adolessente ondersoek deur van verskillende dieetassesseringsmetodes gebruik te maak. In

Suid-Afrika is daar egter slegs drie studies ten opsigte van geldigheid en betroubaarheid onderneem, en geeneen van hulle het uitsluitlik op adolessente gekonsentreer nie. Aangesien die geldigheidsresultate van die dieetopname-metodes van die internasionale studies nie na swart Suid-Afrikaanse adolessente geëkstrapoleer kan word nie, het hierdie studie dus voortgevloei om ondersoek in te stel na die geldigheid en betroubaarheid van veelvoudige 24-uur herroepe vir swart adolessente in 'n geriefliksheidsteekproef van graad agt leerders van 'n hoërskool in 'n informele nedersetting in die Noordwes Provinsie. Die studie was deel van die multidissiplinêre "*PhysicaL Activity in the Young*" (PLAY) studie. Eerstens was die optimale hoeveelheid herhalings van 24-uur herroepe bepaal deur die betroubaarheidskoëffisiënte van energie, uitgesoekte nutriënte en voedselgroepe te bereken. Die resultate het getoon dat vier 24-uur herroepe die beste betroubaarheidskoëffisiënte vir die meeste van die nutriënte en voedselgroepe van swart gedeeltelik-verstedelikte Suid Afrikaanse adolessente getoets het.

Tweedens het die soeke na 'n verwysingsmetode om die gemete energie-inname met energieverbruik te meet gelei tot 'n ondersoek na basale metaboliese tempovergelykings en fisiese aktiwiteitsmetodes met die oog daarop om energieverbruik te bepaal. Die geldigheid van die gerapporteerde energie-inname wat met die veelvoudige 24-uur herroepe en geskatte energieverbruik geassesseer is, is getoets met behulp van die Pearson korrelasiekoëffisiënt, asook die afhanklike t-toets. Daar was geen ooreenkomste nie omdat die Pearson korrelasiekoëffisiënt so laag was tussen die energie-inname en energieverbruik vir die seuns (0.32) en vir die dogters (0.17), terwyl die afhanklike t-toets egter min verskille tussen die herroepte energie-inname tussen die verskillende gemete tye gewys het. Dit kan verklaar word deur die groot variasie binne die persone self; daarom is die verskil tussen die verskillende persone nie so groot nie. Die resultate het dus getoon dat die veelvoudige 24-uur herroep-metode oor twee jaar deur van vyf 24-uur herroepe gebruik te maak om dieetinname te bepaal, nie 'n geldige meting van energie inname was in swart Suid Afrikaanse adolessente nie.

Laastens was die verhouding van die gerapporteerde energie-inname en -verbruik geëvalueer teen die energie-afsnypunte wat spesifiek vir die ouderdom en etniese groep bereken was. Die resultate het daarop gedui dat 85% van die proefpersone hulle energie inname onderrapporteer het.

Die resultate kon beïnvloed geword het deur die basale metaboliese spoed-vergelykings wat die basale metaboliese spoed onakkuraat bereken het of deur die groep wat hulle fisiese aktiwiteit onakkuraat herroep het. Dit word dus aanbeveel dat verdere studies onderneem word in adolessente om die geldigheid van hulle dieetinname te bepaal, asook dat energieverbruik vergelyk moet word deur 'n kaloriemeter of dubbelgemerkte watermetode en daarna vergelyk moet word met gerapporteerde energie-inname. Analisering van verskillende biochemiese veranderlikes wat voedinginnames weerspieël kan ook gebruik word as 'n objektiewe verwysingsmetode om die betroubaarheid van dieetdata wat deur vraelyste verkry is te assesseer.

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ABBREVIATIONS

AMS	Assessments mean square
ANOVA	Two way analysis of variance
BMI	Body mass index
BMR	Basal metabolic rate
BMS	Between subjects mean square
Ca	Calcium
CI	Confidence interval
CPs	Cut-off points
DA	Dietary assessment
DONALD	Dortmund Nutritional and Antropometric Longitudinally Designed
DLW	Doubly labeled water
DRI	Dietary reference intake
EE	Energy expenditure
EE_{est}	Estimated energy expenditure
EFR	Estimated food records
EI	Energy intake
EI_{rep}	Reported energy intake
FAO	Food and Agriculture Organisation
Fe	Iron
FFM	Fat free mass
FFQ	Food frequency questionnaire
ICC	Intra class correlation
mEE_{est}	Mean estimated energy expenditure
NCCD	Non-communicable chronic disease
NFCS	National Food Consumption Survey (South Africa)
NSSA	Nutritional status of South Africans
PAF	Physical activity factor
PAL	Physical activity level
PCC	Pearson correlation coefficient
PDPAR	Previous day physical activity recall
PLAY	The PhysicaL Activity in the Young Study

QFFQ	Quantitative food frequency questionnaire.
RC	Reproducibility coefficient
RDA	Recommended dietary allowances
RMS	Residual mean square
SD	Standard deviation
SQFFQ	Semi-quantitative food frequency questionnaire
TEE	Total energy expenditure
WFR	Weighed food records
Zn	Zinc

NOMENCLATURE

CV_b	Variation coefficient between participant
CV_p	Variation coefficient in PAL
CV_w	Variation coefficient within participant
EE_{rep}	Multiple BMR and PAL calculations
i	Individual
k	Number of assessments
MS_w	Mean square of the within effect
N	Total number data
n	Sample size
S	Overall coefficient of variation for physical activity level
S^2_B	Estimated variation between components
$Z_{\alpha/2}$	Physical activity level of a group

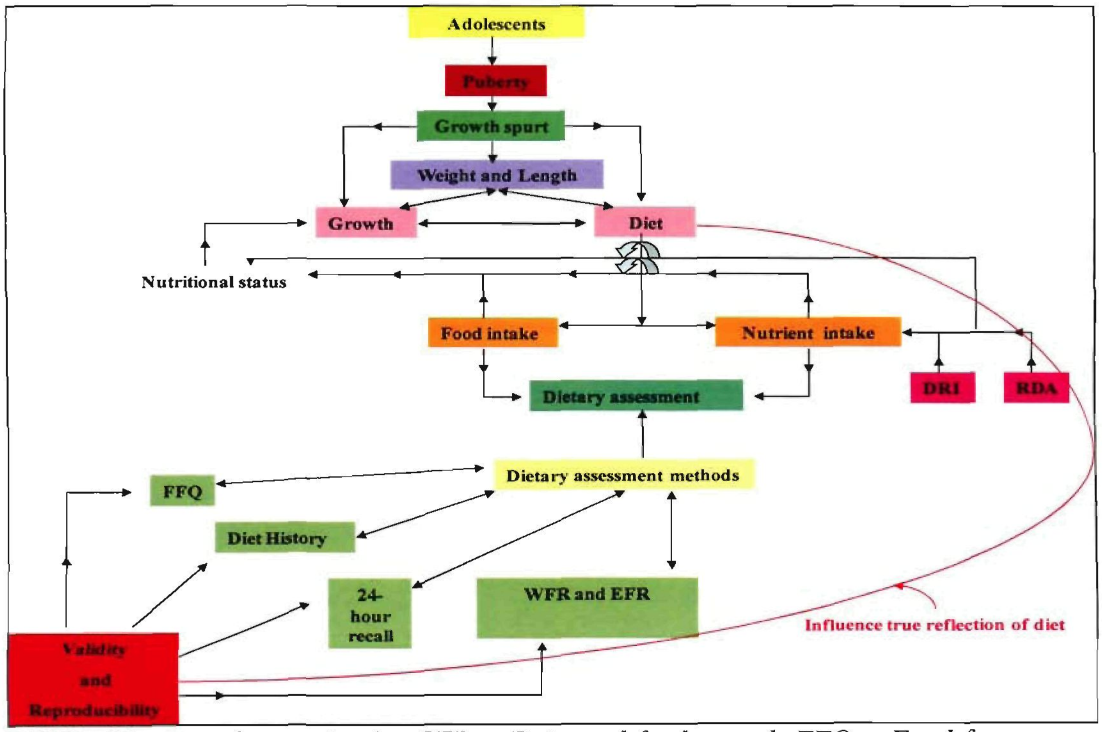
THE REFERENCE STYLE OF CHAPTER 1 IS WRITTEN ACCORDING TO THE HARVARD STYLE WHICH IS THE STANDARD OF THE NORTH-WEST UNIVERSITY.

CHAPTER 1

INTRODUCTION AND AIM OF THE STUDY

Background to the problem

Puberty in adolescence starts with a growth spurt that triggers an increased demand of specific nutrients and energy (Story & Neumark-Sztainer, 2002). In addition, adolescents are vulnerable due to rapid physical development and changes of dietary habits and patterns. These dietary changes and their high energy and nutrient demands increase the risks of not meeting their nutritional requirements (Stanner, 2004). Hence, dietary intake plays a major role in adolescence. Figure 1 depicts the complex interplay of diet, growth and nutritional status in adolescents.



DRI =Dietary reference intake; EFR = Estimated food record; FFQ = Food frequency questionnaire; RDA = Recommended dietary allowances; WFR = Weighed food record

Figure 1 The integration of dietary intake and growth spurt in adolescents

Adolescents need to gain 50% and 20% of their adult weight and height respectively during the growth spurt. Therefore adequate intakes of energy, protein and micronutrients such as thiamin, riboflavin, niacin, vitamins A, B_6, B_{12}, C, D and E, calcium, iron and zinc are essential for this growth to be achieved (Stanner, 2004).

The availability of sufficient foods to meet the increased nutrient requirements is a major concern in developing countries such as those in Africa, Asia, the Middle East and Latin America (Popkin, 2004). These countries have a high prevalence of stunting among children and adolescents (Popkin *et al.,* 1996). During a review of the literature (1975 to 1996 data), similar results were found by Vorster *et al.* (1995) on the Nutritional Status of South Africans. This association between stunting and low food availability, however, may not always be apparent (Kruger, 2005), because one would expect that underweight and stunting would be the results of low food availability. However, chronic malnutrition causes stunting in children and this leads to a decrease in basal metabolic rate (BMR) which may cause a higher store of energy as body fat, especially in girls (Freedman *et al.*, 1999; Holness, 2001; Kruger *et al.*, 2004).

The association between stunting and overweight/obesity is caused by the following factors: (1) chronic undernutrition causes stunting and a decrease in the BMR (Mukuddem-Petersen & Kruger, 2004) and (2) hormonal changes occur during the growth spurt associated with adolescence (Cameron & Getz, 1997). This growth spurt causes a catch-up growth which leads to fat deposition due to low BMR (Adair & Cole, 2003). The fat deposition accumulates mostly intra-abdominally early in life and relates to non-communicable chronic diseases (NCCD) later in life. Stunted children may be more at risk of developing NCCD than non-stunted children (Popkin *et al.*, 1996). The association between stunting and the risk of developing NCCD later in life is of particular concern in South Africa, since 22% of one to nine-year olds were stunted and 10% were underweight-for-age in 1999 (Labadarios *et al.,* 2005).

Studies in the United States done by Troiano *et al.* (1995; 1998) indicated that, from 1988 to 1994, the prevalence of overweight/obesity among children had increased by 11%. The prevalence of children at risk of being overweight had increased by 22%. During 2003 and 2004, the United States reported new statistical data indicating that the prevalence of overweight in children aged two to five years increased from 5.0% (2003) to 13.9% (2004). Children aged six to 11 years showed an increased prevalence from 6.5% (2003) to 18.8%

(2004) and for adolescents aged 12 to 19 years, the prevalence had increased from 5.0% (2003) to 17.4% (2004) (Center for Chronic Disease Prevention and Health Promotion, 2005). In South Africa a similar picture, regarding overweight/obesity in children and adolescents is seen. The National Food Consumption Survey indicated that 17% of South African children were overweight and obese [body mass index (BMI) ≥25] (Steyn *et al.*, 2005) while Kruger *et al.* (2006) indicated that 7.8% of 10 to 15 year old children in the North West Province, South Africa, were overweight or obese according to the International Obesity Task Force standards for BMI-for-age. The overweight/obesity prevalence was higher among girls (10%) in all ethnic groups compared to that of boys (5.6%). The white children had the highest prevalence of overweight/obesity (14.2%) compared to the black (7.1%), Indian (6.4%) and coloured children (2.9%) (Kruger *et al.*, 2006).

South Africa should also focus on the national health objectives for Americans for the year 2010 which intend to reduce the prevalence of obesity among adults to less than 15% (Center for Chronic Disease Prevention and Health Promotion, 2005). Current data of the Center for Chronic Disease Prevention and Health Promotion (2005) indicate that the situation is worsening rather than improving, which makes the situation problematic. Since eating habits learned in childhood are carried over into adulthood the problem areas early in life need to be identified and addressed, only then the prevalence of obesity amongst adults will decline (Stanner, 2004).

To obtain accurate reflection of the dietary intakes of adolescents, the dietary assessment (DA) tool used needs to be valid with good reproducibility characteristics for the specific age group. Dietary intakes obtained using a DA tool that was not tested for validity and reproducibility should be interpreted with caution, because such data may not give a true reflection of actual intake (Vereechen *et al.*, 2005). There are a number of different DA methods available including weighed and estimated food records, food frequency questionnaires, 24-hour recalls and dietary histories that may be of use when gathering data on adolescents' diets. One of the most important points for choosing a DA method is that it needs to measure what it intended to measure and it needs to be closest to the true intake (Gibson, 2005). Although different DA methods have been used over time, no one can be considered a golden standard regardless of how well they are designed due to major shortcomings and insufficient measures of dealing with imperfections. The DA method used needs to be tested for reproducibility and validity, specifically to be culture and eatingbehaviour sensitive. World-wide large numbers of studies (Johnson *et al.,* 1996; Bandini *et al.,* 2003; Andersen *et al.*, 2004) have focused on the reproducibility and validity of different DA methods for adolescents and children, while in South Africa there are only a few studies which addressed these issues and were either performed on adults (MacIntyre *et al.,* 2000a and 2000b) or children (Kruger, 2003).

The purpose of the study

As indicated previously, adolescence is a complex life stage and it is necessary to understand the interrelations of North West Province, South African adolescents' diets, growth spurt and nutritional status. To investigate this relationship, the number of 24-hour recalls required to gather reproducible data was determined, and this DA method was tested for reproducibility and validity in the target population within the PhysicaL Activity in the Young (PLAY) study wherein adolescents from a convenience sample participated.

The aim of the study

The aim

The aim was to determine the optimal number of 24-hour recalls needed to give true reproducibility of adolescents' intakes and also to test the validity of the energy intake (EI) of these reports (24-hour recalls).

Objectives of the study

The main objectives of the study were:

- To identify the most appropriate DA tool to use in the assessment of dietary intake of children and adolescents which is valid and reproducible, by exploring the scientific literature (Chapter 2).
- To determine the optimal number of 24-hour recalls needed in a multiple 24-hour recall method study, specifically in peri-urban black adolescents, to obtain the most reproducibility of the results (Chapter 3).
- To determine the relative validity of EI derived from multiple 24-hour recalls of peri-urban black adolescents by comparing reported EI to estimated energy expenditure. To calculate estimated energy expenditure, the most appropriate BMR equations

(Henry *et al.*, 1999) and physical activity factors (Brooks *et al.*, 2004) for our study were identified from the literature (Chapter 4).

The structure of the thesis

This thesis is presented in article format and consists of three articles to reach each of the objectives and deals with each sub-study as a complete article. The relevant references of the chapters are provided at the end of each chapter. The technical style, dialect and referencing methods of Chapter 1 and 5 are according to the mandatory style stipulated by the North-West University, while Chapter 2 is written according to the author's instruction of the South African Journal of Clinical Nutrition (accepted for publication) and Chapter 3 and 4 according to the instructions of the European Journal of Clinical Nutrition (submitted for publication).

A review article identifying valid and reproducible DA methods for DA of adolescents follows the introductory chapter. This chapter provides background information on the reproducibility and validity of DA methods of adolescents world-wide and in South Africa. In Chapter 3 the number of 24-hour recall questionnaires for the best reproducibility is determined for both nutrient and food intakes by using a prospective study design. Chapter 4 addresses the question of the validity of EI reporting by peri-urban South African adolescents derived from multiple 24-hour recalls through a prospective study design. This reported EI of multiple 24-hour recalls was compared to an estimated EI that was calculated with appropriate and literature-based BMR equations and physical activity factors. Finally, EI reporting was evaluated by calculation of the energy cut-off points of the study group using the formula of Goldberg. Chapter 5 summarises the importance of the findings of this study and gives recommendations for further studies.

Appendix A shows an example of the informed consent form that each participant completed before he or she was included in the study.

Appendix B shows the demographic questionnaire used to identify the groups' demographic characteristics.

Appendix C shows an example of the 24-hour recall questionnaire used for the DA of the adolescents.

Appendix D was used to note down each participants' anthropometric measurements in triplicate.

The Previous Day Physical Activity Recall questionnaires, Appendixes E (for previous week) and F (for previous weekend), were used to calculated the physical activity factors of each participant.

In the literature, certain terminology pertaining to this field of research is used. Since the meaning of certain terms could be unclear the following table will present definitions as used in this thesis (Table 1).

Table 1 Definitions of terminology pertaining to DA methods

Term and Reference	Definition
Adolescent (Jones *et al.*, 2009)	Adolescence starts in the 9.8 to 10th life year in urban South Africans and ends with the full development of the adult form at 18 to 20 years of age.
Bias (Brown and Prescott, 2006)	Is any external influence that may affect the accuracy of statistical measurements.
Child or children (Anderson *et al.*,2002)	The period of life spanning from birth to adulthood.
Overestimation (Gibson, 2005)	Is the appraisal higher than actual food intake or portion sizes due to either a lack of knowledge or inability to estimate accurately.
Overreporting (Gibson, 2005)	Reporting food intake higher than the true or actual food intake, due to intentional intrusion of food items in a report.
Precision (Dietz *et al.*, 1991)	The statistical precision of a sample statistic as "the closeness with which it can be expected to approximate the relevant population value. It is necessarily an estimated value in practice, since the population value is generally unknown".
Reproducibility (Wassertheil-Smoller, 2004)	Is one of the main principles of the scientific method and refers to the ability of a test or experiment to be accurately reproduced or replicated.
Relative validity (Gibson, 2005)	Dietary intake of participants that were determined by a relative valid DA method are not free of bias, due to the reference DA method's bias and reflects not the actual dietary intake, but only a relative dietary intake.
Suprailiac skinfold (also called Supraspinal skinfold) (International Society for the Advancement of Kinanthropometry, 2001).	The site at the intersection of two lines: (1) the line from the marked Iliospinale (the most inferior or undermost part of the tip of the anterior superior iliac spine) to the anterior axillary's border and (2) the horizontal line at the level of the marked Iliocristale (the point on the most lateral aspect of the iliac tubercle, which is on the iliac crest).
Validity (Wassertheil-Smoller, 2004)	Validity refers to the extent to which the assessment measures the desired performance and appropriate inferences can be drawn from the results. Meaning the dietary intakes of participants determined by a valid DA method are likely to be true, believable and free of bias and reflects the actual dietary intake it was designed to measure.
Underestimation (Gibson, 2005)	Estimation of food intakes or food portions lower than the actual amount of food consumed due to lack of knowledge or inability to estimate accurately.
Underreporting (Gibson, 2005)	Reporting food intake less than the true or actual food intake, due to omitting of food because of either a lack of memory, knowledge or doing so purposefully.

Major contributions of the study

This study:

- highlights the gap in the literature regarding data on the reproducibility and validity of DA methods in the South African context for the adolescent age group and therefore, dietary intake determined with a method not tested for validity and reproducibility should be interpreted or extrapolated with caution;
- provides the first data on reproducibility of 24-hour recalls as an assessment tool for dietary intake for South African adolescents by determining the optimal number of 24-hour recall questionnaires that should be used;
- provides the first data on validity of energy reporting of South African adolescents derived from multiple 24-hour recalls; and
- provides the only calculated energy cut-off points for black peri-urban South African adolescents to our knowledge.

Author's Contributions

The three studies reported in this thesis were planned and executed by a team of researchers. The contribution of the researchers involved in the studies are presented in Table 2.

Table 2 Research team's titles, affiliations and roles

Title, initials, and surname	**Affiliation**	**Role in the study**
Mrs. D. Rankin (Dietician and PhD candidate)	School for Physiology, Nutrition and Consumer Science of the North-West University	Responsible for supervising 24-hour recall administration during data collection; computerisation and interpretation of the results as well as writing up the data.
Prof. U.E. MacIntyre	Professor/Director, Institute for Human Nutrition, University of Limpopo (Medunsa Campus)	Interpretation of the results and guidance regarding the writing up of the data. Promoter of PhD candidate.
Dr. S.M. Hanekom (Dietician)	School for Physiology, Nutrition and Consumer Science of the North-West University	Statistical analysis and guidance regarding the writing up of the data. Co-Promoter of PhD candidate.
Dr. H.H. Wright (Dietician)	School for Physiology, Nutrition and Consumer Science of the North-West University	Guidance regarding the writing up of data. Co-Promoter of PhD candidate.
Dr S.M. Ellis (Statistic Consultant)	Statistical Consultation Service, North-West University (Potchefstroom Campus)	Statistical analysis, guidance regarding interpretation of the results. (Chapters 4)
Prof HS (Jr).Steyn (Statistic Consultant)	Statistical Consultation Service, North-West University (Potchefstroom Campus)	Statistical analysis, guidance regarding interpretation of the results. (Chapters 3)

I declare that I have approved the above-mentioned articles, that my role in the articles published in this thesis as indicated above is representative of my actual contribution and that I hereby give my consent that it may be published as part of the thesis of Driekie Rankin.

Prof. U.E. MacIntyre

Dr. S.M. Hanekom

Dr. H.H. Wright

Dr S.M. Ellis

Prof HS (Jr).Steyn

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CHAPTER 2

ACCURACY OF DIETARY ASSESSMENT METHODS IN CHILDREN AND ADOLESCENTS

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The purpose of this review is to identify the most valid and reproducible dietary assessment tool for use in the assessment of children's and adolescent's dietary intake by exploring the scientific literature. A detailed literature review was undertaken to trace articles reporting on the validity and/or reproducibility of food records, food frequency questionnaires and 24-hour recalls for dietary intakes of children and adolescents, especially among South Africans in the following databases: Medline, Science Direct, Academic Search Premier, Repertorium of South African Journals, Health Source and PubMed. Original studies published between 1990 and 2008 were included with the exception of original relevant articles published before 1990. Of the reviewed studies nine were South African based and only three of these showed clear evidence that the authors tested reproducibility and/or validity. Dietary assessment of children and adolescents is complex due to several factors including the development of new eating patterns and rapid growth. Results revealed that the children and adolescents have better compliance with estimated weighed records than actual weighed records. However, both types of food records tend to overestimate energy intake of young children by more than 11% if parents or dieticians assisted with the reporting and underestimated. On the other hand, energy intake is underestimated (>18%) in adolescents. Comparing the food frequency questionnaires with a food record >16% of energy intake was overestimated and compared to a 24-hour recall >24% of energy intake was overestimated. The 24-hour recall method showed the least over- and underestimation of all the reviewed methods. Comparing it to an

observed intake method <11% of underestimation was found and <4% underestimation was found when tested against the doubly labelled water method. It can be concluded that 24-hour recall is the most valid and reproducible dietary assessment method to use for children and adolescents. It is, however, urgent to perform more reproducibility and validity studies of dietary assessment methods amongst South African children and adolescents.

Background

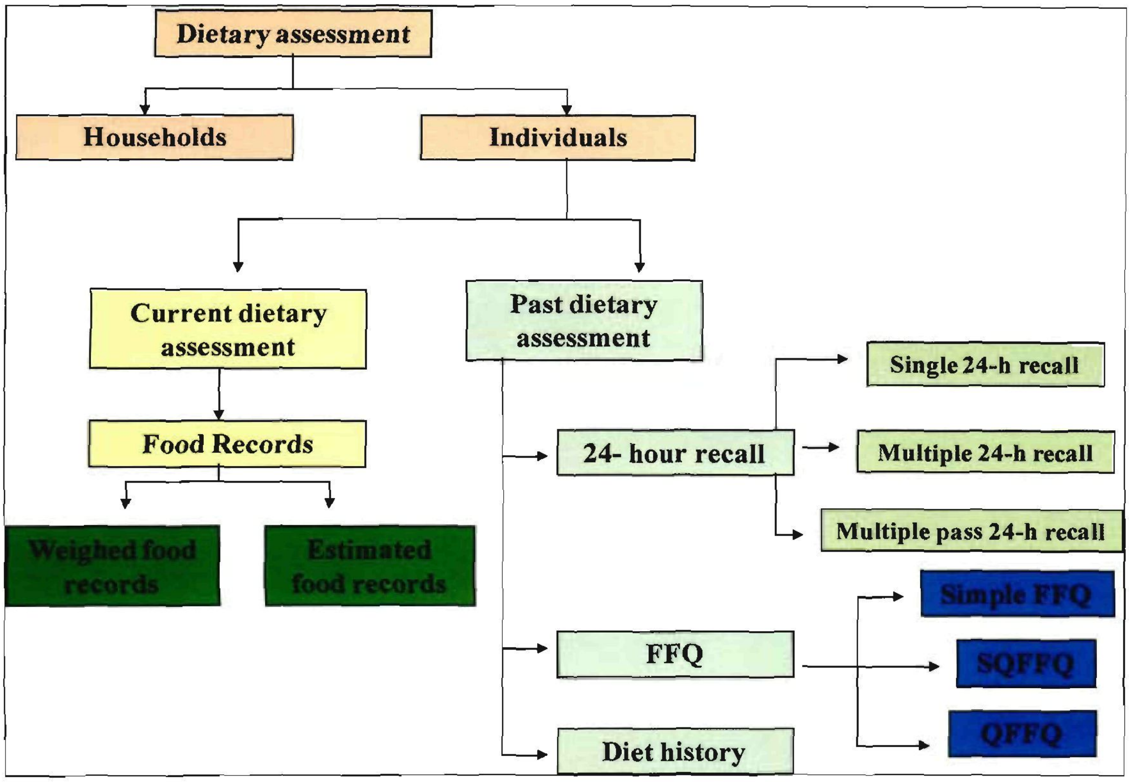
Adolescence, which starts in urban South Africans at a younger age because the tempo of mar maturation is increasing (9.8 to 10 years, which are considered in other countries as children) and ending with the development of the full adult at 18 to 20 years,[1] is one of the most challenging periods in human life. It is a period characterised by rapid growth and increased hormone production called puberty that affects every organ of the body, including the brain. These changes spur special nutritional needs and when combined with increased physical activity, the need for optimal nutrition is increased even further.[2,3] . Data on adolescents' food and nutrient intakes are, therefore, important to aid in the evaluation of the nutritional status of individuals or population groups and to identify those at risk of nutrient deficiencies or diseases of lifestyle.[4-7] This specific nutritional interest is due to the need to prevent the development of chronic diseases later in life.[8] If adolescents' diets are unbalanced, adverse effects such as iron deficiency anaemia, obesity, diabetes and dental caries can occur. These can lead to long-term complications in their adult life such as chronic diseases, obesity and cancer.[9] However, to assess dietary intake of adolescents or any other population group accurately remains a challenge.

Methods

A detailed literature review was undertaken to find articles reporting the validity and/or reproducibility of food records, food frequency questionnaires and 24-hour recalls for dietary intakes of children and adolescents, especially in South Africans. International journal databases such as Medline, Science Direct, Academic Search Premier, Repertorium of South African Journals, Health Source and PubMed were searched. The literature search was done for the period 1990 to 2008, using keywords "adolescents", "children", "validity", "reproducibility", "reliability", "food records", "FFQ", "food frequency questionnaire", "24-hour recalls" and "dietary assessment". Relevant studies older than 1990 were also included. Reference lists of articles obtained were reviewed for additional relevant studies.

A variety of methods are described in the literature to assess food and nutrient intakes. The type of method chosen is usually determined by the study design and characteristics of the study population.[5] Currently, few studies focus on identifying and/or developing reproducible and valid dietary assessment methods specifically for the adolescent population. Reproducibility of dietary assessment methods is characterised by the ability of the dietary assessment method to obtain identical results when it is administrated again at a later stage under similar circumstances, therefore rendering it reliable.[10] Validity describes the accuracy of a dietary method to measure what the participants have actually eaten.[11] Dietary methods designed to characterise usual intakes of individuals are the most difficult to validate, since the "truth" is never known with absolute certainty.[12] Testing for absolute validity is time consuming and poses practical difficulties because the actual food intake during, before or after the study period needs to be observed and then compared to the responses of the participants. Relative validity, in which a new method is compared with an existing method thought to give accurate results, is the most practical validation method to use. Absolute validity implies that the reference method reflects the true dietary intake, while relative validity recognises that the reference method itself is subject to error.[11] Thus, the extent of agreement between the tested and reference method is used to indicate the relative validity of the test method and the extent to which the reference method is believed to yield the truth. Biomarkers are an expensive and alternative approach to determine dietary intakes and are often compared to recalled nutrient intakes.[11]

The main focus of this review is on the characteristics, possible shortfalls, validity and reproducibility of methods used to assess past and current dietary intakes of adolescents. Also included are similar studies done in children in order to broaden the scope of this review, because adolescence starts in urban South Africans already at a young age (8-9 years)[1] and due to limited studies performed on adolescents as well as a scarcity of studies evaluating validity and reproducibility of dietary assessment methods in all age groups. The dietary intake assessment methods addressed in this review are summarised in Figure 1.



FFQ = Food Frequency Questionnaire, SQFFQ = Semi-Quantitative Food Frequency Questionnaire, QFFQ = Quantitative Food Frequency Questionnaire.

Fig. 1 Dietary assessment methods

Food records

Food records entail that the participant weighs or estimates the amounts of all foods and beverages consumed over a given period of time. Foods and amounts, as well as recipes of composite dishes are recorded on either non-consecutive random days[5-6] or consecutive days[10,13-15] at the time of consumption. Records are reviewed by a trained interviewer at specified times during and at the end of the recording period.

Weighed and estimated food records

WFRs give the exact portion sizes of food eaten, whereas estimated food records (EFRs) are influenced by the estimation of portion sizes by participants. Chinnock[16] as well as MacIntyre and co-workers[14] found that the accuracy of estimation of portion sizes was within 10% of the actual weight when standard measuring cups and spoons, food models or food portion photographs were used. Weighed food records (WFRs) might also not reflect the exact truth. Participants are aware that they need to weigh the food they eat: therefore may change their usual intake to simplify weighing and recording. The results of Chinnock's study[16] support this hypothesis by showing weight loss amongst participants during their weighed-food recording period. Even if participants are trained and motivated to keep accurate WFRs and EFRs, nutrient data should still be interpreted with care, because the participants could misrepresent their food intakes and food choices which may lead to inaccurate results.[10] Due to these reasons Chinnock[16] stated that EFRs are the preferred method for epidemiological studies because they are less expensive, can be kept for longer periods and give more reliable data.

An example of the use of food records to assess the dietary intakes of children and adolescents is the study of Kirsting, Alexy and Wolfgang[17] in which the diets of children and adolescents aged one to 18 years were assessed. Younger children were assisted by their parents while older children and adolescents weighed and reported their own food intake. It is, however, unclear what age cut-off points were used for assisted food records by parents and the dietary intake results should, therefore, be interpreted with caution.[17] In the Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) study the dietary intakes of healthy infants, children and adolescents were measured using three-day weighed-food records (WFRs). Parents (with high literacy levels) of the child and infant participants weighed (on an electronic food scale) and recorded all foods and beverages consumed during the three-day period, as well as the leftovers while the adolescents weighed and recorded their own intakes.[15]

Food records used as reference method

Food and beverage intakes are recorded at the time of consumption, therefore, errors due to dependence on the participants' memory and accuracy of estimation of portion sizes are minimised.[18] For this reason, food records have been used as a reference method to determine the comparative validity of other dietary assessment methods. Estimated records could, however, be difficult to use due to the burden on the participants to estimate and to note down all the consumed foods or beverages.[19,20] The studies of Schröder and co-workers[21], Masson and co-workers[22], Flood and co-workers[23] and Kruger and co-workers[24] are examples of the use of EFRs and WFRs to determine the comparative validity of a food frequency questionnaire (FFQ), 72- and 24-hour recalls (see results of the studies in the FFQs and 24-hour recall section).

Validity and reproducibility of food records

While food records have been used as reference methods for the validation of other methods, few studies exist that report on the validity and reproducibility of food records themselves.

a) EFRs have been tested for validity against interviewer observed intakes in adolescents and adults (15 to 58-year olds)[25] and nine to 10-year olds.[26]
   - When the intakes derived from EFRs and the observed intakes were analysed for nutrients, the adults' and adolescents' EFRs showed significant differences in the mean intakes for more than half of the nutrients while Pearson correlation coefficients were higher than 0.68.[25]
   - In contrast, the nine to 10-years olds showed fewer significant differences between mean nutrient intakes. The energy intakes derived from the EFRs were either with 25% underreported or with 10% overreported.[9]

However, it should be noted that these studies were conducted under controlled conditions and it is uncertain whether similar results would have been obtained in free-living conditions.

b) Validity of EFR by using WFR
   - Bonifacj and co-workers[27] and Chinnock[16] investigated the validity of EFR by using a WFR as the reference method. When mean estimates of energy, macronutrients and micronutrients derived from the EFR were compared to intakes derived from WFRs no significant differences between the two methods were shown.[16,27] It appears that EFR yields similar results to the WFR, but compliance seems to be better for the EFR.[28]

Doubly labeled water as reference method to validate reported energy intake from WFRs and EFRs

The use of doubly labeled water as an objective means of determining energy expenditure provides an independent measure of validity of reported energy intakes.[29] Studies comparing energy intake assessed by WFR with energy expenditure estimated by the doubly labeled water method have shown an underestimation of energy intakes in adults[30,31] and a more marked underestimation in children and adolescents.[29] Bandini and co-workers[29,32,33], Livingstone and co-workers[34], Champagne and co-workers[35], Green and co-workers[36] and Bratterby and co-workers[37] all used the doubly labeled water method to test for validity of energy intake derived from EFRs. Table 1 shows a summary of these results[29-37].

Table 1: Estimated energy intakes for children and adolescents in different age groups compared with doubly labeled water method.[29-37]

Age	**Estimation of energy intake derived from EFRs as a percentage of energy expenditure measured by DLW**[a]	**Reported by**	**Conclusion**
< 9 years	97% ± 15 % to 108 % ± 25%	Parents of participants	Overestimation
12 years	82 % ± 21% to 89% ± 12 %	Parents of participants or dieticians	Underestimation
15 – 18 years	78% ± 18 % to 58 % ± 17%	Participants themselves	Underestimation

[a]DLW: Doubly labeled water

From the above summary (Table 1) it seems that energy intakes derived from EFRs were overestimated for children younger than nine years who were assisted by their parents. In contrast children, 12 year and older underestimated energy intake whether completed by themselves, or with the assistance of parents or dieticians.[29,32,33] This underestimation could be ascribed to the fact that 12-year old children also eat away from home and may not report this additional food intake.[33] The underestimation of energy intake in the study of Champagne and co-workers[35] could have been attributed to the parent's assistance. The under- and overestimation or underreporting of energy intake may give an inaccurate portrayal of children and adolescents' dietary intake. Adolescents have unstructured eating patterns and ingest fast foods which could also lead to underreporting by WFRs or EFRs. When summarised, both under and over reporting as well as under and overestimation within this age group could be attributed to; 1) forgetfulness of what they have eaten away from home, 2) lack of compliance to weigh the food, and 3) lack of motivation to record intakes on an almost hour-to-hour basis, due to irritation and boredom.[38] Therefore, dietary intake of children and adolescents determined by WFRs and EFRs needs to be interpreted carefully.

Biological determinants that influence validity of food records

The validity of food records may also be influenced by several other factors including gender, age and body mass index (BMI) of the participants. Karveti and Knuts[25] found no differences in relative validity of a two-day EFR (when compared with observation of food intakes) between gender and different age groups. Contradictory to this, Bandini and co-workers[29] indicated that the accuracy of reported energy intake in girls declined longitudinally with age while Champagne and co-workers[35] found that girls underestimated energy intake with 27% and the boys had a slightly lower underestimation of energy intake of 24%.

When BMI was taken into account, Bandini and co-workers[29,32,33] and Kruger and co-workers[24] found that average reported energy intake (% of total energy expenditure [TEE]) was significantly lower in the obese (58% ± 23.6%) than in the non-obese (80.6% ± 18.7%) groups. Underreporting of energy intakes, especially in girls, could also be due to preoccupation with body weight, body frame and body image. They may record less food than actually eaten to imply they eat very little and do not want to gain weight.[34] A few studies[29,32,34,37] showed an underestimation of total energy intake in 15-18 year olds, the underestimation especially apparent within obese girls.

WFRs and EFRs do not seem to be sensitive enough as dietary assessment tools for accurate measurement of energy intake in children and adolescents because of difficulties concerning underestimation, underreporting and compliance. A possible solution to this problem is suggested by Hise and co-workers[39] where trained observers only recorded and weighed fixed meals while participants completed a 24-hour snack recall for in-between meal snacks and meals eaten away from home. This combined observer-recorded WFRs and 24-hour snack recall showed a 99.4% ± 17.9% accuracy for energy intake when compared with energy expenditure, as tested by the doubly labeled water method.[39]

Food Frequency Questionnaires

A FFQ is typically comprised of a list of questions on foods to which the participant responds by reporting the frequencies (number of times) and amounts (portion sizes) of foods consumed per day, per week or per month.[6] Different kinds of FFQs can be used, for example quantitative food frequency questionnaires (QFFQs), semi-quantitative food frequency questionnaires (SQFFQs) and non-QFFQs. In a QFFQ the frequency of consumed foods and beverages are recorded together with more precise (quantified) food portion sizes in terms of grams or millilitres.[4] Nöthlings and co-workers[40] compiled a QFFQ with 180 food items with three portion sizes for each food item. They then compared measured food intake in grams with the number of servings to investigate the difference in outcome if either one of these methods were used to determine the dietary intake and relative risk for chronic diseases. The results showed no significant difference between these two methods of measuring.[40] In a SQFFQ, portion sizes of foods and beverages typically consumed are estimated in terms of *small, medium or large*.[41] The main purpose of a non-QFFQ is to examine the participant's usual frequency of food and beverage consumption listed in the questionnaire, without the estimation of portion sizes.

The FFQ, a dietary assessment tool with a good response rate, is low in cost, gives a better representation of usual dietary intake than diet records and can be used in populations with low literacy levels.[42,43] FFQs can either be self-administered[44,45] or administered by an interviewer.[24,46] One of the largest longitudinal studies in South Africa (Birth-to-Ten Study and subsequently the Birth-to-Twenty Study) used SQFFQs to determine children's macro- and micronutrient intakes at different age intervals.[47,48] One of the most important characteristics of a FFQ is that individuals can be ranked according to their intake of specific foods and/or nutrients into quantiles (such as thirds or quarters of the distribution of intakes) in order to determine relative risk of disease for different categories. Another form of ranking is to categorise the individuals from the highest to the lowest food intake.[42] Molag and co-workers[49] suggested that the inclusion of more than 200 food items in a FFQ improves the ranking of participants for most of the nutrients compared to a shorter FFQ. When standard portion sizes were included in the FFQ the authors found that the correlation coefficients for energy-adjusted micronutrients were higher. Mean food intakes determined by FFQs enabled Theron and co-workers,[50] to rank the thirty most often consumed food items in 12 to 24-month old children.

Since the FFQs to not include the participants' dietary intake in detail, the following limitations arise:

- Underreporting of energy: Goldberg and co-workers[51] developed a method where energy intake was compared to basal metabolic rate to identify underreporting in FFQs. With this method Bedard and co-workers[52] found underreporting of energy in 54% of male and 35% of female participants. Underreporting was the highest in older, heavier males and individuals with higher BMI and with a lower education level.
- The estimation of quantities of food consumed is less accurate than food record methods.[6] Bingham and co-workers[53] reported an underestimation of energy at high energy intakes while Sawaya and co-workers[54] observed a 20% under-estimation of energy compared with the doubly labeled water technique.

- FFQs usually investigate the frequency with which adults and children consumed listed food items, expressed as number of times per day, per week, per month or per year, relying strongly on memory.[6] The time span of FFQs when relying on memory alone could be a source of error. Since cognitive function plays an important role in children's ability to recall dietary intake accurately, questions pertaining to the colour, taste, smell and form of foods should be incorporated in the FFQs to aid proper, reliable responses.[55]
- The FFQs should be culture sensitive to represent the traditional foods and true dietary intake of the target population.[6] A specific FFQ should therefore be developed for each population, in their own language and incorporate all traditional foods. If the FFQ is not culture sensitive the participants could underreport because of incomplete lists of food not representative of the type of foods usually consumed by the study population.[14]
- Inaccurately reporting of portion sizes reporting in children and adolescents. Children younger than thirteen years seemed to need assistance from their parents for this method,[19] while older children seemed to report portion sizes inaccurately due to guessing rather than matching it with the correct portion sizes. However, the estimation of inaccurately portion sizes (40% inaccurate) could be improve with 35% (meaning only 5% of the comparisons are incorrect), when photographs of the food items had exactly the same appearance than the actual served portion sizes. [19,20]

Several studies[36, 55-63] tested the reproducibility and/or validity of FFQs as a dietary assessment tool in children and adolescents. The summary in Table 2 only included studies which investigated only the estimation of energy intake determined by FFQ and which are compared to a reference method.

Table 2: Estimated energy intakes of children and adolescents determined by FFQ in different age groups compared with food records or 24-hour recall[57,58,64,65]

Age	Reference method	Estimation of energy intake determined by FFQ as a percentage when compared with the reference method	Reported by	Conclusion
4-9 years[65]	Food record	19.7%	Parents of participants	Overestimated
5-10 years[64]	Food record	17%	Parents of participants	Overestimated
9-12 years[57]	Food record	40%	Participants themselves	Overestimated
8-10 years[58]	24-hour recall	26%	Participants themselves	Overestimated

It is clear from the summary that parents' assistance plays a major role in lowering the overestimation of energy intake of children and adolescents. When the validity of a FFQ was tested against the multiple 24-hour recall, it seemed to agree better with food items high in fat than food items high in fibre.[56] When using observation as a references method FFQs overestimate both energy and nutrient intake, while a lunch recall indicated better validity for the FFQ, due to the more focused questionnaire.[60] Lytle and co-workers[61] found similar results in fourth grade children, however, some studies (Table 1) showed that food records underestimated the energy intake in children and adolescents.

Ambrosini and co-workers[66] calculated the limits of agreement and Pearson's correlation coefficients to determine the reproducibility of several SQFFQs. These calculations illustrated that the mean FFQ intake estimated by repeated measurements showed differences. The EFRs were administered between the first and second FFQs. This could, have made the participants more aware of eating habits and could have influenced the second FFQ report. This awareness could have led to a lower reproducibility of repeated FFQs.[66] A similar process was used with the development of a QFFQ for the North West Province (South Africa) population where the reproducibility was tested with Spearmen rank correlation coefficients, paired t-tests and Bland-Altman plots. Despite careful preparation and implementation of the North West Province QFFQ, the reproducibility showed differences between the assessments. Alcohol and vitamin A showed the best reproducibility values. For protein, fat, carbohydrates, fibre, calcium, iron and vitamin C the reproducibility was satisfactory on at least two of the analyses.[14]

FFQs administered to children might show lower reproducibility than those of adults since young children find it difficult to report the portion sizes and frequency of food they have eaten during a certain time frame due to their lack of literacy.[67] In the reproducibility study of Field and co-workers,[62] sixth and seventh grade students found it easier to complete the FFQ than fourth and fifth grade students. In the study by Yaroch[68] the natural log-transformed energy-adjusted, deattenuated correlation coefficients between a second FFQ and the average of three 24-hour recalls exceeded 0.50 for most nutrients, ranging from 0.32 (protein) to 0.87 (saturated fat). The energy and nutrient values from the first FFQ were higher than those from the second FFQ. Almost none of the correlation coefficients for the test-retest reproducibility of the FFQ were significant. According to Yaroch,[68] this could be due to the small sample size (n=22).

Twenty-four-hour recall

The 24-hour recall questionnaire was developed by Wiehl[69] in 1942 and is still in use. Participants report all foods and beverages consumed, estimating portion sizes from household measurements, during the previous 24-hours.[10] The questionnaire is administered by a trained interviewer with knowledge on the terminology and locally available, traditional foods and beverages.[6,70] Dietary information obtained in this manner is detailed but accuracy depends on the participant's memory and their ability to recall portion sizes which could lead to recall bias.[6] The South African National Food Consumption Survey (NFCS) used a 24-hour recall in combination with the QFFQ to assess the dietary intake of 1-9 year old South Africans assisted by their parents.[46]

A Cape Town study[71] investigated the food items consumed by school-attendees (twelve year olds) using a three-page questionnaire (adapted from the 24-hour recall used in the study of Steyn and co-workers[72]). The questionnaire included questions regarding consumption of main meals and the children were required to classify several foods as being healthy or unhealthy from an additional list of food items in the questionnaire. Most children (84%) knew which of the listed foods were healthy or unhealthy, but fewer children were aware

(47%- 61%) that pies, cola drinks and samoosas were less healthy food choices. The majority ate breakfast before school and food consumed during school break, either brought from home or bought at the tuck shop was unhealthy. [71]

Sequence and manner of how they recall their food intake help children to remember with more accuracy the specific food items as well as the frequency with which they were consumed on the previous day. Prompting should not be done during the interview process, due to the cognitive burden it places on the child's memory, but could be used after the child's memory is exhausted to increase the accuracy of the 24-hour recall.[55] The accuracy of children's memory is affected by the recall period [prior 24 hours or previous day (from midnight to midnight)]. When a prior 24 hours target period was used the omission (foods which they ate but, did not reported) rate was approximately one-third and intrusion (foods which they reported but, did not ate) rate one-half lower thus reducing inaccuracy[73].

The 24-hour recall has several advantages: It is a quick way to assess past as well as usual dietary intakes (when more than one 24-hour recall is used) of individuals and groups; it is suitable for use in populations with low literacy levels; it has a low respondent burden; the response rate is good, and administration costs are relatively low.[6,70] Therefore, Goodwin and co-workers,[19] suggested that a 24-hour recall might be more useful than any other method for children and adolescents due to its simplicity.

Possible shortfalls of 24-hour recalls are as follows: this method relies on memory and measures participants' perception of what their typical diet is, and is subjective and vulnerable to socially-desirable responding. Adolescents' eating habits and patterns are sometimes erratic and change continuously. This often leads to difficulty in documenting new patterns of dietary intakes and prolongs the dietary assessment interview while burdening the attention and memory span of the respondent.[38] Adolescents have social, emotional and physical issues which determine their food intake which may lead to biased data.[74]

The multiple or repeated 24-hour recall method is one of several techniques used to improve the reproducibility and aids in giving a more accurate calculation of the mean usual nutrient intake.[10,24,75] Although this method also reports consumption during the past 24 hours, several 24-hour recalls per respondent are repeated at different times. It is recommended that these recalls be done on non-consecutive days and that at least two recalls per respondent should be taken.[10] When reviewing research from 1979 to 2000, Gibson[5,10] provided a relatively reproducible estimation of the mean usual intake when a calculated number of 24-hour recall assessments (required to convey the average intakes of micronutrients) are done on non-consecutive days. The relative validity of 24-hour recalls seem to be high in adolescent girls due to the non-significant differences between actual intakes and reported intakes of protein, calcium and zinc.[10] Dietary data should always be interpreted with caution since accuracy of multiple 24-hour recalls is influenced by BMI (the lower the BMI, the lower the omission and intrusion rate).[76]

Another technique to increase reproducibility of the 24-hour recall is called *the multiple pass 24-hour recall.* This technique increases retrieval of the requested information by allowing the participant to review the food and beverage intake of the previous 24 hours several times. The fieldworker firstly investigates which foods the participant ate during the past 24-hour period, then collects more detail about the foods consumed, preparation methods, and finally the portion sizes.[77] When the accuracy of the multiple pass 24-hour recall method was tested against the doubly labeled water measurement in four to seven-year olds a 3% underestimation of energy intake was found. The reported energy intake and total energy expenditure were not significantly different, which suggests that the underestimation may be due to random variations associated with the dietary assessment methods.[78]

The 24-hour recall could lead to significant problems of precision within the same individual, but internal and external validity is found to be at an acceptable level in children aged ten years and older.[13] When evaluating the validity of a 24-hour recall questionnaire against a WFR and observed report, respectively, underreporting of 22.1%[79] and 25%[80] were found. Children have difficulty in estimating of portion sizes[79,80] but this would most likely resolve in the adolescent years due to the higher literacy level and brain development[79] and might explain the validity of diet recalls at adolescent level.[38] Another approach which could improve the estimation of the portion sizes is to use a photographic food item book which have the precise appearance than the actual consumed food items .[20]

South African studies

During the literature search it was found that studies investigating dietary intake of adolescents world-wide are rare and that most data were collected on other age groups. In South Africa even fewer studies were found[14,24,81] probably due to the difficulty in conducting dietary assessment intakes in developing countries.[82] Only three[14,24,81] of the nine studies[14,24,47,48,71,72,81,83,84] found and investigated (Table 3) showed clear evidence for the testing of reproducibility and/or validity. In two of the studies[71,83] references were made to a another study where the dietary assessment tool was validated for a different population group.

MacIntyre and co-workers[14,81] tested the reproducibility and validity of the QFFQ in the black South Africans of various ages and found a relatively good reproducibility and validity. However, when the dietary nitrogen intake was compared with the urinary nitrogen excretion data, underreporting was clearly of great concern. Kruger and co-workers[24] tested a multiple 24-hour recall questionnaire for reproducibility and validity by using a three-day EFR as a reference method in adolescents. Underreporting of vitamin A, folate, nicotinic acid, iron and magnesium found could be ascribed to adolescents' imprecise recall and omission of foods consumed away from home. Contrastingly overreporting of vitamin E and C in the multiple 24-hour recall was found. The 3-day EFRs could have been influenced by dishonesty, simplifying food intake, varied perception of portion sizes according to personal preference, the role of food in the meal, the type of food, obese individuals who selectively underreport high-fat foods, as well as boredom and irritation by food-intake recalls and forgetfulness. A lack of compliance could also have had an influence on the difference between the multiple 24-hour recall and 3-day estimated-weight record.[24]

Table 3 DA studies with tested reproducibility and validity for adolescents and children in South Africa[16,24,71,81,83,85,86]

Author	Date	Dietary assessment method	Sample size	Reproducibility	Validated & Reference method	Results
Steyn *et al.*[83]	1986	24-hour recall	843 (12-year old girls and boys)	No	No Refer to studies of Anon[85] and Gersovitz and co-workers [86]	The 24-hour recall questionnaire method of measuring dietary intake yielded a relatively valid estimate of the mean intake of the group.
Steyn *et al.*[71]	1993	24-hour recall	No (due to the fact that validity was only adapted from the study by Steyn *et al*[83]	No	This questionnaire was adapted from the validated questionnaire described by Steyn and co-workers'[83] undertaken in 12-year old girls and boys	A relatively valid estimation was assumed for the previous study by Steyn *et al*[83]
*Mac-Intyre *et al.*[14]	2000a	QFFQ	144 (15-65 year olds)	Yes	No	Spearmen rank correlation coefficients between the two administrations varied from 0.14 (calcium) to 0.75 (for alcohol). The mean % difference between intakes was 8.5 (std deviation: ±9.9). Energy, protein, carbohydrate and calcium gave differences within 10%. Bland-Altman plots showed significant proportional bias for protein, fibre and vitamin C. <70% of the participants were classified into adjacent quintiles for all nutrients. For food groups, correlation coefficients ranged from 0.25 for milk and 0.45 for vegetable and maize meal groups, and 80% of participants were classified into adjacent quintiles

Table 3 continued....

Author	**Date**	**Dietary assessment method**	**Sample size**	**Reproducibility**	**Validated & Reference method**	**Results**
*Mac-Intyre *et al.*[81]	2000b	QFFQ	74 (15-65 olds)	No	Yes WFR	Spearman rank correlation coefficient between the QFFQ and weighed-food record ranged between 0.14 for fibre and 0.59 for vitamin C. The QFFQ tended to underestimate intakes compared with weighed records. Quintile distributions were similar for the two methods. The correlation between urinary nitrogen excretion and dietary intake was poor. Possible underreporting was identified for 43% of the participants with the QFFQ and 28% with the weighed-food record.
Kruger *et al.*[24]	2006	24-hour recall	1257 overweight and obese 10-15 year olds	Yes 289 participants complete duplicated 24-hour recalls	Yes 289 participants done 3-day EFR record	Reproducibility: The reproducibility of the dietary intakes of fibre, vitamin A and folate were low. Validation: Comparison between the multiple 24-hour recalls (tested method) and 3-day estimated-weight record (reference method) showed underreporting of vitamin A, folate, nicotinic acid, iron and magnesium and over-reporting of vitamin E and vitamin C in the multiple 24-hour recalls.

Discussion and Conclusions

When seeking answers to the following question: "Which dietary assessment method shows the most accurate dietary intake of adolescents?" the following aspects need to be considered.

Population-based studies to test reproducibility and validity of dietary assessment methods in adolescents are relatively scarce, especially in South Africa. It is important to understand the complex interrelations between genetic, environmental and nutritional factors that influence the current health status of adolescents as well as later adulthood. Accurate dietary intake assessment is exceptionally difficult in children and adolescents.

Underreporting is of great concern in adolescents' dietary intake assessment, even with WFR, which is believed to be one of the most accurate dietary assessment methods.[29] Weighing and noting all consumed food and drinks is a burden for adolescents. Adolescents constantly form new eating habits, often eat take-aways, easily become irritated and bored with the WFR process or simply forget to weigh and notate all the consumed foods. EFRs eliminate a specific burden (weighing of foods), but still show under- and overreporting when compared with WFRs.[29,32-37] Factors such as preoccupation with body weight, frame and image (especially in girls)[34] and difficulty estimating portion sizes play a role in under- and overreporting.[19,20]

The National Children's Study by Potischman and co-workers[74] was one of the most recent and largest studies done and according to their results, the best dietary assessment tools to use in adolescents are a combination of the FFQ and multiple 24-hour recalls. Several studies,[37,56-63] showed that dietary assessment in adolescents' using FFQs over-estimated (40%) and underestimated (26%) energy intake. Literature showed that young children have difficulty in reporting their food portion sizes and frequency of intake during FFQ dietary assessment.[67] The study undertaken by MacIntyre and co-workers[81] regarding South African black adults and adolescents also showed that dietary assessment with FFQs leads to underreporting of energy intake.

Studies conducted on the validity of 24-hour recalls showed that even young children could estimate their energy intake of the last 24 hours with a 77.9% accuracy, but their low literacy lead to an overestimation of portion sizes.[24,79] The higher literacy level of adolescents[79] will improve accuracy, but since photographs with the same appearance as actual food items lead to a more accurate estimation of portion sizes[20] it is advisable to use these photographs in children and adolescents. Contradictory to this the literature also showed a trend of underestimated energy intake when compared with the WFR.[29] But when the energy intake of children derived from a pass 24-hour recall dietary assessment method was compared to the energy intake derived from the doubly labeled water method, the results showed a 3% underestimation of energy intake.[78]

The authors, therefore, conclude that when each of the dietary assessment tools were compared with the most appropriate reference method (doubly labeled water method) the WFRs, EFRs and FFQs could represent biased results due to the retrospective estimation of the dietary intake. However, a repeated 24-hour recall, a simplified and easily administered dietary assessment method, seems to give a less biased result. It appears that the 24-hour recall tool is the most appropriate dietary assessment method in children and adolescents. It is important to note that available studies investigating reproducibility and validation of 24-hour recalls in adolescents are scarce. It is, therefore, recommended that more studies be undertaken in which 24-hour recalls are compared to the doubly labeled water method, since it is an accurate reference in adolescents, and specifically South African adolescents, before an answer to the question can be given with certainty. Dietary intake determined with a method not tested for validity and reproducibility should be interpreted or extrapolated with caution. This is due to imperfections of dietary methods regardless of how well they are designed.

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References

References in text are indicated in the text by name and date e.g. (Pampiglione & Ricciardi, 1986) and (Kusin *et al.*, 1994), and listed at the end of the paper in alphabetical order of first author. References should be listed and journal titles abbreviated according to the style used by Index Medicus, examples are given below. All authors should be quoted for papers with up to six authors; for papers with more than six authors, the first six only should be quoted, followed by *et al.* Please use recent references wherever possible.

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Kusin KA, Kardjati S and Renqvist UH (1994): Maternal body mass index: the functional significance during reproduction. *Eur. J. Clin. Nutr.* **48**, Suppl, 3 S56-S67.

Martin JC, Bourgnoux P, Fignon A, Theret V, Antoine JM, Lamisse F *et al.* (1993): Dependence of human milk essential fatty acids on adipose stores during lactation. *Am. J. Clin. Nutr.* **58**, 653-659.

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CHAPTER 3

DIETARY INTAKES ASSESSED BY MULTIPLE 24-HOUR RECALLS IN PERI-URBAN AFRICAN ADOLESCENTS:

1. Reproducibility

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Abstract

Objective: To determine the comparative validity of reported energy intake derived from multiple 24-hour recalls of African adolescents against estimated energy expenditure. In order to calculate energy expenditure, we incorporated the most appropriate basal metabolic rate equations and physical activity factors as reported in the literature.

Design: This analysis was nested in the multidisciplinary *PhysicaL Activity in the Young (PLAY) Study* and a prospective study design was used.

Setting: Peri-urban black South African adolescent learners from Seiphemelo Secondary School (Ikageng) in North West Province, South Africa were investigated.

Participants: A convenient sample of grade eight to nine pupils (135 girls and 115 boys) was recruited. An inclusion criterion was used to identify the sample size of each different data set, in order to ensure validity

Methods: The Pearson correlation coefficients and Bland-Altman plots between the BMR estimates derived from published equations were calculated, in order, to identify the equations which estimate the basal metabolic rate (BMR) the most accurate. A p-value of less than 0.05 was used to indicate statistical significance. After estimated energy expenditure had been calculated for each participant, the validity of the multiple 24-hour recall protocol was tested with three different data sets using Pearson correlations and Bland-Altman plots. The EI:EE on the five measurements were compared using dependent t-tests to test for seasonal differences in EI. Reproducibility coefficients for five 24-hour recall episodes on non-consecutive days were analysed by a published reproducibility method. Cut-off points were calculated by the formula of Goldberg, and under and overreporting was identified.

Keyword: adolescents; 24-hour recalls; reproducibility; dietary assessment; number of 24-hour recalls

Introduction

Studies of adolescent eating habits suggest that adolescent diets contribute to the development of chronic diseases later in the adult years (Stanner, 2004). The impact of adolescent eating habits on future health in adulthood may stem from their nutritional vulnerability that could lead to insufficient (undernutrition), excessive (overweight and obesity) and unbalanced dietary intakes (micronutrient deficiencies) due to increased nutrient demands and changes in lifestyle and food habits (Spears, 2000). The impact of adolescent diets on long-term health underlines the importance of dietary assessment (DA) and the critical need for accuracy during dietary reporting. However, DA of adolescents is complex, and a specific DA tool is needed to investigate dietary habits. Factors such as memory, motivation, forgetfulness, boredom, preoccupation with body weight, body build and self-image affect adolescents' compliance to report dietary intake accurately (Livingstone et al., 1992; Domel, 1997; Livingstone & Robson, 2000). It is important to find a DA method that is sensitive to these difficulties associated with DA in adolescents.

Undoubtedly, no DA method perfectly fulfils the requirements of a validated DA method. The doubly labeled water (DLW) method could be used as an objective measure of the validity of energy intake (EI) determined by DA methods (Bandini et al., 1997). This method measures energy expenditure (EE) over a period of two weeks using the simple principal of energy balance, where EE and EI are equal under conditions of stable body weight and composition (Gibson, 2005). Food records have been thought to provide a true reflection of the dietary intakes of adults (Bingham et al., 1994; Gibson, 2005). The DLW method, however, has indicated that food records underestimate the EI of children (older than 10 years) and adolescents (Livingstone et al., 1992), especially adolescent girls (Bandini et al., 1997). Bandini et al. (2003) also suggest that the older the adolescents, the more inaccurate are the EI reports.

In a literature review of DA methodologies utilised prior to the National Children's Study in the United States, Potischman and co-workers (2006) concluded that, at the time of writing, food frequency questionnaire (FFQ) and multiple 24-hour recall methods were the best ways to assess dietary intakes in adolescents. The same results regarding multiple 24-hour recalls were found by Johnson and co-workers (1996), who tested EI derived from multiple 24-hour recalls against the EE obtained from the DLW method in children. Their results indicated that the reported dietary EI was 97% of the measured total EE. A review by McPherson et al. (2000) came to a contradictory conclusion regarding the use of FFQ for DA in adolescents due to a discrepancy with the validation standards. These authors, however, agreed with the National Children's Study that multiple 24-hour recalls are required when assessing the diets of adolescents because single 24-hour recalls over or underestimated EI when tested against the DLW method. Livingstone and co-workers (1992) also showed methods, such as FFQ and 24-hour recalls in adolescents that seem to result in overreporting or underreporting of dietary intakes due to the high burden of long interviews and measurements, as well as to poor memory and perception of their typical diet.

Importance of the study

Recent nutritional surveys in developing countries show that adolescent dietary habits and food intakes increase their risk of developing chronic lifestyle diseases, such as cardiovascular disease, diabetes mellitus, osteoporosis and cancers. In developed countries a large number of research studies examining the best DA methods for adolescents have been conducted. In South Africa, however, only a few studies focusing on the methodology of DA have been performed. From the literature it is known that multiple 24-hour recall method is one of the DA tools that give a more accurate dietary intake of children and adolescents (Johnson et al., 1996; Potischman et al., 2006).

However, clarity regarding the number of 24-hour recalls required to assess dietary intake of adolescents optimally remains elusive. It is, therefore, crucial for researchers to focus on reproducibility studies, in order to identify the optimal number of 24-hour recalls to assess dietary intakes of adolescents and to emphasise the importance of this subject.

Aim

The aim of the present study was to determine the optimal number of 24-hour recalls in a multiple 24-hour recall method study, specifically in peri-urban black adolescents, to increase the reproducibility of the results.

Participants and Methods

Study design, participants, setting and ethics

This prospective study was nested in the multidisciplinary *PhysicaL Activity in the Young (PLAY)* study and investigated the dietary intakes of peri-urban black adolescents. A convenience sample of learners attending the Seiphemelo Secondary School in Ikageng, an informal settlement in Potchefstroom in the North West Province of South Africa was used. Measurements were taken in March, May, June, August and September of 2004.

Permission to conduct this study was obtained from the school principal. The parents/guardians and participants were informed of all aspects of the study and were required to complete an informed consent form. The study was conducted under free-living conditions and the participants were requested to maintain their normal daily routine [eating pattern and physical activity level (PAL)] for the duration of the study. The PLAY study was approved by the North-West University Ethics Committee (Ethics number 04M01). The PLAY study was funded by the National Research Foundation.

Demographic assessment

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

Dietary assessment

Multiple 24-hour recall questionnaires were used to assess the dietary intakes amongst adolescents. DAs were performed on five non-consecutive days in the year 2004. All participants were interviewed in their home language by two trained and experienced interviewers, fluent in the most commonly spoken languages in the study area. Information obtained was translated into English during the interview. The interviewers were continuously supervised by a registered dietician with post-graduate qualifications. Participants recalled their food and beverage intake of the previous day (midnight to midnight, starting with the first food/beverage consumed on waking) without prompting during the interview. Prompting was used only after the participant's memory was exhausted to identify foods that were not mentioned and to obtain information on preparation methods, brand names, portion sizes or other details not given. The portion sizes were estimated using a food portion photograph book previously validated in the study area (Venter *et al.,* 2000). The 24-hour recall interview took approximately 20 minutes to complete. Time available for interviews was not limited, therefore, participants were not rushed and the interview could be completed in a relaxed atmosphere.

Due to the multidisciplinary nature of the study the time available had to be used effectively and, therefore, it was not possible to match a specific interviewer to a specific child on each DA measurement. Participants moved from one measurement station to the next and were interviewed by whichever interviewer was free at the time they reached the DA station. The following steps were taken in an attempt to attain inter and intra rater reliability: the supervisor revised the correct procedures for conducting 24-hour recalls with the interviewers before each of the measurement days; the same two interviewers were responsible for all 24-hour recall interviews; the supervisor scrutinised all 24-hour recalls to detect any visible errors and omissions of preparation methods and portion sizes and any errors, and omissions or inconsistencies were discussed with both interviewers.

Demographic data analysis

The demographic questionnaires were computerised using Excel XP (2004) and the data analysis was performed by also using Excel XP (2004).

Dietary data analysis

The dietary data obtained from the 24-hour recalls were computerised using the *FoodFinder3®* programme (Medical Research Council, Tygerberg, 2007), first by a data input assistant. In cases of composite dishes, the most similar food item listed in the *FoodFinder3®* programme (Medical Research Council, Tygerberg, 2007) was used. The accuracy of food items and portion size entry was verified and the data were corrected when necessary by the first author to ensure consistency in the use of food items across all assessments. Analysed data were exported from the *FoodFinder3®* programme to Excel (2004) spreadsheets, in which energy, macronutrients (carbohydrate, fat and protein), minerals [calcium (Ca), iron (Fe) and zinc (Zn)] and vitamins (A, C, B_{12}, B_6, folate, thiamin, riboflavin and niacin) were extracted prior to statistical analysis. In order to analyse the data according to foods and food groups, data were imported into Foxpro 2.6a (Microsoft Corporation, 1994) and analysed using programmes developed and verified for a previous study (MacIntyre, 1998).

The number of consumers and the mean (standard deviation) portion size of each food item per DA measurement were calculated. The authors then identified the ten food items most frequently consumed by the participants.

Each consumed food item was classified into a food group according to the classification of the *FoodFinder3®* programme (Medical Research Council, 2007), but modified for the present study (Table 1). From existing data within this study area (MacIntyre et al., 2002; Labadarios et al., 2005; Kruger et al., 2006), maize meal porridge and bread were known to be the staple foods of the study population. It was, therefore, decided to treat maize meal porridges and bread as separate food groups in order to test the reproducibility of intakes of their staple food. In the bread group, fat cakes and dumplings were included, since these two food items were made from bread dough.

Table 1 Classification of food items into the different food groups

Food group	Type of foods
Maize meal group	Maize meal porridge
Bread group	Bread, dumplings*, and fat cakes**
Cereal group	Rice, sorghum porridge, oats porridge, any type of breakfast cereal, maize rice and pasta
Fruit and vegetable group	Any type of fruit and fruit juice, sweet potato, potato, and vegetables
Meat group	Red meat, liver, chicken, fish, processed meat, eggs, and pork
Milk group	Cheese, milk, custard, and yogurt
Sweets group	Sugar, cold drink, sweets, chips, chocolate, cookies, and cakes

**dumplings: steamed bread; **Fat cakes: similar to doughnuts without the sugar or other coatings.*

For each food group, the percentage of consumers and the mean portion size for each food item were compared throughout the year. The difference between the percentages of consumers per DA measurement of each food group was then calculated and the difference between the highest and lowest percentage was ranked according to the following ranking system: a difference <20% received a ranking of A, between 21-30% a ranking of B, between 31-40% a ranking of C, between 41-50% a ranking of D, between 51-60% a ranking of E and >60% a ranking of F. A second ranking was given regarding the consistency of the mean portion sizes per food group, if the mean portion sizes of the different food items were within 20% of each other, the food group received a ranking of 1, if not a ranking of 2. These calculations was done using Excel XP (2004)

Furthermore, the percentages of total carbohydrate and micronutrient (Ca, Fe, Zn, vitamin A, C, B_{12}, B_6, thiamin, riboflavin, niacin and folate) intakes provided by the food groups for each participant at each DA measurement were calculated. The percentage nutrient contribution by food groups was summarized as follows: a ranking of 0 was given if the food group contributed <10% to the intake, 1 for 11% to 15% contribution, 2 for 16% to 25% contribution, 3 for 26% to 35% contribution, 4 for 36% to 45% contribution, 5 for 46% to 55% contribution, 6 for 56% to 65% contribution, 7 for 66% to 75% contribution, 8 for 76% to 85% contribution, 9 for 86% to 95% contribution and 10 for >95% contribution.

Statistical Analyses

The reproducibility of four different multiple 24-hour recall groups was investigated (two, three, four and five dietary measurements, respectively in each group). Each multiple 24-hour recall group had the same sample size, in order to remove the effect of different sample sizes on the reproducibility coefficient (RC). All of the following calculations were performed using the SAS System for Windows (SAS Institute Inc., 2003): descriptive statistics were done to identify the extreme nutrient values; extreme values were checked for accuracy by comparing the food items and amounts computerised in *FoodFinder3®* with the original 24-hour recalls and correcting the data input where necessary; the normality was tested from the data of the participants who had five DAs. To obtain normally distributed data the Box-Cox log transformation was done for each selected nutrient and combined food group. These transformed data were then used to calculate the intra class correlation (ICC) coefficient for a single measurement for each selected nutrient and food group by performing a two-way analysis of variance (ANOVA) with participants and assessments as factors. Using the *between subjects* mean square (BMS), the *between assessments* mean square (AMS), and the participant by *assessment interaction* mean square, which is the *residual mean square* (RMS) in this context Shrout & Fleiss (1979: case 2) provided the following estimate for the population ICC:

$$ICC(1) = \frac{BMS - RMS}{BMS + (k-1)RMS + k(AMS - RMS)/n},$$ where k is the number of assessments and n is the number of participants.

Note that both participant and assessment effects were regarded as random; that is, the participants were viewed as a random sample, while the five assessments were assumed to be randomly obtained from many possible assessments.

When dealing with the mean of k assessments, the reliability coefficient [presented in this study as reproducibility coefficient (RC)] can be obtained by means of the Spearman-Brown formula (Shrout & Fleiss, 1979):

$$ICC(k) = \frac{k\ ICC(1)}{1 + (k-1)\ ICC(1)}$$

Assuming normality of the data of participants' assessment and residuals, Shrout and Fleiss (1979; equation 7) indicate $(1-\alpha)100$ % confidence for ICC.

The single measurement ICC (ICC1) was then used to calculate the following:

i. ICC for each selected nutrient and food group (dietary data analysis section) obtained from five 24-hour recall measurements of the participants.

ii. ICC was calculated for each selected nutrient and food group based on four 24-hour recalls by randomly discarding one out of five DAs.

iii. ICC calculation performed with only three DAs per participant by randomly discarding two DAs from each of the 87 participants.

iv. A final estimation of the ICC was calculated for two 24-hour recalls using the same sample size and randomly discarding three 24-hour recall assessments.

The RC of each nutrient and food group is given with a 95% confidence interval (CI).

Results

Demographic

Although a total of 256 participants were recruited at baseline in March 2004, only 87 participants completed five 24-hour recalls at the end of 2004. Therefore, the sample size was 87. The participants were from Tswana, Sotho, Xhosa, or Zulu ethnic groups. The participants' demographic profiles revealed a mean age of 14.7 ±1.5 years, with 68% (n=59) girls and 32% (n=28) boys. The average household included five to six people living in an informal house (*mokuku*) with four rooms, two of which were bedrooms, and with pre-paid electricity. On average, only two persons in these households received an income. Households shared a communal toilet and cooked their food on gas or paraffin stoves. The majority had a tap with clean, running municipal water in their yard. A minority of the adolescents (29%) stated that they were often hungry, while the majority (71%) stated that they were seldom hungry.

Dietary intake

The most frequently consumed food item was bread, maize meal porridge second, chicken third, milk fourth, beef fifth, vegetables sixth, fruits seventh, cold drink eighth, rice ninth and sweets tenth. On the other hand, the number of participants who consumed the food group appeared to differ. The maize meal group was consumed most frequently while the bread group was the second most frequently consumed group. The less frequently consumed fat cakes and dumpling (an average of 22% of the participants) influenced the frequency of consumption of the bread group. The milk group was the third most frequently consumed and the meat group was the fourth most frequently consumed. Vegetables were consumed more frequently than the fruits, however, the fruits and vegetables group was consumed more frequently than the sweets group. Only one of the food items (rice) found in the cereal group was listed as one of the ten most frequently consumed food items, which made the cereal group one of the less consumed food groups.

The food groups with their rankings regarding their differences between the percentages of consumers are listed in Table 2, in order to identify whether the number of participants who consumed the food groups was constant or not throughout the year. Table 2 also shows the consistency of the mean portion sizes of each food group consumed by the participants and the food item most frequently consumed in the food group.

Table 2 Ranking of food groups and food items according to the consistency of the percentage of consumers and mean portion sizes between 24 hour recalls

Food group	Ranking regarding the difference of the % consumers per food group throughout the year	Ranking regarding the mean portion sizes per food group	Most frequently consumed food item in the food group	Ranking regarding the difference of the % consumers per most frequently consumed food item in the food group throughout the year	Ranking regarding the mean portion sizes of most frequently consumed food item in the food group throughout the year
Maize meal	A	1	Maize meal porridge	A	1
Bread	B	1	Bread	D	1
Cereal*	D	1	Rice	A	1
Milk and milk products	A	2	Milk	B	2
Meat	C	2	Chicken	A	2
			Beef	C	1
Fruit and vegetable**	D	2	Apples	A	2
			Tomatoes	A	2
Sweets	D	1	Cold drink	E	1

**The cereal group could have had a higher ranking regarding the % of consumers, but the difference of the % consumers of breakfast cereal as a food item was very large. **The number of participants who consumed carrot and the pumpkin were constant and the differences in the mean portion sizes were within 10% throughout the year.*

The following rankings indicate the difference between the % of consumers per DA measurement: A = <20% difference, B = between 21-30% difference, C = between 31-40% difference, D = between 41-50% difference, E = between 51-60% difference and F = >60% difference. The ranking of 1 for the mean portion sizes indicated if the mean portion sizes of the different food items were within 20% and 2 if not.

Figure 1 shows the average energy contribution of the different food groups over the five DA measurements. The majority of the EI (75%) comes from carbohydrate rich food groups (maize meal, bread, cereal and sweets group).

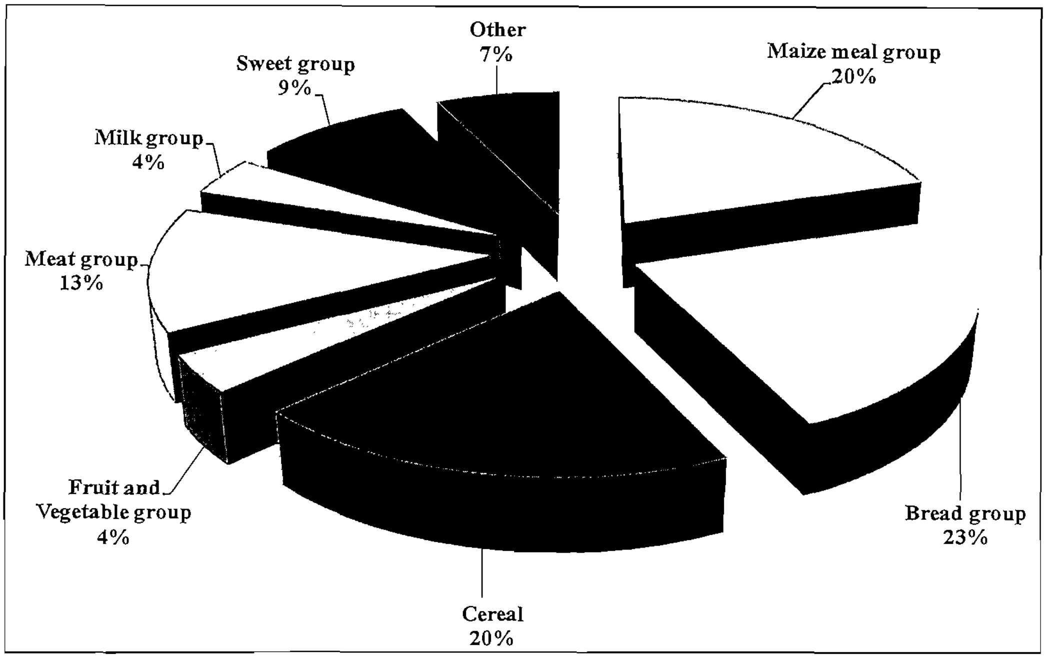

Figure 1 **Contributions of the different groups as a percentage to the total EI of the average of five 24-hour recalls**

Table 3 shows which of the food groups provided the greatest contributions to the nutrient intakes.

Table 3 The rankings of the food groups regarding the contribution to nutrients

Nutrients	**Food groups**						
Micronutrients	**Maize meal**	**Bread**	**Cereal**	**Milk & milk products**	**Meat**	**Fruit & vegetable**	**Sweets**
Calcium	-	4	1	3	0	0	-
Iron	1	3	2	0	2	0	-
Zinc	1	3	2	0	4	0	-
Vitamin B_{12}	-	-	-	2	7	-	-
Vitamin B_6	0	-	3	0	3	1	-
Vitamin C	-	-	1	1	1	4	-
Vitamin A	-	0	1	2	1	2	-
Folate	1	5	1	0	0	0	
Riboflavin	0	1	3	0	2	0	-
Thiamin	3	3	2	0	2	0	-
Niacin	0	3	1	0	5	0	-
Macronutrient mostly derived from staple foods	**Food groups**						
Carbohydrate	3	3	2	0	-	0	1

0 = <10 contribution, 1 = 11-15% contribution, 2 = 16-25% contribution, 3 = 26-35% contribution, 4 = 36-45% contribution, 5 = 46-55% contribution, 6 = 56- 65% contribution, 7 = 66-75% contribution,8 = 76-85% contribution, 9 = 86-95% contribution, 10 = >95% contribution.

The variations in the frequency of consumption and the mean portion sizes of consumed foods over the different DA measurements play a role in the reproducibility of the different food groups and the relevant nutrients.

Reproducibility of Nutrients and Food groups

The RCs and 95% CIs of the essential nutrients and food groups for adolescents are shown in Table 4 and Table 5 respectively. Although there were no significant differences between RCs (as evidenced by the overlapping 95% CI), the RCs of nutrients and food groups derived from four and five 24-hour recalls were remarkably higher and the 95% CI narrower than those obtained for two and three 24-hour recalls. Additionally, little difference was seen between the RCs and 95% CIs of the nutrients and food groups with four compared to five 24-hour recalls.

Table 4 The mean RC and 95 %CI of different nutrients for different numbers of 24-hour recalls (n=87)

Descriptions	Two 24-h recalls			Three 24-h recalls			Four 24-h recalls			Five 24-h recalls		
	RC	- 95% CI	+ 95% CI	RC	- 95% CI	+ 95% CI	RC	- 95% CI	+ 95% CI	RC	- 95% CI	+ 95% CI
Energy	0.17	-0.21	0.46	0.28	-0.03	0.49	0.54	0.33	0.67	0.54	0.35	0.67
Carbohydrate	0.15	-0.24	0.45	0.26	-0.05	0.48	0.60	0.40	0.71	0.56	0.37	0.68
Protein	0.04	-0.37	0.37	0.35	0.06	0.55	0.55	0.34	0.68	0.59	0.40	0.70
Fat	0.08	-0.33	0.40	0.13	-0.22	0.39	0.43	0.19	0.59	0.49	0.28	0.63
Calcium	0.38	0.04	0.60	0.28	-0.03	0.49	0.56	0.36	0.69	0.53	0.34	0.66
Iron	-0.03	-0.46	0.33	0.36	0.08	0.56	0.53	0.31	0.66	0.53	0.33	0.66
Zinc	0.18	-0.20	0.46	0.33	0.04	0.53	0.47	0.24	0.62	0.55	0.36	0.68
Vitamin B_{12}	-0.22	-0.70	0.20	0.22	-0.11	0.45	0.40	0.15	0.57	0.35	0.10	0.53
Vitamin B_6	0.17	-0.20	0.45	0.44	0.17	0.61	0.59	0.39	0.71	0.58	0.39	0.69
Vitamin C	0.22	-0.15	0.49	0.35	0.07	0.55	0.43	0.19	0.59	0.44	0.21	0.59
Vitamin A	0.42	0.09	0.62	0.32	0.02	0.52	0.52	0.30	0.66	0.52	0.32	0.65
Folate	0.04	-0.37	0.37	0.32	0.02	0.52	0.58	0.37	0.70	0.54	0.34	0.66
Riboflavin	-0.01	-0.44	0.34	0.30	0.00	0.51	0.25	-0.05	0.46	0.31	0.04	0.50
Thiamin	0.27	-0.09	0.52	0.24	-0.08	0.47	0.45	0.22	0.60	0.46	0.24	0.61
Niacin	0.43	0.11	0.62	0.49	0.23	0.64	0.55	0.35	0.68	0.60	0.41	0.71

RC = Reproducibility coefficient; -95% CI = Lower 95% Confidence Limit; + 95% CI = Upper 95% Confidence Limit; 24-h recalls = 24-hour recalls

Table 5 The mean RC and 95 % CI of different food groups for different numbers of 24-hour recalls (n=87)

Descriptions	Two 24-h recalls			Three 24-h recalls			Four 24-h recalls			Five 24-h recalls		
	RC	- 95% CI	+ 95% CI	RC	- 95% CI	+ 95% CI	RC	- 95% CI	+ 95% CI	RC	- 95% CI	+ 95% CI
Maize meal	0.49	0.17	0.67	0.47	0.21	0.63	0.59	0.39	0.71	0.65	0.48	0.75
Bread group	0.26	-0.10	0.52	0.31	0.01	0.52	0.57	0.36	0.69	0.61	0.44	0.72
Cereal group	0.01	-0.40	0.35	0.30	0.00	0.51	0.51	0.29	0.65	0.55	0.35	0.67
Milk group	0.55	0.24	0.70	0.50	0.25	0.65	0.51	0.29	0.65	0.56	0.37	0.68
Meat group	0.13	-0.27	0.43	0.14	-0.21	0.40	0.38	0.12	0.55	0.45	0.23	0.60
Fruit and vegetables	0.06	-0.35	0.39	0.26	-0.05	0.48	0.49	0.27	0.63	0.44	0.21	0.59
Sweets	0.06	-0.36	0.39	0.23	-0.09	0.46	0.50	0.27	0.64	0.40	0.16	0.56

RC = Reproducibility coefficient; -95% CI = Lower 95% Confidence Limits; + 95%CI = Upper 95% Confidence Limits; 24-h recalls = 24-hour recalls

However, for five of the RC of nutrients (total fat, total protein, niacin, thiamin, Zn) and four food groups (bread, cereal, maize meal and meat) there was a trend towards a higher RC from five 24-hour recalls compared to two, three and four 24-hour recalls. The trend, furthermore, showed that the RCs of four 24-hour recalls were slightly lower than the RCs of five 24-hour recalls (Figure 2).

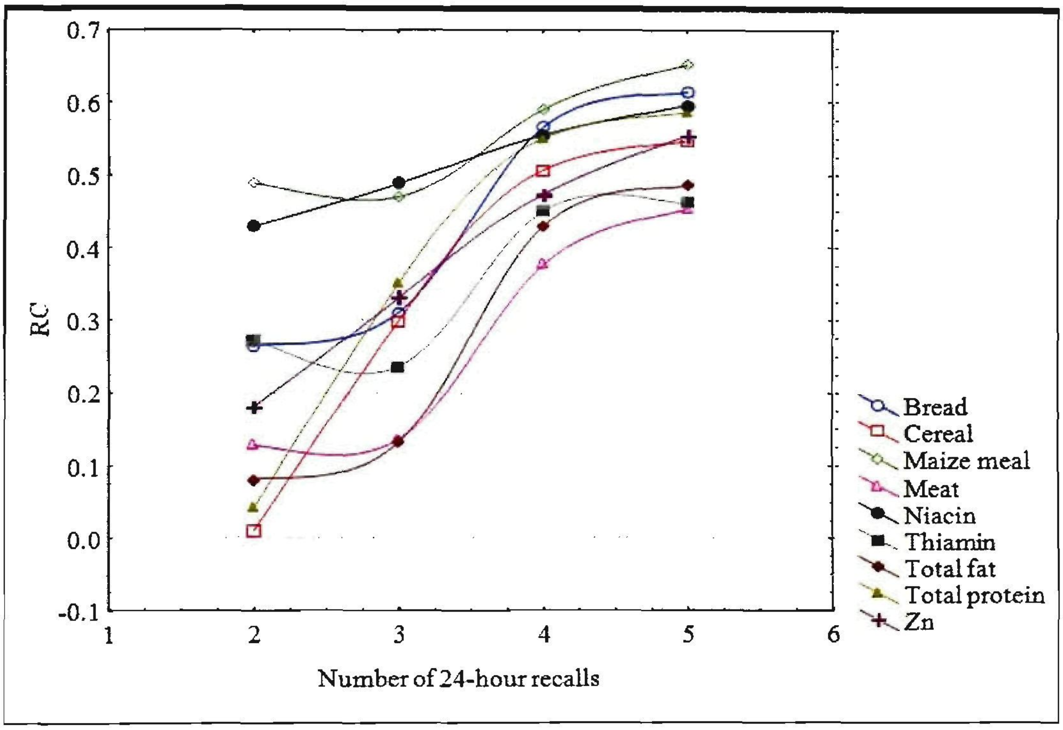

Figure 2 The RC of food groups and nutrients at five different numbers of 24-hour recalls

On the other hand, the RC of some nutrients and food groups (energy, carbohydrates, Fe, folate and vitamins C, B_{12} and B_6 and the sweets and fruit and vegetables groups) tended towards a higher RC from four 24-hour recalls compared to two, three or five 24-hour recalls (Figure 3).

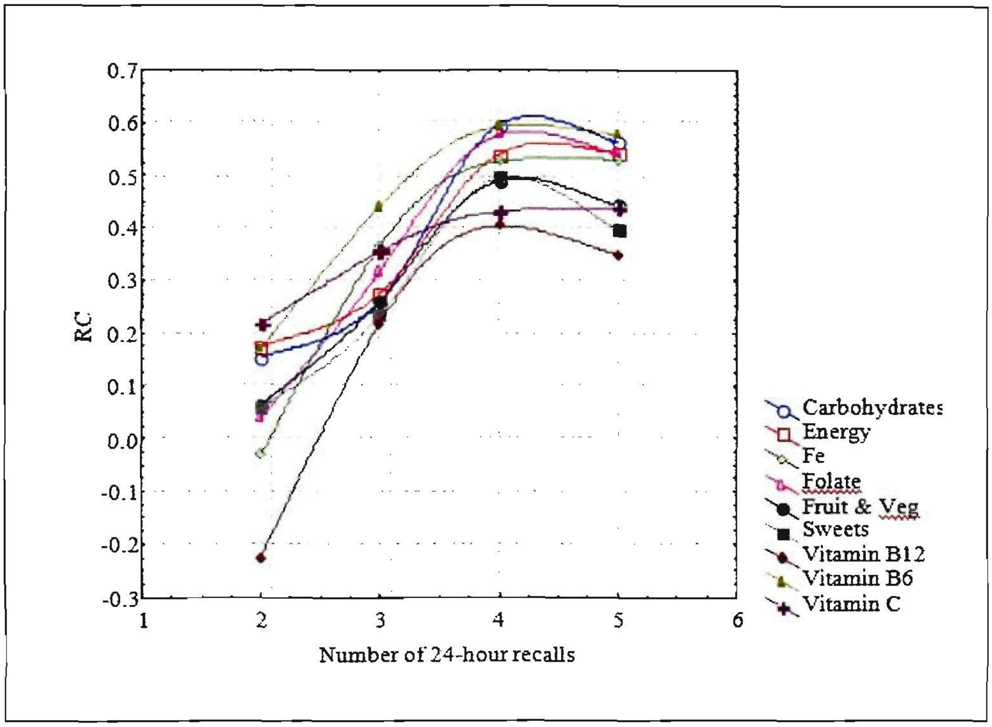

Figure 3 **The RCs of specific food groups and nutrients at five different numbers of 24-hour recalls**

Interesting results were found for the RCs of vitamin A and Ca where, although the highest RC was found at four 24-hour recalls, a very poor RC was found at three 24-hour recalls compared to two, four and five 24-hour recalls (Figure 4).

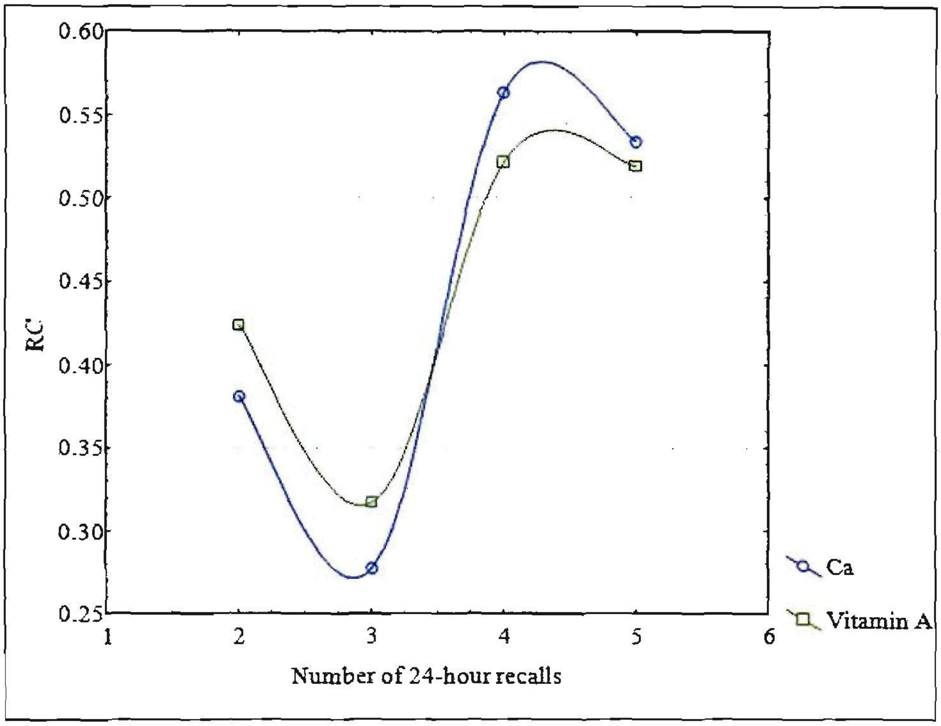

Figure 4 **Trend for the RC of vitamin A and calcium for different numbers of 24-hour recalls**

Discussion

To our knowledge no data are available on the reproducibility of 24-hour recalls amongst African adolescents which makes this study unique. This study found that if a multiple 24-hour recall DA method is used to study the dietary intake of peri-urban black South African adolescents, four 24-hour recalls appear to provide the strongest RC for most nutrients and food groups. It should, however, be kept in mind that the reproducibility of certain food groups and nutrients was very low.

Reproducibility studies on 24-hour recalls are limited compared to the large body of reproducibility studies on FFQ, dietary histories and food records. A review of publications from 1970 to 1999 by McPherson and co-workers (2000) only found validity studies for 24-hour recalls. In addition, Rosalind Gibson's (2005) book does not refer to any 24-hour recall reproducibility studies amongst adolescents, although she referred to outdated 24-hour reproducibility studies (1978 and 1989) performed in adults.

The adolescent age group is not only one of the most important age groups in which to investigate dietary intake, but also one of the most difficult age groups from which to obtain accurate dietary intake reports. This high rate of reporting error emphasises why reproducibility studies that refer to random measurement error are important. In this study the RC values for the chosen nutrients and food groups differ between the various number of 24-hour recalls. Kruger (2003) touched on the reproducibility of two 24-hour recalls from pre-adolescents in her doctoral thesis. The Spearman correlation coefficient of all nutrients and food groups between the two 24-hour recalls ranged from 0.016 (vitamin B_{12}) to 0.512 (sugar) in that study. Compared with the results of the present study, the RC had a slightly narrower range for the RC of nutrients and food groups from 0.25 (riboflavin) to 0.6 (carbohydrates). Contrastingly, the present study showed that two 24-hour recalls provided poor RCs and reproducibility improved only with four 24-hour recalls. Although Kruger (2003) concluded that the reproducibility of the two 24-hour recalls was good, only two nutrients had RCs above 0.4, while the remaining nutrients had RCs of 0.3 or lower. This indicates that, in reality, the two 24-hour recalls of Kruger (2003) were not reproducible, as evidenced by the low RCs. A possible reason for the difference in results could be that the present study investigated the reproducibility of nutrients and food groups with two, three, four, and/or five 24-hour recalls. This method differs from that used in Kruger's study, which only investigated the means of the nutrients between two 24-hour recalls.

Another reproducibility study on two 24-hour recalls performed by Andersen and co-workers (2004) among pre-adolescents showed that the Spearman correlation coefficient between the two 24-hour recalls for the fruit and vegetable group was 0.78 (95% CI of 0.70 to 0.84). When the RC of four 24-hour recalls in the present study was compared with the correlation coefficient obtained in the study performed by Andersen and co-workers, it is clear that the Andersen study had a higher RC for the fruit and vegetable group. The present study also had a wider 95% CI range for fruit and vegetables than that reported by Andersen *et al.* (2004). A possible explanation for the narrower 95% CIs could be the slightly larger sample size (22 participants more than the present study).

The low RC value obtained for the fruit and vegetable group [0.49 (95% CI of 0.27 to 0.63)] in the present study can be explained by the different number of participants who consumed fruits and vegetables per DA measurement. Lower seasonal availability and higher costs of fruits and vegetables during Autumn and Winter could have contributed to decreased consumption. During Spring more vegetables were consumed, possibly due to higher availability. Fruit intake, however, remained low in more than a third of the participants. Since fruits are more expensive than vegetables (cabbage, spinach, carrots and pumpkin) financial constraints could have contributed to their low consumption. From the demographic information it is clear that the adolescents were mainly of low socio-economic status and that 29% (± 1 out of 4) of the adolescents were often hungry. Labadarios and co-workers (2000) demonstrated similar results in peri-urban South African children aged 1-9 years (1999) where EI from the fruit and vegetable group was low (5% of the total EI).

The results of the present study were compared with another study (MacIntyre et al., 2000) that focused on the same peri-urban ethnic group (15-65 years) in the same province, but tested the reproducibility of dietary intake derived from two administrations of FFQs. From this comparison, a remarkable difference was detected. The study performed by MacIntyre and co-workers (2000) investigated the RCs (Spearman Rank) between two administrations of a FFQ in terms of energy (0.28), protein (0.31), carbohydrates (0.22), fat (0.39), Ca (0.14), Fe (0.28), vitamin A (0.34) and C (0.38). These RCs are considerably lower than the highest mean RCs found in the present study, which were derived from four 24-hour recall measurements. Low RCs for nutrients measured by FFQ may reflect the high participant burden thereof. The 24-hour recall method has a lower burden on the memory and cognitive aspects of adolescents, which could have resulted in better reproducibility. However, the short-term memory of adolescents is limited and in order to ensure that the dietary intake from multiple 24-hour recalls is accurate, reproducibility testing is important (Domel, 1997).

To calculate an individual EI derived from 24-hour recalls, the Food Habits of Canadians Survey showed that thirty 24-hour recalls are required to report the EI within 10% of the 'actual EI', but when eight or three 24-hour recalls were used the 'actual EI' is respectively reported within 20% and 30%. The accuracy of the reported EI would increase when eight or three 24-hour recalls were used to determine a mean of the 'actual EI' of a group and not an individual, as in the present study (Palaniappan et al., 2003).

In the present study the RCs appeared to be nutrient and food group-sensitive. The results show that most of the nutrients and food groups tested had a relatively good reproducibility when four and/or five repeated 24-hour recalls were used (RC>0.5) and also that the RCs of the nutrients and food groups derived from both were similar. However, when practicality to administer a large study and the sample size are taken into consideration, four 24-hour recalls are more practical, the cost is lower and the sample size is better maintained than when five 24-hour recalls are used. Therefore, from the present study it seems that four 24-hour recalls is the optimal number to use in a multiple 24-hour recall method study of peri-urban black adolescents in order to increase the accuracy and reproducibility of the DA.

The nutrients and food groups, derived from four 24-hour recalls, with the highest RCs in this study were vitamin B_6, folate, carbohydrate and the maize meal group (RC≥0.58) and those with the lowest RCs at four 24-hour recalls (RC≤0.4) were riboflavin, vitamin B_{12} and the meat group. Hence with reference to Table 2 and 3 and the RC of nutrients and food groups derived from four 24-hour recalls, the RC of these nutrients and food groups will be discussed in more detail.

The results of the food groups (maize meal and bread groups) with high RCs showed that the mean portion sizes between the different DA measurements were constantly within 20% of each other and also the number of participants, who consumed the food group was constant. Food groups are comprised of food items, which are comprised of nutrients. Therefore, the number of the participants who consumed food items and the consistency of the mean portion sizes of the food items throughout the year that contribute the most to a specific nutrient would influence its RC. The food groups, which are rich in carbohydrate such as maize meal, bread, cereal and sweets groups mostly contributed to the energy intake and because of the high RCs of these four food groups, the carbohydrates had the highest RC. Two of these food groups are also the staple foods of the present study population and had the highest RCs, meaning that four 24-hour recalls would measure the most important foods consumed by the present population group accurately. On the other hand, the same food groups that contributed to the carbohydrates intake (including the meat group) contributed to the thiamin intake. The inconsistent number of participants who consumed the meat group and the inconsistency of the mean portion sizes caused the RC of thiamin to be as low as 0.45. The results revealed three patterns for nutrients to have high RCs. Firstly, the food groups that mostly contributed to a specific nutrient (i.e. calcium, folate and niacin) were consumed by a constant number of participants and the mean portion sizes of the food item in the food groups were consistent. Secondly, two food groups, which contributed the same percentage to the same nutrient (i.e. vitamin A and B_6) and the number of the participants consuming both food groups, were inconsistent. For example, vitamin B_6 (Table 3), the meat group and cereal group contributed the same percentage to the vitamin B_6 intake. However, the number of participants who consumed both food groups (meat and cereal) was inconsistent, the meat group had at one of the four DA measurements a low number of the participants and at the same DA measurement, the number of the participants who consumed the cereal group was high. This means that the number of participants who had a vitamin B_6 intake at the same DA measurement was brought in line with the number of participants of the other DA measurements. Therefore, the number of participants for the vitamin B_6 intake throughout the year was constant. Lastly, there was a combination of the above-mentioned patterns (iron). On the other hand the lowest RC was found to be for riboflavin. This low RC could be explained as such: the specific food item (breakfast cereal) in the food group that mostly contributed to riboflavin intake had a large difference in mean portion sizes between DA measurements, and the number of participants who consumed the breakfast cereal was inconsistent throughout the year.

Conclusion

These results suggest that, when 24-hour recalls were taken on non-consecutive days spread over seven months, the best reproducibility was obtained from four repeated recalls. Four 24-hour recalls showed the highest RCs for energy, carbohydrates and the majority of nutrients (Ca, Fe, folate, vitamin A, C, B_{12} and B_6) and fruit and vegetable and sweets groups, although the RCs obtained for these four food groups showed no significant differences between four and five 24-hour recalls. Four 24-hour recalls are; more cost effective to administer in a large study, they maintain a larger sample size and are more practical than five 24-hour recalls. The results of the present study showed that the consistency of the number of participants and the consistency of the mean portion sizes of the food items consumed influence the RC of the food groups and the nutrients derived from four 24-hour recalls. Thus, the RCs were higher among food groups and nutrients that had a consistent number of participants who consumed the relevant food items with consistent mean portion sizes within 20% throughout the year.

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References in text are indicated in the text by name and date e.g. (Pampiglione & Ricciardi, 1986) and (Kusin *et al.*, 1994), and listed at the end of the paper in alphabetical order of first author. References should be listed and journal titles abbreviated according to the style used by Index Medicus, examples are given below. All authors should be quoted for papers with up to six authors; for papers with more than six authors, the first six only should be quoted, followed by *et al.* Please use recent references wherever possible.

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CHAPTER 4

DIETARY INTAKES ASSESSED BY 24-HOUR RECALLS IN PERI-URBAN AFRICAN ADOLESCENTS:

2. VALIDITY OF ENERGY INTAKE COMPARED WITH ESTIMATED ENERGY EXPENDITURE

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Abstract

Objective: To determine the comparative validity of reported energy intake derived from multiple 24-hour recalls of African adolescents against estimated energy expenditure. In order to calculate energy expenditure, we incorporated the most appropriate basal metabolic rate equations and physical activity factors as reported in the literature.

Design: This analysis was nested in the multidisciplinary *PhysicaL Activity in the Young (PLAY) Study* and a prospective study design was used.

Setting: Peri-urban black South African adolescent learners from Seiphemelo Secondary School (Ikageng) in North West Province, South Africa were investigated.

Participants: A convenient sample of grade eight to nine pupils (135 girls and 115 boys) was recruited. An inclusion criterion was used to identify the sample size of each different data set, in order to ensure validity

Methods: The Pearson correlation coefficients and Bland-Altman plots between the BMR estimates derived from published equations were calculated, in order, to identify the equations which estimate the basal metabolic rate (BMR) the most accurate. A p-value of less than 0.05 was used to indicate statistical significance. After estimated energy expenditure had been calculated for each participant, the validity of the multiple 24-hour recall protocol was tested with three different data sets using Pearson correlations and Bland-Altman plots. The EI:EE on the five measurements were compared using dependent t-tests to test for seasonal differences in EI. Reproducibility coefficients for five 24-hour recall episodes on non-consecutive days were analysed by a published reproducibility method. Cut-off points were calculated by the formula of Goldberg, and under and over reporting were identified.

Results: Pearson correlation coefficients of all the different calculated basal metabolic rates were good and ranged from 0.97 to 0.99. The Bland-Altman equation showed acceptable agreement between two equations for each gender. Only one equation for each gender was used to calculate the energy expenditure. Pearson correlation coefficients between reported energy intake and estimated energy expenditure for all three data sets were weak indicating poor agreement. In this present study there were no seasonal differences between the five different EI measurements. Poor reproducibility between multiple 24-hour recalls was found due to higher *within participant variations* (37.71% for girls and 40.5% for boys) than *between participant variations* (12.62% for girls and 21.34% for boys). After different cut-off points for each physical activity group had been calculated, the results showed that 87% of the boys and 95% of the girls underreported.

Conclusion: Single 24-hour recalls measured at five measurements over a two year period offered poor validity when reported energy intake was compared against estimated energy expenditure.

Keywords: 24-hour recalls; validity; reproducibility; energy cut-off points; dietary assessment; adolescents

West Province, South Africa. In order to calculate EE, the most appropriate equation for the calculation of BMR (Henry et al., 1999) and physical activity factors (Brooks et al., 2004) were identified from the literature.

Participants and methods

Study design

This analysis was a longitudinal observational study nested within the multidisciplinary *PhysicaL Activity in the Young (PLAY) Study.* The study was conducted over a period of two years with eight DA measurements: March (baseline), May, June, August and September 2004 and March, June and September 2005. These specific months were selected to assess dietary intakes across different seasons (March - Autumn, June - Winter and September – Spring). It was not possible to include a summer month, since data collection could not take place during the end-of-year school examination period (October to November), the summer school holidays (December to early January) and the beginning of the school year (January to February). Furthermore, anthropometric measurements were taken on only five measurements (March and September 2004 and March, June and September 2005). Thus dietary data from these assessment measurements were used for the present analyses, where the dietary data was investigated over the two year period.

Participants

After the North-West University Ethics Committee approved the present study (Ethics code: 04M01), an availability sample (135 girls and 115 boys) was recruited in March 2004. The children were grades eight to nine, low socio-economic, Tswana, Sotho and/or Xhosa speaking adolescents who attended Seiphemelo Secondary School in Ikageng, North West Province, South Africa. Written authorisation was obtained from the school's principal to conduct this study. Each recruited participant and their parents/guardians completed an informed consent form before they were included in the study.

Three different data sets were used to determine the effect of the number of 24-hour recalls on the validity of EI. In order to be included in a given data set the participants had to be

Introduction

Accurately measuring dietary intake by using dietary assessment (DA) tools is crucial for researchers and dieticians. Validity is the degree to which the DA tool reveals the actual dietary intake (Flood et al., 2004). A good example is children's dietary reporting. This reporting may be influenced by children's low literacy levels, lack of knowledge of food types, inability to correctly estimate portion sizes, lack of food preparation experience and familiarity with added ingredients, general lack of interest and short attention span. Knowledge of a DA tool's validity increases interpretation quality and improves the accuracy of dietary intake evaluation (Flood et al., 2004). Therefore, it is essential to validate DA tools for children and adolescents to improve and simplify DA protocols for these challenging age groups (Crawford et al., 1994).

To know a DA tool's absolute validity is impossible because researchers can never know the true dietary intake with absolute certainty. Therefore, researchers have developed different methods to measure relative validity (Block, 1982). One approach is to compare dietary intake derived from a "*test*" DA method against 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 used to measure validity depends on external variables such as biomarkers and body components that have a strong direct relationship with dietary intakes. The most general biomarkers used are several vitamins (vitamin B6, vitamin C and folate) measured in plasma or serum (Flood et al., 2004), 24-hour urinary nitrogen excretion and energy expenditure (EE) (Gibson, 2005). Specialised and expensive equipment is necessary to measure these biomarkers (Henry et al., 1999). The doubly labeled water (DLW) method is increasingly used in international studies (Crawford et al., 1994) to validate energy intake of children and adolescents measured by different DA methods (Chapter 2). However, in developing countries such as South Africa this method is financially impractical. Basal metabolic rate (BMR) equations can, however, be used to calculate estimated energy expenditure, which may be used as a biomarker to validate energy intake derived from DA methods (Henry et al., 1999).

The present study's aim was to determine the relative validity of energy intake (EI) derived from multiple 24-hour recalls of peri-urban South African adolescents living in the North younger than 17 years + 0 days. A power calculation to determine sample size was not performed because the sample was selected only on the basis of availability.

Demographic assessment

Demographic characteristics such as the participant's age, gender, home language and socio-economic class were obtained from the participants self, by means of a structured demographic questionnaire.

Dietary assessment

Dietary intake was assessed using the 24-hour recall method for five dietary data measurements from March to September (non-consecutive) in 2004. Similar assessments were conducted in 2005 but only on three non-consecutive days during March to September. Two trained experienced interviewers administered questionnaires using face-to-face interviews in the home language (Tswana, Sotho and Xhosa) of the adolescents. The interviewers revised the correct protocol for 24-hour recall interviewing before each of the measurement days. Information obtained was translated to English during the interview. The interviewers were continuously supervised by a registered dietician with post-graduate qualifications. Participants had to recall their food intake (foods and drinks) of the previous day (midnight to midnight) without prompting during the interview process. Prompting was only used to increase the accuracy of the 24-hour recall after the participant's memory was exhausted. Portion sizes were estimated using a validated food portion photograph book designed by MacIntyre in 1996 (Venter et al., 2000) to improve accuracy. A supervisor was present during all interviews and scrutinised the 24-hour recall for visible errors, omissions of preparation methods and portion sizes (to increase the inter- and intra-rater reproducibility). To create a relaxed atmosphere the participants were not rushed during the interview.

Anthropometric and physical activity measurements

Triplicate anthropometric measurements were recorded by level two qualified anthropometrists at baseline (March 2004), September 2004 and in May, June and September of 2005. The measurements were taken while participants were dressed in their underwear. Body mass was measured with a portable electronic scale (Precision Health Scale, A&D Company, Tokyo, Japan) to the nearest 0.1 kg. Heights were measured without shoes, with participants standing upright with their heads in the Frankfort plane (Norton & Olds, 1996) with a Stadiometer (IP 1465, Invicta, London, UK) measuring height to the nearest 0.5 cm. Skinfolds (suprailiac, abdominal, subscapular and tricep) were measured with a John Bull calliper (British Indicators, London, UK) according to approved methods [International Society for the Advancement of Kinanthropometry, 2001]. Body fat free mass (FFM) was determined by air displacement plethysmography in the BodPod® measurement system (Life Measurement Inc, Concord, CA) using Boyle's law of pressure/volume. The anthropometric measurements were used in the BMR equations to predict the adolescents' BMR.

Habitual physical activity for each participant was assessed for the previous weekday and a weekend day using the Previous Day Physical Activity Recall (PDPAR) questionnaire (Trost et al., 1999) at five (March, September 2004 and March, June and September 2005) physical assessments. Their reported activity of each participant was coded, and a literature-based metabolic equivalent minutes/week value (Ainsworth et al., 1993) was assigned to each coded activity. Each participant was then classified into one of three physical activity level (PAL) categories. Brooks and colleagues (2004) equate each PAL category with walking a certain number of km/day. PAL 1 (low active) = 3.52 km/day, PAL 2 (medium active) = 11.68 km/day and PAL 3 (high active) = 26.73 km/day.

Statistical analysis

The dietary intakes as determined by the 24-hour recall questionnaires were analysed for energy and macro and micronutrients using the *FoodFinder®* dietary analysis software (Medical Research Council, Tygerberg, 2000). In this study, only the EI was studied. The average energy intake of multiple 24-hour recalls is represented in this paper as EI_{rep}.

The equations to calculate BMR recommended by Henry and colleagues in 1999 are shown below and include those of the Food and Agriculture Organisation (FAO) (1985) and Schofield et al. (1985). The following equations were used for the girls:

Two equations from Henry and colleagues (1999):

$$BMR = \text{weight (kg)}\ 47.9 + 3230 \qquad (1)$$

$$BMR = \text{weight (kg)}\ 21.0 - \text{height (cm)}\ 11.0 + \text{FFM (kg)}\ 80.7 - \text{age (y)}\ 154.6 + 5319 \qquad (2)$$

Two equations from FAO (1985):

BMR = 12.2 weight (kg) + 746 (3)

BMR = 30.9 weight (kg) + 2 016.6 height (m) + 907 (4)

Two equations from Schofield and colleagues (1985):

BMR = 0.056 weight (kg) + 2.898 (5)

BMR = 0.035 weight (kg) + 1.948 height (cm) + 0.837 (6)

The following BMR equations were used for the boys.

Two equations from Henry and colleagues (1999):

BMR = weight (kg) 66.9 + 2876 (7)

BMR= weight (kg) 78.5 + suprailiac (mm) 45.3 – triceps (mm) 54.99 – subscapular (mm) 38.3 + 294 (8)

Two equations from FAO (1985):

BMR = 15.3 weight (kg) + 679 (9)

BMR = 69.4 weight (kg) + 322.2 height (m) + 2 392 (10)

Two equations from Schofield and colleagues (1985):

BMR = 0.074 weight (kg) + 2.754 (11)

BMR = 0.068 weight (kg) + 0.574 height (cm) + 2157 (12)

Baseline data were used to determine the most appropriate BMR equation. The estimated BMR for each participant was calculated, and *Statistica*® (Version 7) (StatSoft, 2004) was used in all analyses. The correlations between BMR derived from the different equations were compared, where a statistically significant correlation had a p-value of less than 0.05.

Possible bias in estimation and lack of agreement were measured by Bland-Altman plots. The Bland-Altman plot gives an indication of whether there is a consistent bias or whether there is a relationship between bias and magnitude of the BMR (Bland & Altman, 1999). The limits of agreement were calculated by a 95% confidence interval for the difference in estimated BMR as determined by the above-mentioned BMR equations.

After the most appropriate estimated BMR equations for both genders had been identified, the estimated energy expenditures (EE_{est}) were calculated with the following formula:

$$EE_{est} = BMR \times \text{Physical Activity Factor (PAF)} \quad (13)$$

The different PAL categories were assigned to specific PAF values, which were identified by Brooks and colleagues (2004). The PAF values were as follows: *PAL 1* = 1.55, *PAL 2* = 1.7 and *PAL 3* = 2. The average EE_{est} of multiple calculated EE is represented in this paper as $m\text{EE}_{\text{est}}$.

Ages were calculated in months using Excel XP (2004) as the difference between the date of measurement and the date of birth. The genders, ages (months) and heights (cm) of the participants were exported from Excel XP (2004) into EpiInfo version 3.5 (Dean et al., 2008). The "Nutrition" module of EpiInfo version 3.5 was used to calculate the height-for age percentile of each child at each data collection measurement using the Center for Disease Control and Prevention 2000 reference values (Dean et al., 2008). After the addition of the height-for-age percentiles to the data file, the file was read into the "Analyze Data" module of EpiInfo version 3.5 (Dean et al., 2008) for calculation of the means, standard deviations and 95% confidence intervals and frequency distribution of the height-for-age percentiles.

Differences in energy intakes over the eight different DA measurements over two years due to seasonality were tested with the repeated measure analysis of variance (ANOVA), but no statistically significant differences were found. The validity of energy intake derived from multiple 24-hour recalls was tested over different time periods (a single measurement, five measurements over two years and four measurements over one year). Therefore, three different data sets were used to test the validity of the energy intake derived for the multiple 24-hour recalls. Each of the three data sets had a different sample size and was consistent with the following criteria

Data set 1 was the EI of one 24-hour recall at baseline (March 2004) compared with the same baseline EE_{est}.

Data set 2 was the EI_{rep} of five 24-hour recalls (March, September 2004 and March, June and September 2005) compared with mEE_{est} (March, September 2004 and March, June and September 2005).

Data set 3 was the EI_{rep} of four 24-hour recalls (March, June, August and September 2004) compared with mEE_{est} (March and September 2004).

The validity of the EI of all three datasets was determined with Pearson correlations with the intention of using Bland-Altman plots (Bland & Altman, 1999) to further explore the relationship between EI_{rep} and mEE_{est}.

The reproducibility of 24-hour recalls for EI over the two-year period could not be determined explicitly due to fluctuation in the participant's weight and thus the same expected fluctuation of BMR and the energy intake of participants during this time. Therefore, the reproducibility of EI:EE was determined according to Rieper and colleagues (1993), by using the EI_{rep}:EE_{est} of *Data set 2* [March and September 2004 and March, June and September 2005]. Furthermore, *Data set 2* was specifically tested for differences between the means EI:EE of five DA measurements for statistical significance using paired t-tests. The reason for a second test for seasonality differences was to incorporate the fluctuation of their BMR, due to their weight changes. Variability was investigated using a one-way analysis of variance with the participant as the independent variable. The coefficient of *variation within* participants (CV_W) was derived as the square root of the mean square of the *within effect* (MS_W) of a one-way ANOVA, expressed as a percentage of the mean EI:EE_{est}. Likewise, the estimated *between component variance* (S^2_B) is the difference between the mean square of the between effect MS_B and MS_W divided by the average number of repeated measurements,

$$k = \frac{N - \left(\sum k_i^2 / N\right)}{n-1}, \qquad (14)$$

where N is the total number of data, k_i the number of repeated measurements for individual *i* and *n* the number of individuals. From S^2_B, the coefficient of *variation between* participants CV_B was determined as a percentage of the mean EI:EE_{est} (Rieper et al., 1993).

The literature revealed no cut-off points for under and overreporting of energy intake for South African Adolescents. To identify possible under- and overreporting of EI, population specific cut-off values for plausible EI:EE ratios were calculated using Goldberg's equations (Black et al., 1997; Black, 2000): Cut-off value for EI:EE = $PAL \times \exp\left[z_{\alpha/2} \times \frac{(S/100)}{\sqrt{n}}\right]$,

where PAL is assumed to be the average. PAL of a group, $z_{\alpha/2}$ is taken as ±2, the approximate critical values for α=0.05, for the respective cut-off value, where 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. S is given by $S = \sqrt{CV_W^2/k + CV_B^2 + CV_P^2}$, 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 diet assessment (Rieper et al., 1993), CV_B is the coefficient of *variation in repeated EE measurements* (taken as 8% according to Schofield et al., 1985) and CV_P is the coefficient of *variation in PAL*, taken as 0 for a specific PAL group. Specific cut-off points for each PAL group were calculated to determine under- and overreporting (Livingstone et al., 2000).

Results

Sample sizes

The sample size gradually decreased from baseline to the end of the study. Each data set had a different sample size due the criterion of only participants younger than 17 years + 0 days were included. The reason for this criterion was that the grade eight to nine pupils had different ages, from 13 to 18 year olds. Data set 1 had a sample size of 87 girls and 44 boys, while the sample sizes of data set 2 and data set 3 were similar (55 girls and 26 boys).

Antropometric

The anthropometric measurements were used only to calculate the different BMR equations in order to identify the most appropriate one for each gender. Age and anthropometric characteristics of girls and boys are given in Table 1. The average heights of girls and boys were similar at baseline, but at the end of the study, the data showed that the boys were slightly taller than the girls. In the girls, a high average body fat percentage (contributing to a greater weight) was found at baseline, while the boys had a lower average body fat percentage. The average body fat percentage for girls was higher towards the end of the study than at baseline and lower than baseline for boys. The average weight of the boys was lower than the girls at baseline but similar at the end and the average fat-free mass in both genders was higher towards the end than at baseline.

Table 1 Anthropometric characteristics for adolescents at baseline and end assessments

Descriptive	Age (yr)	Weight (kg)	Height (cm)	Body Fat %	Fat free mass (kg)	Age (yr)	Weight (kg)	Height (cm)	Body Fat %	Fat free mass (kg)
Measurement	Baseline (n=87) of Girls					End (n=55) of Girls				
Mean	13.6	43.1	151.7	26.6	30.81	15.1	48.33	154.5	28.8	36.15
±SD	0.55	8.29	5.72	6.11	4.63	0.55	7.51	5.4	6.19	5.07
- 95% CI	13.47	40.88	150.1	24.9	29.49	15	45.62	152.5	26.8	34.29
+ 95% CI	13.76	45.32	153.2	28.4	32.13	15.3	51.04	156.5	30.9	38.01
Measurement	Baseline (n=44) of Boys					End (n=26) of Boys				
Mean	13.5	39.33	151.3	21	30.27	15	47.34	159.8	18.2	38.14
±SD	0.59	7.07	7.39	4.86	5.58	0.59	9.02	7.59	4.61	10.64
- 95% CI	13.30	36.41	148.5	19	28.01	14.8	43.12	156.3	16	33.16
+ 95% CI	13.77	42.25	154.1	23	32.52	15.3	51.56	163.4	20.3	43.12

SD=standard deviation; CI=confidence interval; cm=centimetre; kg=kilogram; n=number; yr=year

The average height-for-age of all measurement occasions for both genders of 25.5% of the sample fell below the third percentile. Furthermore, the average height-for-age of 45% of the sample fell between third and 25th percentiles and only 8.7% had a height-for-age above 50th percentile. No significant differences were found between the mean height-for-age percentiles of genders (p=0.35) or between the mean height-for-age percentiles from the different measurement measurements (p=0.82).

From the beginning to the end of the study the body fat percentage of the girls increased by 2.2% but there was a 2.8% decrease in the body fat percentage of the boys. When the body fat percentages of both genders at the beginning and the end were compared to the body fat percentages recommendations of Taylor and colleagues (2002), the majority of the girls with a mean of 26.6 (baseline) and 28.8 (end) were classified as obese and the majority of the boys with a mean of 21 (baseline) and 18.2 (end) as overweight.

Comparison of BMR equations for peri-urban South African adolescents

The present study used the equations suggested by Henry and colleagues (1999) to identify the most appropriate BMR equation for African adolescents. Pearson correlation coefficients (PCC) between all the BMRs calculated by the different BMR equations for both genders were high and ranged from 0.97 to 0.99. Further investigation with the Bland-Altman plots showed that two BMR equations for both girls (Figure 1) and boys (Figure 2) showed acceptable agreement (limits of agreement for girls between -810 kJ and 0 kJ and boys between 58 kJ and 158 kJ). The BMR equations identified for the girls were equations 2 and 5, and equations 9 and 12 were identified for the boys. The results showed that the BMRs calculated for boys using equation 12 were on average 104 kJ higher than with equation 9. However, equation 12 comprised two variables (weight and height) and there is evidence that suggests that height does not significantly improve the precision of prediction for both genders, but only the girls' BMR (Dietz et al., 1991, Molnár et al., 1992, 1995). Moreover, one extra variable could introduce an additional source of error in the estimation of BMR not present in equation 9, which featured only one variable (weight) (FAO, 1985). Equation 9 was used to calculate the BMR for the boys in all other analyses. The BMR calculated for girls with equation 2 was 400 kJ lower than the BMR calculated with equation 5. For the same reason that equation 9 was selected for the boys and also because the BMRs calculated with the other equations of the girls were all similar to that of equation 5, it was selected and used for all the other analyses for the girls in the study.

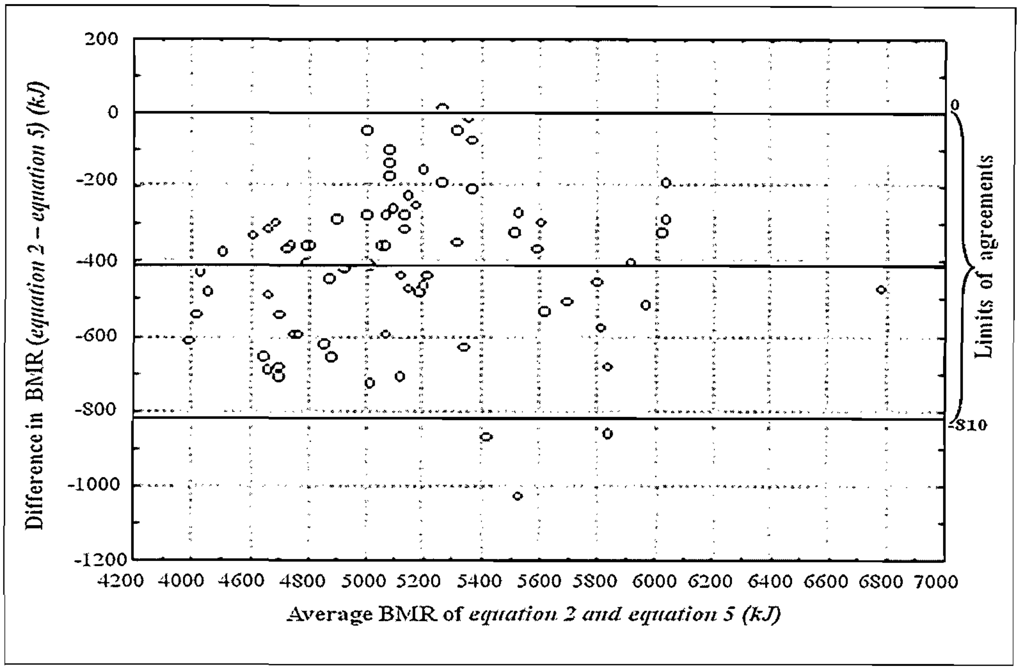

Figure 1 **Bland-Altman plots and limits of agreement for the girls' comparing BMR equations 2 and 5**

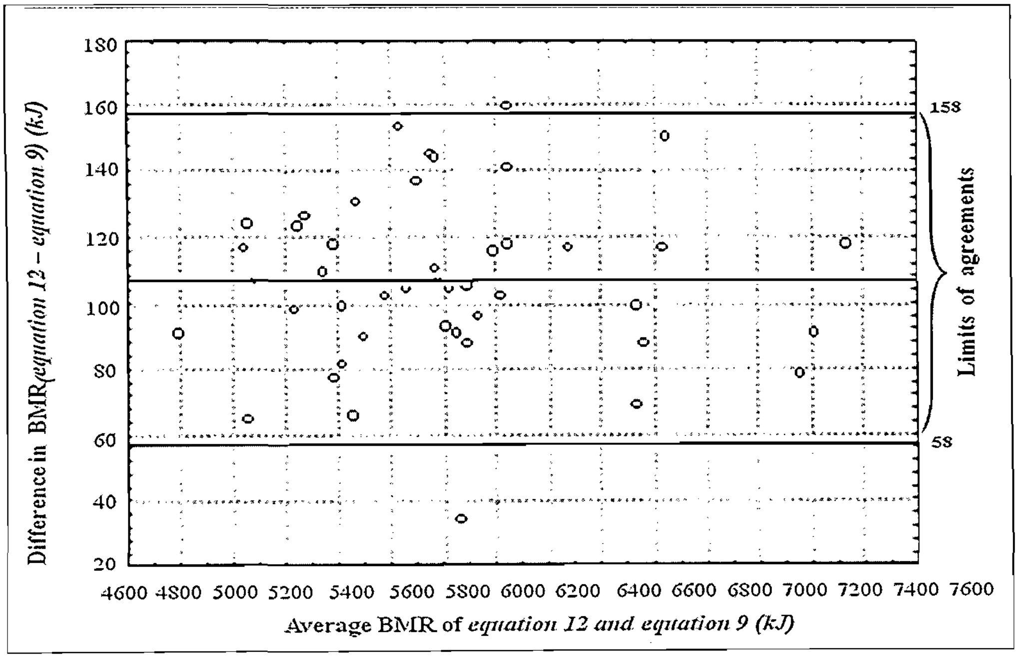

Figure 2 **Bland-Altman plots and limits of agreement for the boys' comparing BMR equations 9 and 12**

Validation of energy intake across multiple 24-hour recalls of peri-urban South African adolescents

Table 2 shows the PCC of EI_{rep} *versus* mEE_{est} for boys and girls. The EI_{rep} *versus* mEE_{est} on five measurements over two years (*data set 2*) showed a PCC for the boys and girls of 0.32 and 0.17 and, therefore, showed low correlation between EI_{rep} and mEE_{est}. The PCC of EI_{rep} *versus* mEE_{est} of four 24-hour recalls over one year (*data set 3*) was also tested to investigate if multiple 24-hour recalls over a shorter time period (1year) would give higher correlations, however, a lower PCC than with five 24-hour recalls over two years was found. The PCC of one 24-hour recall (*data set 1*) was low, as expected, in the boys, while the correlation for girls between EI_{rep} and mEE_{est} was higher than the multiple 24-hour recalls over one or two years, but still too low for any possible relationship. The PCC for the different PAL categories indicated that the boys and girls who were more active showed potential to improve the PCC of EI_{rep} *and* mEE_{est}; however, the correlations were still low.

Table 2 PCCs of EI_{rep} and mEE_{est} of the different *data sets* and *of data set 1* with participants grouped into different *PAL categories*

Data set	PAL	Boys		Girls	
		n	PCC	n	PCC
Data set 1	1, 2 & 3	44	0.04	87	0.20
Data set 2	1, 2 & 3	26	0.32	55	0.17
Data set 3	1, 2 & 3	26	0.18	55	-0.12
Data set 1	1	8	-0.14	35	-0.15
Data set 1	2	7	0.38	19	0.14
Data set 1	3	29	0.31	33	0.37

PCC = Pearson correlation coefficient; PAL 1 = light active; PAL 2 = medium active; PAL 3 = high active; n = number of participants;
Data set 1= the EI at baseline (March 2004) compared with the same baseline EEest;
Data set 2 = the EIrep of five 24-hour recalls (March, September 2004 and March, June and September 2005) compared with mEEest (March, September 2004 and March, June and September 2005).
Data set 3 was the EIrep of four 24-hour recalls (March, June, August and September 2004) compared with mEEest (March and September 2004)

The low PCCs indicated that there were no linear relationships and thus no agreement between EI_{rep} and mEE_{est} (Field, 2004). As a result, Bland-Altman plots (Bland & Altman, 1999) were not used further to investigate the relationship between EI_{rep} and mEE_{est}.

In order to test the statistical significant effect of the seasons, independent from the fluctuations of the participant's weights, the dependent t-tests were performed between the $EI{:}EE_{est}$ of the different DA measurements by using *data set 2*. The dependent t-test of the boys showed no significant differences between the mean $EI{:}EE_{est}$ across all dietary data recording measurements. Conversely, the dependent t-test of the girls showed significant differences between mean $EI{:}EE_{est}$ of March 2004 *vs*. June 2005 ($p = 0.031$) and March 2005 *vs*. June 2005 ($p = 0.005$) (data not shown).

Reproducibility of $EI{:}EE_{est}$ in the context of 24-hour recalls of peri-urban South African adolescents

The reproducibility of $EI{:}EE_{est}$ was assessed by using *Data set 2* where the average number of recalls (*k*) was calculated (equation 14) to be 2.77 for the boys and 2.52 for the girls. The results showed that the *within participant coefficients* of variation (CV_W) for the boys and the girls were 40.5% and 37.71%, respectively. These were higher than the *between participant coefficient* of variation (CV_B), which measured 21.34% for the boys and 12.62% for the girls.

Cut-off points and reporting of energy intake by peri-urban South African adolescents

The calculated Goldberg cut-off points (CPs) according to Black (2000) for each PAL group in the present study are shown in Table 3. The highest calculated CPs for the PAL 1 group of the boys were approximately the same as the lowest CPs for the PAL 3 group. In other words, an $EI{:}EE_{est}$ of a boy in the PAL 1 group who overreported would have the same $EI{:}EE_{est}$ as a boy in the PAL 3 group who underreported. Across both genders, the majority of the participants were in the PAL 3 group.

Table 3 Peri-urban South African adolescents' specific calculated Goldberg CPs for different estimated PAL categories

Descriptive	PAL 1 (PAF = 1.55)		PAL 2 (PAF = 1.7)		PAL 3 (PAF = 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

PAL = Physical Activity Level; PAF = Physical Activity Factor; CP=Cut-off Point

When each adolescent in a PAL group's EE:EE_{est} ratios were compared to the present study's calculated cut-off points, it became clear that most of the boys (87%, n = 39) had underreported EI, while 2% (n = 1) overreported. Likewise, the majority of the girls (95%, n = 83) also underreported, and only 2% (n = 1) overreported.

The results of the Bland Altman plots (Figure 1 and Figure 2) indicated that BMR equation 9 for the boys and equation 5 for the girls were the most appropriate BMR equations to calculate EE_{est} for peri-urban South-African adolescents. However, the results showed weak correlation between EI_{rep} and the mEE_{est} in both genders. Furthermore, the *variation within the participants* in both genders was higher than the variation between the participants, resulting in poor reproducibility of energy intake derived from the 24-hour recalls. The majority of the participants seemed to underreported EI in the context of the multiple 24-hour recall method.

Discussion

To our knowledge, no data to determine the validity of EI derived from multiple 24-hour recalls as a DA method in African adolescents are available, which makes the present study unique. The salient finding of this study is that multiple 24-hour recalls need to be clearly defined, because one 24-hour recall measured at five measurements over two years (which is defined as multiple 24-hour recalls) showed a similar lack of validity of EI to a single measurement. Furthermore, the question needs to be asked if a single 24-hour recall can represent the dietary intake of two to three and a half months (five 24-hour recalls spread over 12 months). The present study, however, did find that energy intake derived from five 24-hour recalls spread over one year or four 24-hour recalls spread over two years is not valid.

Sample size

After the first interview period, the sample size decreased gradually. The reason for this was that some of the adolescents relocated during the two year study period, dropped out of school or were absent on some of the interview days. In addition, certain participants could be included, since they were older than 17year + 0 days at the given data set.

Comparison of BMR equations for peri-urban South African adolescents

Since estimated BMR is predicted from anthropometric measurements and multiple variables such as gender and stage of puberty, the rapid body composition changes during adolescence could influence the accuracy of the estimated BMR. Henry and colleagues (1999) compared calculated BMR with a measured BMR (indirect calorimetry) and found that multiple variables improved the calculated BMR slightly, but they also reported that the more variables, the greater the risk of error in the calculation of the BMR. Furthermore, the slight improvement in BMR was only seen in pre-menarche girls and 11 year old boys. The main finding was that weight was the most important variable in a BMR equation in both genders (FAO, 1985, Henry et al., 1999). Only two of the six BMR equations tested in each gender group were appropriate as indicated by agreement for the present population even though high PCCs were obtained between all the different BMR equations across both gender groups. The PCC, however, only identifies how well two variables correlate with each other and not the agreement between variables. This implies that another statistical analysis such as the Bland-Altman plots needs to be performed to explore the extent of agreement. The Bland-Altman plots indicated proportional bias between different estimated mean BMRs (calculated using different BMR equations) except for two estimated BMRs (calculated from two different BMR equations) across each gender. These two BMR equations in both gender groups exhibited minimal proportional bias for the present population.

Validity and reproducibility of energy intake as reported during multiple 24-hour recalls by peri-urban South African adolescents

Twenty-four hour recalls are easily administered, can accommodate participants of low literacy level, are inexpensive and offer a low respondent burden and a good response rate (Deakin, 2006, Goodwin et al., 2001). These benefits make the 24-hour recall a high-quality

DA tool for peri-urban South-African adolescents. However, without proven validity of EI these benefits are of no value and the disadvantages of 24-hour recalls such as interviewer bias come more to light.

In this present study no validity for EI derived from multiple 24-hour recalls was found. Thus dietary intakes derived from multiple 24-hour recalls spread over one or two years need to be interpreted with caution in this present population group. These results contradict those of other studies (Crawford et al., 1994; McPherson et al., 2000; Andersen et al., 2004; Potischman et al., 2006). Lytle and colleagues (1993) found results similar to the present study; however, their validity test was performed on children from grade three. They also stated that the validity for the 24-hour recall would improve with brain development towards adolescence. Other studies (Johnson et al., 1996; Jonnalagadda et al., 2000) found that using multiple pass 24-hour recall techniques might improve overall validity. The statistical analyses of the studies of Lytle et al. (1993), Crawford et al. (1994) and Andersen et al. (2004) did not include the Bland-Altman test and only used correlation coefficients and dependent t-tests. This omission could have resulted in an overestimation of validity. If two DA tools measure similar variables, such as EE_{est} and EI_{rep}, the Pearson and Spearman correlation coefficients are not sufficient to prove validity because the correlation coefficients only measures association between the two variables that are tested. The Bland-Altman plots are more trustworthy because they measure the extent of the difference between the two variables and leave the interpretation to the researchers (Nelson, 1997). However, the Bland-Altman plots cannot be used if there is a poor correlation between the two variables (Field, 2005). If there is a good correlation between the two variables, however, Bland-Altman plots need to be performed to claim validity. Therefore, validity results that were not measured by the Bland-Altman plots should be used with caution.

In the present study the dependent t-test showed little evidence that the average EI:EE_{est} of 24-hour recall questionnaires changed statistically significantly for peri-urban black adolescents over five DAs over two years. However, the results of the reproducibility of the multiple 24-hour recalls showed a larger *within participant variation* and a smaller *between participant variation.* This explains the results of the dependent t-test: the high variation within EI reporting per person from one measurement to another over all the participants led to the inability to detect significant differences over different recalls. This suggests that the reproducibility of the multiple 24-hour recalls in the present study over a two year period was poor. The reason for such low reproducibility could have been influenced by one of the most difficult obstacles to overcome in DAs with multiple 24-hour recalls, the longer the study the higher the dropout rate. Thus, one starts with a large sample but ends with a small sample of participants who attended all of the required DA measurements. This tendency was found in the present study where only an average of 2.77 24-hour recalls for boys and 2.52 for girls could be used over the two year period to test for reproducibility. The study performed by Rankin and colleagues (submitted to the European Journal of Clinical Nutrition) showed that at least four 24-hour recalls are necessary for acceptable reproducibility.

The reasons why multiple 24-hour recalls might not have been valid in the present study include the following:

A single 24-hour recall cannot represent the actual dietary intake over several (two to three and a half) months, which is the reality when five single 24-hour recalls are used to assess the dietary intake of adolescents over two years. Furthermore, adolescents change their eating habits continuously which could have contributed to the high *within participant coefficients* of variation.

From the results statistically significant differences in mean EI:EE_{est} occurred only between June 2005 and March of both 2004 and 2005. Differences between the mean EI:EE_{est} of the various seasons did not form a pattern, as one would think that the food intakes of adolescents would be higher at the DA measurements during the Winter and Autumn months and lower during the Spring months. However, the results showed that the adolescents had a significant lower EI at the DA measurement during Winter than Autumn months. The EI in Spring were also visibly, but not significantly, higher than EI in Winter months. A reason for this could be, because of their low-socio economic status, the household income during the various months would probably be similar, but during Winter money would be used to buy products such as anthracite or paraffin for heating, resulting in less money being available for food. Thus seasonal variation did not seem to play a major role in the low validity as expected, but rather contributed to the difference of EI over the year. Other reasons could play a role specifically in the difference of EI over the different seasons, such as the availability of the foods the adolescents buy from the vendors at school. The vendors could have been less active during Winter months.

From the literature, it is accepted that one 24-hour recall does not offer a true reflection of actual dietary intake. Even though the present study administered five 24-hour recalls over two years (March, September 2004 and March, June, September 2005), in reality only one 24-hour recall was administered over two and a half to six months periods. Even with the administration of a single 24-hour recall to represent only one month, the single 24-hour recall would not be able to reflect the adolescent's eating habits of that month. The results of the present study also showed that the EI derived from the single 24-hour recall at baseline had a similar poor validity to the EI derived from five 24-hour recalls over two-years or from four 24-hour recalls over one-year. Thus, one could say that the time period in which the multiple 24-hour recalls are administered needs to be narrowed down. Interpretation of dietary intake derived from multiple 24-hour recalls should be done with caution, until an appropriate time frame has been identified.

A last reason which could have contributed to the poor validity of the EI is that the results from the PDPAR questionnaire, which was not tested for validity, could have been inaccurate and could have introduced bias into the PAL categories. This could have resulted in an incorrect PAF that is, the BMR could have been under or overestimated.

Cut-off points of energy intake as evidenced from multiple 24-hour recalls of peri-urban South African adolescents

Reports in the literature suggest that EI:EE CPs can be used to evaluate data to identify possible under and overreporting. However, these CPs need to be group-specific and must be calculated consistent with each participant's PAL (Black, 2000). The majority of the participants in this study group had a high PAL. The EI_{rep}:$m$$EE_{est}$ of each participant was compared with specific calculated CPs. The high percentage of underreporting is an indication of the poor validity of EI derived from the 24-hour recalls. Because more than 85% of all participants were classified as underreporters, one could not identify any relationships between EI and BMI, age or gender. Baxter and colleagues (2006) also found no relationship between reported EI and BMI or age, but they found a correlation between under- and overreporting and gender. Furthermore, Lytle et al. (1993), Jonnalagadda (2000) and Kruger et al. (2006) found non-significant differences between the EI and EE (normal reporting of EI) in peri-urban black overweight/obese adolescents and children. The reasons for the underreporting of EI could be due to the adolescents reporting their dietary intake inaccurately. Alternatively, the PAF equations used may have overestimated the activity level or the reporting of the PDPAR questionnaires of the adolescents could have been invalid. A study by Mukuddem-Petersen and Kruger (2004) found a larger number of stunted children in peri-urban areas than in urban areas. When children were chronically malnourished, their BMR declined, causing a hormonal response change during adolescence and resulting in increased fat accumulation. This present population group may have a similar hormonal response since a quarter of the adolescent were classified as stunted and 45% had a height between the third and the 25th percentile for height for age. Furthermore the majority of the girls had fat percentages which lay in the ranges which classified them as obese while the majority of the boys could be classified as overweight. These recommendations of Taylor and colleagues (2002) were identified by predicted body fat percentages which were associated with BMI cut-offs where the body fat percentage for overweight adolescents ranges from 18% to 23% in boys and from 20% to 34% in girls and obese adolescents ranges from 24% to 36% in boys and 26-46% in girls. However, these classifications need to be interpreted with caution, because these body fat recommendations were identified in white adolescents. These results therefore suggest that fat accumulation might have increased due to hormonal changes, which could have increased the estimated EE (which is primarily weight dependent) and caused the difference in agreement as well as the underreporting.

When investigating dietary intake of peri-urban black adolescents in developing countries using the 24-hour recall questionnaire, the authors would recommend taking at least **four** 24-hour recalls per data sampling period. Future studies should further explore the validity of four 24-hour recalls per data sampling period by using a calorimeter or DLW as reference for EE. Additionally, analysing blood samples for vitamin B_{12} or folate, or urinary nitrogen excretion per participant at each data sampling measurement can aid in validating the 24-hour recall questionnaire. Further studies need to focus on the time frame between the multiple 24-hour recalls

Conclusion

Since the multiple 24-hour recalls were collected as a single 24-hour recall over several months, omission or intrusion in the EI_{rep} may have occurred because the single 24-hour recalls might have not be able to capture changes in sociological and eating habits over the different months. Therefore, the EI derived from the multiple 24-hour recalls over two or one year was not valid. Thus the study underlines the importance of validating the 24-hour recall methodology for black African adolescents before using it as a DA tool in a large epidemiological study. Finally, the study also showed that high correlation coefficients are not sufficient to show agreement between two different measurements on the same participants, but Bland-Altman plots need to be analysed additionally to determine the limits of agreement.

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THE REFERENCE STYLE OF CHAPTER 5 IS WRITTEN ACCORDING TO THE HARVARD STYLE WHICH IS THE STANDARD OF THE NORTH-WEST UNIVERSITY.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Conclusion

The general view on adolescence and nutrition is that once puberty starts, this group is at risk of inadequate dietary intake due to high nutritional requirements caused by rapid growth and physical development (Spears, 2000). Inadequate dietary intake could potentially lead to non-communicable chronic diseases, obesity and cancer later in adulthood (Stanner, 2004). In order to identify the dietary deficits that increase these risks, accurate dietary assessment methods need to be identified. Because dietary assessment tools that measure adolescents' dietary intake are challenged by changes in their dietary habits, increased self-consciousness about their body-image and boredom regarding unnecessary questions, it is of utmost importance to find a reproducible and valid dietary assessment method specifically for adolescents.

International studies indicated that energy intake of adolescents measured by estimated or weighed food records, underestimated their actual energy intake by more than 18%. Food frequency questionnaires overestimated adolescents' energy intake by at least 16% compared to food records. Furthermore, the food frequency questionnaires overestimated energy intake by more than 24% compared to energy intake measured by 24-hour recalls. Energy intake measured by 24-hour recalls was underestimated by less than 11% compared to an observational intake method. Finally, energy intake by 24-hour recalls was underestimated by less than 4% compared to the current golden standard reference measurement for energy expenditure; the doubly labeled water method.

In South Africa, studies done on a randomised sample of the North West Province black population showed a poor validity for dietary intake measurement using a quantitative food frequency questionnaire (QFFQ) and good validity for dietary intake measurements using 24-hour recalls. When energy intake measured by QFFQ was compared with estimated energy expenditure, 43% of the participants underreported. Additionally, when energy intake measured by QFFQ was compared with energy intake measured by weighed-food records, 28% of the participants underreported (MacIntyre *et al.*, 2000). Kruger and colleagues

(2006) reported the 24-hour recall measurements for energy, macronutrients and most of the micronutrients in children (10-15 years old) to be valid compared to a 3-day estimated-weight record. However, validity was only determined using the correlation coefficient and t-test methods, which does not give a clear picture of the truth.

The need for more detailed South African-based studies was underlined by the review article (Chapter 2) included in this thesis. Subsequently Chapters 3 and 4 of this thesis discussed the methodology of 24-hour recall dietary assessment methods in adolescents of the North West Province with the purpose of increasing the knowledge of researchers in South Africa regarding reproducibility and validity of dietary intake. Results from the study showed that for most nutrients and food groups, four 24-hour recalls had the highest reproducibility coefficients.

The mean energy intake assessed over a two-year period by one 24-hour recall measured on five occasions, lacks validity, when compared to estimated energy expenditure. A similar result was found when the dietary assessment period was reduced from two years to one year with four occasions. Further investigations on the reproducibility of 24-hour recalls over two years showed a high within participant variation. The high percentage of underreporting (85% of all participants) is an indication of the poor reproducibility and validity of multiple 24-hour recalls when used to assess the actual dietary intake of adolescents over a period of two years. Because the percentage of underreporting was so high, no relationships were found between energy intake and body mass index (BMI), age or gender. Finally, researchers are advised not to trust only correlation coefficients to show agreement between two different measurements on the same participants, but also to use the Bland-Altman plots to determine the limits of agreement.

Recommendations

For future research undertaken on the dietary intakes of peri-urban black adolescents in developing countries, it is recommended that at least **four** 24-hour recalls per dietary assessment occasion, with a short time interval between the four measurements, be used. It is further recommended that four sets of four repeated 24-hour recalls be used during a prospective study period of a year. Future studies should explore the validity of four 24-hour recalls per data sampling period by using biochemical determinants of nutritional intakes, a calorimeter or the doubly labeled water technique as reference for energy expenditure.

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APPENDIX A

INFORMED CONSENT FORM

THE PRPOJECT HAS BEEN APPROVED BY THE ETHICS COMMITTEE OF THE NORTH WEST UNIVERSITY (Potchefstroom Campus), project number 04M01

I CONFIRM THAT:
It has been explained to me, that:

1. The purpose of the research study is to collect information on growth and activity among Grade 8 schoolchildren in Boitshoko Secondary School, North West Province.
2. I have been told that the researchers will measure me. The participant will be weighed and his/her height as well as circumferences and skinfolds of his/her arm will be measured without causing any pain to the child. For those measurements boys and girls in separate groups will be asked to undress in the privacy of a class-room, because some measurements must be taken with the children dressed in underwear only, or a light shirt and pants/skirt. The researchers will also ask me to indicate my own level of physical maturation from pictures. The different age groups will be measured separately. The researchers and fieldworkers will work in a professional way, not to embarrass the children.
3. Fitness testing will be done and blood pressure will be tested.
4. The measurements will be done twice, in April and November, to assess growth.
5. The researchers will ask me about my home environment, the food that I usually eat and activities that I do. None of these questions will be to see if I am clever, or know correct answers. I can just tell them what I usually do.
6. Guidelines for appropriate, culture sensitive, practical and sustainable intervention programmes for children will be developed.
7. The information I will give shall be kept confidential, only to be used anonymously for making known the findings to other scientists.
8. It was also clearly explained to me that I can refuse to participate in this research study or I can stop answering the questions at any time during the interviews.

The information in this consent form was explained to me by Mrs Susan Legoete (interviewer) in________________(language) and I confirm that I have a good command in this language and understood the explanations, OR it was translated to me by_____________(Name of translator) in my language________________. I was also given the opportunity to ask questions on things I did not understand clearly.

I the participant (child) hereby agree voluntarily to take part in this research survey.

Signed/confirmed __________________ at_____________________on____________2004

Witness________________________

Representative of participant (parent/guardian)____________________________

APPENDIX B

DEMOGRAPHIC QUESTIONNAIRE

Subject number | | | |

1. Age in years

10 – 12		1
13 – 15		2
16 – 18		3
19 – 21		4
Above 22		5

2. Gender

Male		1
Female		2

3. Highest level of education

None		1
Primary, Gr 1 – 7		2
Secondary, Gr 8,9,10		3
Secondary, Gr 11 & 12		4

LANGUAGE

4. Home language of respondent

Tswana		1
English		2
Afrikaans		3
Other		4

5. Can you read and understand a letter or newspaper in your home language?

Easily		1
With difficulty		2
Not at all		3

CLINIC

6. Name of clinic...
7. How long does it take you to get to the clinic? .... minutes
8. How do you get to the clinic?

Taxi		1
Own car		2
Walk		3
Bicycle		4

9. If you are sick, what kind of health services do you use?Yes/NO

		Yes		No	
9.1	Traditional healer		1		2
9.2	Clinic		1		2
9.3	Hospital		1		2
9.4	Other, (spesify)				

HOUSING

10. What type of house do you live in?

Traditional hut		1
Mokuku		2
Brick house		3
Other (specify)		4

11. What is the main source of drinking water for members of your household? (Choose only one)

Own piped water (tap)		1
Piped water in yard		2
Public tap (share water)		3
Water carrier/tanker		4
Borehole/well		5
Dam/river/stream/spring		6
Rain-water tank		7
Other / Remarks:		8

12. How long does it take you to get the water and come back? .... minutes

13. What kind of toilet facility does your household have?

Flush toilet (own)		1
Flush toilet (share)		2
Bucket latrine		3
Pit latrine		4
No facility/Bush/Field		5
Other / Remarks:		6

14. What does your household use for cooking and heating? Record all mentioned.

		Yes		No	
14.1	Electricity		1		2
14.2	Gas		1		2
14.3	Paraffin		1		2
14.4	Wood		1		2
14.5	Coal		1		2
14.6	Animal dung		1		2
14.7	Other / Remarks:				

15. How many people are in your household .... people
16. How many rooms are in your household? .... rooms

17. How many rooms in your household are used for sleeping? .... rooms

18. Do you or someone in the household benefit from a feeding scheme?

Yes		1
No		2

19. If yes, how many of the people in this household belong to a feeding scheme?

.... people

20. Do you have a food garden? If answer is NO ask reason

Yes		1
No		2

Reason:

21. Would you say that the people here often, sometimes, seldom or never go hungry? Mark the answer.

Never		1
Seldom		2
Sometimes		3
Often		4

22. Does your household have one or more of the following:

		Yes		No	
23.1	Electricity		1		2
23.2	Radio		1		2
23.3	Television		1		2
23.4	Telephone (land-phone)		1		2
23.5	Cell-phone		1		2
23.6	Refrigerator		1		2
23.7	Washing machine		1		2
23.8	Personal computer		1		2

23. Does any member of your household own one or more of the following:

		Yes		No	
24.1	Car		1		2
24.2	Motorcycle		1		2
24.3	Bicycle		1		2
24.4	Donkey/horse		1		2
24.5	Sheep/cattle		1		2

POVERTY

24. What is the job description of the main breadwinner?

Professional		1
Own business		2
Services		3
Clerical		4
Artisan (trained)		5
Labourer		6
Unemployed		7
Housewife		8
Pensioner		9
Other: (spesify)		10

25. How far is the main breadwinner from his place of work

Not applicable		1
Less than one kilometre		2
One to three kilometres		3
More than three kilometres		4

26. What mode of transport are you using?

		Yes		No	
27.1	Taxi		1		2
27.2	Bus		1		2
27.3	Train		1		2
27.4	Bicycle		1		2
27.5	Car		1		2
27.6	Walk		1		2
27.7	Other (specify):				

28. Does anyone in the household receive any grant from social services?

Yes		1
No		2

29. If you answered yes, what kinds of grant?

		Yes		No	
29.1	Child grant		1		2
29.2	Disability grant		1		2
29.3	Foster care grant		1		2
29.4	Old age pension		1		2

30. What do you consider to be the causes of the family living in poverty?

		Yes		No	
30.1	High fertility rate		1		2
30.2	Low income		1		2
30.3	Lengthy unemployment		1		2
30.4	Low educational level		1		2
30.5	No job opportunities		1		2
30.6	Other (specify)				

31. What are the effects of poverty on you family?

		Yes		No	
31.1	Health effects		1		2
31.2	Malnutrition		1		2
31.3	Unhealthy accommodation		1		2
31.4	Family members driven to crime		1		2
31.5	Children tend to go to the streets		1		2
31.6	Excessive substance abuse		1		2
31.7	Family disorganisation		1		2
31.8	Low self-esteem		1		2
31.9	Limited educational opportunities for children		1		2
31.10	Suicide tendencies		1		2
31.11	Chronic depression		1		2
31.12	Other (specify):				

32. What is the total monthly household income? ....
(To the nearest R100)

33. How does your family survive if there is no income?

___

___

___

34. Do you have any idea of a project that you can start to generate extra income?

Yes		1
No		2

35. If yes, tell me more.

___

___

36. Have you tried anything before?

Yes		1
No		2

37. If yes, tell me more about it.

___

___

___

38. Tell me also about the problems you experience.

___

___

___

39. Do you think that a monthly income is security against poverty?

Yes		1
No		2

40. Explain

___

___

___

41. Do you share your accommodation with another family?

Yes		1
No		2

Other (Specify)	

42. How many people in your household have died in the past 12 months?................

43. If anyone died in your household, what was the cause of death? Yes/No

43.1	Pneumonia	Yes		No	
43.2	Cancer		1		2
43.3	AIDS		1		2
43.4	TB		1		2
43.5	Accident		1		2
43.6	Don't know		1		2
43.6	Other, specify				

SPIRITUAL NEEDS

44 Do you belong to a church?

Yes		1
No		2

45 If yes what is the name of your church?

Protestant		1
Catholic		2
Pentecostal		3
Zionist		4
Seventh Day Adventist		5
Other, specify		6

HABITS AND LIFE STYLES

46 Have you or any of the other members of your family smoked some of the following?

		Yes		No	
46.1	Cigarettes		1		2
46.2	Tobacco		1		2
46.3	Snuff		1		2
46.4	Chewing tobacco		1		2
46.5	Dagga		1		2

47 Does any person in the household drink alcohol?

Yes		1
No		2

48 Does any person in the household make beer?

Yes		1
No		2

49 If answered yes, how many bottles a week?

1		1
2		2
3		3
4		4
More		5

50 If answered yes, where do the persons in the household drink their alcohol? Yes/No

50.1	Own house	Yes		Ni		1
50.2	Shebeen		1		2	2
50.3	Club		1		2	3
50.4	Friend's house		1		2	4

51 Do anyone in the household do exercise?

Yes		1
No		2

52 If answered yes, what exercise?

		Yes		No	
52.1	Jogging		1		2
52.2	Cycling		1		2
52.3	Walking		1		2
52.4	Other, specify				

53 Do anyone in the household participate in any sport activities?

Yes		1
No		2

54 If yes, in which of the following?

		Yes		No		
		Yes		No		1
54.1	Netball		1		2	
54.2	Hockey		1		2	2
54.3	Rugby		1		2	3
54.4	Soccer		1		2	4
54.5	Cricket		1		2	5
54.6	Tennis		1		2	6
54.7	Volleyball		1		2	7

INTERVIEWERS OBSERVATIONS
Comments about the respondents
Comments on specific questions

APPENDIX C

24-HOUR RECALL QUESTIONNAIRE

Subject number: ________ Interviewer: ____________________

Creche: ____ Date: ____/ _____/ 200___

Tick what the day was yesterday:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday

Would you describe the food that you ate yesterday as typical of your habitual food intake?

Yes	1	No	2

I want to find out about everything you ate or drank yesterday, including water or food you pick from the veld. Please tell me everything you ate from the time you woke up to the time you went to sleep. I will also ask you where you ate the food and how much you ate.

Time (approximately)	Place (Home, school, etc)	Description of food and preparation method	Amount	Amount in g (office use only)	Code (office use only)
From waking up to going to school, or starting day's activities					

During the morning at school					
Time (approximately)	Place (Home, school, etc)	Description of food and preparation method	Amount	Amount in g (office use only)	Code (office use only)
Middle of the day (Lunch time)					
During the afternoon					

At night (dinner time)					
After dinner, before going to sleep					
Do you take any vitamins (tablets or syrup)?			Yes 1		No 2
Give the brand name and dose of the vitamin/tonic:					

APPENDIX D

ANTHROPOMETRIC MEASUREMENT CHART

Naam en van: ______________________ Geslag: ______________________

DOB: _____/____/_____ Toetsdatum: ___/___/2006 Ouderdom: ______

Proef persoon nr.: _______

			Meting 1	Meting 2	Meting 3/Gem.
1	Massa	kg			
2	Lengte	cm			
3	Armspan	cm			
4	Sittende lengte	cm			
Omtrekke					
5	Bo-arm ontspanne	cm			
6	Maagomtrek	cm			
7	Kuitomtrek	cm			
Velvoue:					
8	Triseps	mm			
9	Subskapulêr	mm			
10	Kuit	mm			
11	Supraspinaal	mm			
12	Abdominaal	mm			

APPENDIX E

PDPAR QUESTIONNAIRE OF PREVIOUS WEEK

Physical activity questionnaire of the previous week day

Subject nr

Name:

Race: 1 W | 2 B | 3 C | 4 I

Age: | Date of birth

Gender: M | F

Grade:

School:

Teacher:

Date: d | d | m | m | y | y

Classification:

Think back about yesterday. For each of the 30 minutes periods, select a primary activity that you performed and write the type of activity in the type of activity column.

Mark the day of the week that you fill in this form

Monday	Tuesday	Wed	Thursday	Friday

Time	TIPE	Activity	METS	Very light	Light	Med-ium	Hard
7:00			•				
7:30			•				
8:00			•				
8:30			•				
9:00			•				
9:30			•				
10:00			•				
10:30			•				
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19:30			•				
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20:30			•				
21:00			•				
21:30			•				
22:00							

Bale Lig | Lig | Medium | Straf

APPENDIX F

PDPAR QUESTIONNAIRE OF PREVIOUS WEEKEND

Physical activity questionnaire of the previous weekend day

Subject no: ____ ____ ____ ____

Name:

Race: 1 W | 2 B | 3 C | 4 I

Age: ____ ____ Date of birth ____

Gender: M | V

Grade: ____ ____

School:

Teacher:

Date: d d m m y y

Classification:

Think back about the weekend. For each of the 30 minutes periods, select a primary activity that you performed and write the type of activity in the type of activity column.

Mark the day of the weekend that you fill in this form

Saterday	Sunday

Time	TIPE			Activity	METS				Very light	Light	Med-ium	Hard
7:00							•					
7:30							•					
8:00							•					
8:30							•					
9:00							•					
9:30							•					
10:00							•					
10:30							•					
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19:30							•					
20:00							•					
20:30							•					
21:00							•					
21:30							•					
22:00							•					

Bale Lig Lig Medium Straf