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The characteristics of underreporting women in the POWIRS II study

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List of abbreviations

ACSM	American College of Sports Medicine
ANCOVA	analysis of covariance
BMI	body mass index
BMR	basal metabolic rate
BP	blood pressure
cm	centimetre
DRIs	dietary reference intakes
EE	energy expenditure
EI	energy intake
fat %	fat percentage
FIL	food intake level
FPPB	food portion photograph book
g	gram
Hip c	hip circumference
IDF	International Diabetes Federation
kg	kilogram
kg/m^2	kilogram per square metre
kJ	kilojoules
m	metre
m^2	metre squared
MJ	megajoules
mg	milligram
Non-URs	non-underreporters
NS	not significant
PAI	physical activity index
PAL	physical activity level
POWIRS	Profiles of Obese Women Suffering from the Insulin Resistance Syndrome
QFFQ	quantitative food frequency questionnaire
TEE	total energy expenditure
TG	triglycerides
THUSA	Transition, Health and Urbanisation in South Africa
TSR	Tukey's studentized range test
URs	underreporters

WHO	World Health Organization
WHR	waist-to-hip ratio
YPAS questionnaire	Yale Physical Activity Survey questionnaire
µg	microgram

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Summary (English)

It is now widely recognized that reported energy intakes in dietary surveys underestimate usual energy intake (Black *et al.,* 1993). During this study specific subject characteristics contributing to underreporting and the possible association between the metabolic syndrome and underreporting were investigated.

A multi-disciplinary cross-sectional case-control study was carried out with 115 apparently healthy Caucasian women. The POWIRS II (Profiles of Obese Women Suffering from the Insulin Resistance Syndrome) study was performed in the Metabolic Unit of the North-West University, Potchefstroom, South Africa. Here, dietary intake was measured using the quantitative food frequency questionnaire (QFFQ). The ratio of energy intake (EI) to basal metabolic rate (BMR) was calculated from the reported EI and BMR estimated using equations. Underreporters (URs) were identified using the Goldberg equation, which compares EI with energy expenditure (EE), both expressed as multiples of the BMR. URs had reported EI <1.27 x BMR, non-URs ≥1.27 x BMR. Total energy expenditure (TEE) was calculated (n=115) and measured in a subgroup (n=63) by using the Actical accelerometer. Physical activity was also divided into three groups by using the Yale physical activity questionnaire.

Most of the women were overweight (45.8%) and 29.2% were obese but only 20 subjects presented with the metabolic syndrome. The prevalence of underreporting women with a food intake level (FIL; reported EI divided by estimated BMR) below 1.27 was relatively low (21%). Overreporting (FIL >2.4) was also low (6.7%). The prevalence of metabolic syndrome did not differ between URs and non-URs (12.5% and 18.7%, respectively). Most subjects were younger than 35 years (mean=33.2), highly educated and received a high monthly income. The subjects fell mostly into the low activity category. URs had a statistically significantly ($p<0.05$) higher percentage EI from fat but lower from carbohydrates (37.4% and 42.9%, respectively) when compared to non-URs (33.5% and 47%; respectively). The mean intakes of most micronutrients were statistically significantly lower in the URs. However, expressed per energy unit, intakes of URs were significantly higher for potassium, selenium and vitamin E. When the food group intakes of URs and non-URs were compared no significant differences were found. Measured TEE was significantly higher ($p<0.01$) in URs and non-URs (13 036kJ and 13 805kJ; respectively) compared to calculated TEE (10 105.8kJ and 10 220.3kJ; respectively). Measured TEE was also significantly higher than reported EI ($p<0.01$). No specific subject characteristics were related to

underreporting. Considering the low reported EI compared to the measured TEE, the cut off values to identify URs might have been too low.

Opsomming (Afrikaans)

Onderskatting van daaglikse energie inname word oral herken in dieetopnames (Black *et al.*, 1993). Gedurende hierdie studie is daar gekyk na spesifieke karakteristieke wat tot onderrapportering kan lei, asook of daar 'n assosiasie is tussen die metaboliese sindroom en onderrapportering.

'n Multidissiplinêre dwarsdeursnit geval-kontrole studie was uitgevoer met 115 skynbaar gesonde wit vroue. Die POWIRS II (Profiles of Obese Women Suffering from the Insulin Resistance Syndrome) studie was in die metaboliese eenheid van die Noord-Wes Universiteit, Potchefstroom, Suid Afrika, uitgevoer. Die kwantitatiewe voedselfrekwensievraelys was gebruik om dieet-inname te bepaal. Die verhouding tussen energie-inname (EI) en basaal metaboliesespoed (BMS) was bereken vanuit die gerapporteerde EI en BMS geskat met behulp van vergelykings. Onderrapporteerders (ORs) was deur middel van die Goldberg-vergelyking geïdentifiseer, waar EI met energie verbruik (EV) vergelyk word. Albei word uitgedruk in terme van veelvoude van die BMS. ORs was geïdentifiseer as gerapporteerde EI <1.27 x BMS, nie-ORs ≥1.27 x BMS. Totale energie verbruik (TEV) was bereken in 115 proefpersone en fisies gemeet in 'n sub-groep (n=63) met behulp van die Actical aktiwiteitsmeter. Fisiese aktiwiteit was gedeel in drie groepe deur die gebruik van die Yale fisiese aktiwiteitsvraelys.

Meeste van die vroue was oorgewig (45.8%) en 29.2% was vetsugtig maar die metaboliese sindroom het in slegs 20 proefpersone voorgekom. Onderrapportering in vroue met 'n voedselinname vlak (VIV; voorgestel deur EI te deel deur geskatte BMS) laer as 1.27, was relatief laag (21%). Oorrapportering (VIV >2.4) was ook laag (6.7%). Die voorkoms van die metaboliese sindroom het ook nie verskil tussen ORs en nie-ORs nie (12.5% en 18.7% respektiewelik). Die meerderheid van proefpersone was jonger as 35 jaar oud (gemiddeld=33.2), het 'n hoë opvoedingspeil gehad en het 'n hoë maandelikse inkomste ontvang. Die aktiwiteitsvlak van die meeste proefpersone was laag. EI was statisties betekenisvol ($p<0.05$) hoër vanaf vet, maar laer vanaf koolhidrate met die ORs (37.4% en 42.9%, respektiewelik) in vergelyking met die nie-ORs (33.5% en 47%, respektiewelik). Die gemiddelde inname van die meeste mikronutriënte was statisties betekenisvol laer in die ORs in vergelyking met die nie-ORs. Nogtans was gevind dat die innames van kalium, selenium en vitamien E in ORs statisties betekenisvol hoër was indien uitgedruk per energie eenheid. Geen statisties betekenisvolle verskil was gevind indien die voedselgroepinnames van ORs en nie-ORs vergelyk is nie. Die TEV (gemeet) was betekenisvol hoër in die ORs en nie-ORs (13 036kJ en 13 805kJ; respektiewelik) teenoor die berekende TEV (10 105.8kJ en 10 220.3kJ; respektiewelik). TEV (gemeet) was ook betekenisvol hoër as die

gerapporteerde EI ($p<0.01$). Geen verband kon gevind word tussen spesifieke karakteristieke en onderrapportering nie. Indien die lae gerapporteerde EI met TEV (gemeet) in ag geneem is, was die afsnypunte om ORs mee te identifiseer moontlik te laag.

CHAPTER 1: Introduction

1.1. Background

Data from national surveys are necessary for the evaluation of a wide array of public food and health programmes and policies, as well as for nutrition research. Thus, this dietary data are necessary to ensure the public's health, safety and well-being (Conway *et al.,* 2004). Consequently, accurate estimates of dietary intake are important in interpreting the effects of dietary interventions on dietary behaviours and treatment outcomes (Samuel-Hodge *et al.*, 2004). According to the previous statement, it can be said that the reported energy intakes of weight-stable subjects (in other words those in energy balance) could in principle be used to predict energy requirements for weight maintenance. However, it is now widely recognized that reported energy intakes in dietary surveys underestimate usual energy intake (Black *et al.,* 1993). Many nutritional studies are dependant on reliable estimates of food consumption in free-living people and responsible investigators make great efforts to validate their dietary assessment techniques (Goldberg *et al.*, 1991).

Epidemiological studies of diet and disease rely on the accurate determination of dietary intake and subsequent estimates of nutrient exposure (Trabulsi & Schoeller, 2001). Assessments of dietary intake are generally obtained by self-report, therefore they are prone to a number of reporting biases which may lead to misrepresentation of actual intake and compromise the validity of the data (Samuel-Hodge *et al.*, 2004). Furthermore, even though methodically developed and tested, the instruments most often used to collect self-reported intake data are subject to error (Trabulsi & Schoeller, 2001). Several dietary assessment methods have been developed, validated and used in dietary surveys. However, any method used to assess self-reported dietary intake is not entirely able to avoid reporting errors (Okubo & Sasaki, 2004). Most dietary surveys may include not only random errors but also systematic errors, such as the misreporting of true intake by certain subject groups (Okubo & Sasaki, 2004).

A large body of literature documents the underreporting of food intake, which can range from ten to 45 percent depending on the age, gender and body composition of the sample (Johnson, 2000). Studies found that underreporting is more prevalent in individuals with infrequent symptoms of hunger (Bathalon *et al.,* 2000). It seems that as children grow older, underreporting also tends to increase (Livingstone *et al.,* 1992). Women tend to underreport more often than men (Hirvonen *et al.,* 1997). It seems that ethnic differences affecting sensitivities and psychological perceptions relating to eating and body weight can also affect the accuracy of reported food intakes (Tomoyasu *et al.,* 2000b). Low socio-economic status, characterized by low income, low educational level and low literacy levels increase the tendency to underreport energy intakes (Briefel *et al.,* 1997; Johnson *et al.,* 1998; Price *et al.,* 1997; Pryer *et al.,* 1997). The effect of excluding underreporters should be examined whenever population means and distributions of nutrient intake are shown and the results are being interpreted (Hirvonen *et al.*, 1997). The reason for this is because underreporting could cause significant bias in nutrient intakes (Hirvonen *et al.*, 1997).

Studies in developing countries are increasingly exploring dietary factors that may explain the rising levels of obesity and related chronic diseases. At present, little is known about the prevalence and patterns of dietary misreporting in developing countries and how inaccurate reporting may influence these analyses (Mendez *et al.,* 2004).

1.2. Problem statement

Self-reported intake is frequently used in dietary intervention studies to estimate compliance with the intervention and to determine dietary differences between intervention and control groups. When self-reported energy intake (EI) is compared with energy expenditure (for example measured using doubly labelled water) and the self-reported EI is consistently lower than energy expenditure, a phenomenon arises that is known as underreporting or low energy reporting (Caan *et al.,* 2004). Studies have shown that underreporting is a large problem and might distort dietary studies (Ballard-Barbash *et al.,* 1996; Black *et al.,* 1991; Pryer *et al.,* 1995; Smith *et al.,* 1994).

This underreporting may result from several factors such as: difficulty in reporting or remembering food composition and portion size; changing eating habits or reported consumption to simplify reporting; to be socially more desirable or comply with a prescribed protocol; not reporting on days with high consumption (for example on weekends) or low consumption (for example when dieting) (Goris & Westerterp, 1999; Goris *et al.,* 2000; Tran *et al.,* 2000). Other possible factors may be erroneous package labelling on locally produced foods or not reporting complicated foods (mixed dishes) (Vuckovic *et al.,* 2000) or small items (bites) (Caan *et al.,* 2004). Other factors also play a role. These factors are explored in this study.

1.3. Objectives

The aim of the study is to determine which characteristics contribute to participants' underreporting food intake. The specific objectives of the study are as follows:

- to determine whether underreporting exists specifically in a group of Caucasian South African women;
- to investigate which characteristics contribute to South African Caucasian women to underreport;
- to determine whether specific food groups, macro- or micronutrients are underreported by subjects;
- to determine whether there is any relationship between the metabolic syndrome and underreporting;
- to determine whether overweight subjects underreport more than normal weight subjects; and
- to determine whether energy expenditure calculated correlates with energy expenditure measured.

1.4. Structure of mini-dissertation

This mini-dissertation is presented in article format. Following this introductory chapter, Chapter 2 gives a summary of energy intake and expenditure assessment instruments. Chapter 3 provides a detailed description of published associations among psychosocial and behavioural characteristics and energy misreporting. Chapter 4 consists of a manuscript on the characteristics of underreporting women in the POWIRS II study (prepared for submission to the Public Health Nutrition journal). In Chapter 5 a general discussion and summary of the results are provided, conclusions are drawn and recommendations made. The relevant references at the end of Chapter 4 are presented according to the editors' instructions of the specific journal for which the manuscript was prepared. However, the relevant references of all the other chapters are provided after Chapter 5 in the style prescribed by the North-West University.

1.5. Authors' contributions

The study reported in this mini-dissertation was planned and executed by a team of researchers. The contribution of each of the researchers is highlighted below. Also included in this section is a statement of the co-authors confirming their individual roles in the study and their permission that the article may form part of this mini-dissertation.

The contribution of each of the researchers involved in this study is given in the following table:

Name	Role in the study
Mrs. K. Raubenheimer B.Sc. (Dietician)	Responsible for literature searches, statistical analysis, interpretation of results. Also responsible for administration of the food frequency questionnaires and determining the dietary intakes of the subjects. Some of the questionnaires were done during the evening and some of them during the morning hours. Where necessary, the food frequency questionnaires had to be repeated by the writer.
Prof. CS Venter Ph.D. (Head of Department)	Supervisor. Supervised the writing of the manuscript, interpretation of statistical results. Assisted with the collection of data in the form of food frequency questionnaires.
Dr. HH Wright Ph.D. (Dietician)	Co-supervisor. Supervised the writing of the manuscript. Assisted with the collection of data in the form of food frequency questionnaires.

The following is a statement from the co-authors confirming their individual roles in the study and giving their permission that the article may form part of this mini-dissertation.

I declare that I have approved the above-mentioned article, that my role in the study, 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 M.Sc mini-dissertation of Karlien Raubenheimer.

Prof. CS Venter

Dr. HH Wright

CHAPTER 2: Assessment of energy intake and expenditure

2.1. Introduction

How much one eats and drinks is quantified predominately by self-reported intake using dietary assessment instruments such as diet records, food frequency questionnaires (FFQs), 24-hour recalls and diet histories (Maurer *et al.,* 2006). As stated earlier, the instruments most often used to collect self-reported intake data are subject to error. It had been assumed that this error was only random in nature, however, an increasing body of literature suggests that systematic error in the reporting of true dietary intake exists (Trabulsi & Schoeller, 2001).

In large population studies the most common instruments employed to assess dietary intake at the individual level include food diaries or records, repeated 24-hour recalls, diet history and FFQ. These can crudely be separated into two categories, namely prospective and retrospective methods. In addition, the techniques can be classified on the basis of the degree of quantitative detail that is provided (Trabulsi & Schoeller, 2001).

The 24-hour recall, diet history and FFQ are examples of retrospective dietary assessments. These methodologies rely on the memory of the participant to recall diets eaten in the past. The food record or diary is an example of a prospective, quantitative method (Trabulsi & Schoeller, 2001).

Random error, such as writing mistakes or processing variations, attenuates true associations between diet and disease resulting in the generation of false-negative conclusions. Self-reported dietary intake may also be subject to systematic error (Trabulsi & Schoeller, 2001). A systematic error such as the underreporting of true intake by certain population groups, could bias nutrient intake estimates and result in misleading conclusions with regard to diet and disease (Wacholder, 1995). This can also cause over or underreporting errors. On the other hand, prospective methodologies, such as the food diary are believed to be subject to reporting bias because the act of recording intake is thought to influence the respondent's usual food choices and alter their intake during the recording period (Trabulsi & Schoeller, 2001). Some studies (Goris *et al.,* 2000; Platte *et al., 1995;* Prentice *et al.,* 1986) have reported a loss of body weight in subjects during the record-keeping period, thus highlighting a potential weakness of this methodology for defining usual or habitual intake. Retrospective methodologies are generally thought to be free of this type of bias but are subject to random error due to poor recollection of past diet as well as systematic error due to the underreporting of true intake (Trabulsi & Schoeller, 2001).

Also, food portion sizes have also been shown to be misreported. It has been speculated that individuals may systematically underreport large food portions (Harnack *et al.,* 2004). Greater difficulty in reporting large food portions has been hypothesized to be attributable to a disparity between the size of the food portion estimation visual aids commonly used to assist individuals in reporting food portions and the actual portion consumed (customary portion). Food portion estimation visual aids commonly used to assist individuals in reporting food amounts consumed are sized to represent servings defined for the purpose of dietary guidance. Portions customarily consumed are often notably larger (Harnack *et al.,* 2004). These researchers also found that the persistent underreporting of food items such as French fries, may reflect the inherent difficulty people have in reporting intake of amorphous food items (Harnack *et al.,* 2004).

In a study by Black *et al.* (1991), the validity of reported energy intake was examined by using 37 published dietary studies. They found that 24-hour recalls tend to give lower intakes than other methods and that, although comparisons between diet records and diet history are less consistent, the diet history tends to give higher intakes than the diet records (Black *et al.,* 1991).

2.2. Energy intake

It should be noted that the accuracy of dietary intake assessment instruments, in the true analytic sense, has rarely been established. This is because there are few criterion methods against which self-reported intake can be validated. Validation has involved comparison of the new assessment instrument against another more established self-reported method. As such, it is actually the relative validity of the new instrument that is being tested. This type of validation will fail to detect true reporting bias if both the new and established instruments have correlated error. Alternatively, the new instrument can be validated against an external criterion such as a biomarker. The doubly labelled water (DLW) technique is an example of a biomarker that can be used to validate self-reported energy intake. The error of the DLW technique is independent of self-reported intake error, thus allowing true reporting bias to be detected (Trabulsi & Schoeller, 2001).

Bathalon *et al.* (2000) compared different dietary intake methods. They found that when the nutrient intakes derived from three 24-hour dietary recalls and a FFQ are compared, the FFQ showed the largest magnitude of underreporting (Bathalon *et al.* 2000). Trabulsi and Schoeller

(2001) found that longer periods of dietary record keeping have an effect on the accuracy thereof. It is imperative that researchers incorporate strategies into their methodology to improve the accuracy of self-reporting of energy intake and reduce the influence of social desirability (Maurer *et al.*, 2006).

2.2.1. Food frequency questionnaire (FFQ)

The FFQ is designed to capture the respondents' usual intake (Freedman *et al.*, 2004). The FFQ requires that the respondent report the frequency of consumption of foods from a list of foods over a specific time period. A strength of the FFQ is its ability to capture the intake of infrequently consumed nutrients that are ingested with a high degree of intra-individual variability (Trabulsi & Schoeller, 2001). In a cross-sectional study by MacIntyre *et al.* (2000), the validity of the quantitative food frequency questionnaire (QFFQ) which was developed for the THUSA study in the North-West Province of South Africa was validated by a seven day weighed food record and biomarkers. It was determined that the QFFQ appeared to measure the intake of staple and frequently consumed foods satisfactorily in that particular population (MacIntyre *et al.*, 2000).

2.2.2. 24-hour recall

The 24-hour recall method requires that the respondent report to an interviewer all foods and beverages and amounts consumed in the previous 24-hour period (Trabulsi & Schoeller, 2001). The 24-hour dietary recall is an instrument that only captures intake a day at a time (Freedman *et al.*, 2004). Typically, data from several 24-hour recalls conducted on both weekdays and weekends are averaged together. The strength of the 24-hour recall is its ability to collect detailed, qualitative information about foods consumed (Trabulsi & Schoeller, 2001).

2.2.3. Five-step multiple-pass method

Since 1894 the United States Department of Agriculture (USDA) has conducted food intake surveys in Americans. The USDA has conducted national food consumption surveys for nearly a century and it has also maintained a research programme in dietary assessment methodology. The most recent product is a standardized dietary instrument for collecting 24-hour dietary recalls called the USDA automated multiple-pass method, a five-step multiple-pass 24-hour dietary recall method (Conway *et al.*, 2004).

The USDA multiple-pass 24-hour recall method consists of these five steps: (1) the quick list, which is an uninterrupted listing by the subject of foods and beverages consumed, (2) the forgotten food list, which queries the subject on categories of foods that have been documented as frequently forgotten, (3) a time and occasion at which foods were consumed, (4) the detail cycle, which elicits descriptions of foods and amounts eaten aided by the interactive use of the USDA food model booklet and measuring guides and finally (5) the **final probe review**.

In a study conducted in a population of children, Johnson *et al.* (1996) compared energy intake estimates based on a multiple-pass method with energy expenditure measurements from DLW and found that this multiple-pass method provided valid group estimates of energy intake. Johnson *et al.* (1996) reported that the multiple-pass method was accurate in assessing group energy but not individual energy intakes. Conway *et al.* (2003) found that 49 women recalled food intake within ten percent of actual intake by using the USDA five-step multiple-pass 24-hour dietary recall method. Conway *et al.* (2003) concluded that under controlled conditions, the USDA five-step multiple-pass method is a practical method for estimating the energy intake of groups.

2.2.4. Diet history

The diet history method inquires about the frequency with which various foods are consumed and also gathers information about the typical content of meals. One of the strengths of the diet history is its detailed assessment of usual meal pattern in addition to the frequency of consumption data collected (Trabulsi & Schoeller, 2001).

2.2.5. Food record or diary

The respondent is required to record all foods and beverages and the amount of each consumed on a daily basis. The amount of food consumed is determined either by weight or common household measures. The recording of dietary intake is usually conducted over a period of three to 14 days. One of the strengths of the food record method is its ability to capture quantitative information because all foods and beverages are weighed and/or measured before consumption. Because of this, the weighed food record has been used as the standard to which other dietary intake methodologies have been compared (Trabulsi & Schoeller, 2001).

Longer diet records have the potential to reduce the effect of day-to-day variation in dietary energy intake and thus should improve the precision of reported energy intake (Trabulsi & Schoeller, 2001). However, Gersovitz *et al.* (1978) showed that the number of incomplete records increases as the number of record keeping days increases. The longer recording period may result in recording fatigue and a larger underreporting of dietary energy intake (Trabulsi & Schoeller, 2001).

Trabulsi & Schoeller (2001) also provide a time period over which weight changes help to identify whether any discrepancy between reported intake and expenditure is due to underreporting or undereating.

2.2.6 Underreporting by dietary assessment method

Livingstone and Black (2003) confirmed widespread underreporting regardless of dietary assessment method. However, Black *et al.* (1991) categorised underreporting by dietary assessment method and found that 64%, 88% and 25% of the results fell below an acceptable cut-off value using diet records, diet recall and diet history, respectively. These data indicate that dietary assessment methods have a strong bias towards underestimation of habitual dietary intake and this is especially true for diet recall, where nine out of ten surveys were not plausible (Johansson *et al.*, 2001).

Hirvonen *et al.* (1997) found that underreporting seems to be the smallest in studies in which energy expenditure was measured in a controlled trial or in some other study design that requires a high degree of co-operation from the participants. Usually these people are highly motivated, have a higher educational level and lower BMI than the average population. It might be that higher involvement in a study makes people less susceptible to underreporting than lower involvement in survey-type studies. Therefore, underreporting might be a greater problem in population surveys than in experimental studies (Hirvonen *et al.*, 1997).

Black *et al.* (1991) showed that subjects reporting the lowest energy intakes were also the most difficult to recruit. Thus, it is probable that studies of randomly selected subjects draw in some who are not highly motivated and in whom cooperation is more apparent than real (Black *et al.*, 1991). In contrast, Black and Cole (2001) showed from studies using volunteers in response to local publicity shows that using highly motivated volunteers is no guarantee of valid dietary reporting. Dietary restrained and unrestrained eaters were studied and compared by Bathalon *et al.* (2000). They were requested to complete a seven day diet record, three 24-hour recalls and a FFQ. Compared with unrestrained eaters, restrained eaters consistently underreported intake to a larger degree, regardless of the dietary methodology employed (Bathalon *et al.*, 2000).

Taren *et al.* (1999) showed disparities reported from studies on free-living individuals, or in populations selected on the basis of their inability to lose weight or body size, may be attributable in part to problems that arise under the field conditions of each study. These problems may include a generalized lack of awareness of food intake when one is maintaining typical fast-paced living patterns. It can also be due to a social desirability driven consumption of 'healthier' kinds and amounts of foods, which was negatively associated with reporting accuracy. It can also include participants that report a more accurate food intake while participating in a nutrition study (Taren *et al.,* 1999).

In a review by Black & Cole (2001), it was found that subjects are consistent over time and across methods in terms of personal reporting bias. A study by Briefel *et al.* (1997) shows that 55% of men and 58% of women who underreported on the first occasion of a 24-hour recall also underreported on a second occasion of the recall. The subject-specific bias implies that the assumption that repeated measures of dietary intake will eventually obtain valid measures of habitual intake is not necessarily true (Black & Cole, 2001).

2.3 Energy expenditure (EE)

2.3.1 Whole-body calorimetry

Whole-body calorimetry is the most accurate method of assessing 24 hour energy expenditure (Goldberg *et al.*, 1991). Several validations of the DLW method have been conducted in which DLW-derived estimates of total energy expenditure (TEE) were compared with measurements of TEE in whole-body calorimeters. Although studies in whole-body calorimeters do not mimic normal life conditions, they do allow for an exact comparison of the DLW method with classic indirect calorimetry, which is considered the most reliable measurement of EE (Institute of Medicine, 2002).

To determine basal metabolic rate (BMR) from indirect calorimetry the subject has to fast and abstain from exercise for 12 hours (usually overnight) before the test (Mifflin *et al.*, 1990), then rest motionless in a supine position 20-30 minutes in a thermally neutral environment (Wong *et al.,* 1996). The subject should also refrain from smoking for at least one hour before testing, but if possible for 12 hours. The subjects are then placed under the canopy hood in a relaxed, supine position and standardized relaxation music is then played (Mifflin *et al.*, 1990). The subject should remain still for the next 30-40 minutes while the indirect calorimetry measurements are taken. This procedure is not only time-consuming but requires extensive subject cooperation as well as accurate and precise flow and concentration measurements, using sophisticated flow and gas analysers (Wong *et al.,* 1996).

2.3.2 Heart rate monitoring

Human EE can be accurately measured using whole-body calorimeters (Dauncy & James, 1979; Prentice *et al.*, 1985) or the DLW method (Prentice *et al.*, 1984). However, the former is expensive and requires considerable expertise and the latter restricts subjects within an artificial environment (Ceesay *et al.*, 1989). In an attempt to develop a simpler technique which could be applied in large epidemiological studies, several investigators have explored the possibility of predicting EE from heart rate (HR) (Bradfield, 1971; Bradfield *et al.*, 1971; Warnold & Lenner, 1977). The method relies on minute-by-minute HR conversion to EE using individual calibration curves (Ceesay *et al.*, 1989).

With recent developments in micro-chip technology there are now a number of ambulatory HR monitors available which record minute-by-minute HR throughout the day and from which information retrieval is extremely easy (Ceesay *et al.*, 1989). The HR method is not as accurate as the DLW technique, but has advantages in terms of cost and ease of use. The ability of the HR method to provide information on within and between-day variability in activity makes it actually preferable to the DLW method for certain purposes, irrespective of the cost differential (Ceesay *et al.*, 1989). Ceesay *et al.* (1989) believe that the HR method can be used as a useful adjunct to other methods in estimating EE, under appropriate circumstances and with prudent application. A disadvantage of using the heart rate monitors is that this method obtains only valid group mean values. It does not produce valid individual estimates of EE which does not make it appropriate to identify URs on an individual level (Scagliusi *et al.*, 2006).

2.3.3 Doubly labelled water (DLW) technique

The DLW method is a relatively new technique that measures TEE in free-living individuals. The DLW method was originally proposed and developed by Lifson for use in small animals (Lifson & McClintock, 1966; Lifson *et al.*, 1986). It has been adapted for human studies and extensively used (Schoeller *et al.*, 1986). The method involves the administration of water containing enriched quantities of the stable isotopes deuterium (^{2}H) and oxygen-18 (^{18}O). The term 'doubly' comes from the fact that both the hydrogen and the oxygen of water are labelled. The oxygen-18 is eliminated from the body in the form of carbon dioxide ($C^{18}O_2$) and water ($H_2{}^{18}O$) and the deuterium is eliminated in water ($^{2}H_2O$). The difference in elimination rate between these two isotopes is a measure of carbon dioxide production rate (Schoeller, 1988), and with knowledge of the composition of the diet, TEE can be calculated (Elia, 1991). The precision of DLW measurements, as assessed by the variability of individual DLW measurements from the indirect calorimetry assessments, varies between two to five percent. These validation studies show that the DLW method can provide an accurate assessment of the CO_2 production rate and hence TEE in a wide range of human subjects (Institute of Medicine, 2002). Another feature of the DLW method is that it provides an unrestricted measure which integrates TEE over long periods (typically ten – 15 days) and it is, therefore, likely to be representative of habitual TEE (Goldberg *et al.*, 1991).

To predict TEE from a measurement of CO_2 production, it is necessary to have an estimate of the average respiratory quotient (RQ) of the subject during the period of measurement. (RQ is the ratio of CO_2 produced to the O_2 consumed). This is because the energy released per litre CO_2 varies with the RQ and hence with the substrate mix oxidized by the body (Elia, 1991). The ratio of the CO_2 produced to the O_2 consumed by the biological oxidation of a representative sample of the diet is commonly referred to as the 'Food quotient' or FQ (Flatt, 1978). Short term measurements of RQ by indirect calorimetry are not useful for the DLW technique because RQ varies markedly during the day, particularly after meals. It is, therefore, more accurate to estimate the average RQ from information on the subjects' dietary intake. When energy balance prevails, the average RQ is equal to the FQ. If substantial gains or losses of body constituents are known to occur during the period of measurement, appropriate adjustments can be made in estimating the average RQ. Although food reports are inaccurate for measuring total energy intake, FQ calculations from food records can be used because FQ has a relatively small effect on DLW measurements of TEE (Institute of Medicine, 2002).

The high cost of the technique and the fact that the subject is restricted within an artificial environment caused it to be used in relatively small-scale studies (Okubo & Sasaki, 2004). As an alternative approach to detect misreporting of energy intake, Goldberg *et al.* (1991) introduced the ratio of reported EI to BMR (EI/BMR). With this ratio Goldberg *et al.* (1991) have attempted to define cut-off limits that will identify the most obviously implausible intake values. Many investigators who have used the Goldberg cut-off value to identify underreporters have indicated that reporting errors have been associated with subject characteristics (Okubo & Sasaki, 2004).

2.3.4 Physical activity level (PAL)

The energy expended for physical activity varies greatly among individuals as well as from day to day. In sedentary individuals, it dissipates less than half as much as is spent to sustain the BMR over 24 hours (BEE). In very active individuals, 24-hour energy expenditure can rise to twice as much as resting energy expenditure (Grund *et al.*, 2001). The level of physical activity is commonly described by the ratio of total to basal daily energy expenditure (TEE/BEE). This ratio is known as the physical activity level (PAL) or the physical activity index (PAI) (Goldberg *et al.*, 1991). Body size and age has an impact on PAL, as these are determinants of the BEE (Institute of Medicine, 2002). Goldberg *et al.* (1991) showed that the combined evidence from hypothetical factorial calculations and real whole-body calorimetry and DLW measurements indicate that it is highly unlikely that any normal, healthy free-living person could habitually exist at a PAL of less than 1.35 (Goldberg *et al.*, 1991). Measurements of energy intake that are lower than this can be rejected as estimates of habitual intake (Goldberg *et al.*, 1991). In addition, the average PAL among adults participating in the DLW studies is about 1.7, reflecting physical activity habits equivalent to walking 8 to 11 km/day at 4.8 – 6.4km/hour in addition to the activities required by a sedentary lifestyle (Institute of Medicine, 2002).

If TEE is replaced by the term BMR x PAL, then energy underreporting can be defined as EI<BMR x PAL or the ratio of EI to BMR x PAL (Samuel-Hodge *et al.*, 2004). Subject mean EI: BMR ratios were, therefore, compared with the PAL values corresponding to minimum and maximum habitual energy expenditures compatible with a normally active lifestyle, namely 1.35 – 2.0 for women and 1.35 – 2.4 for men (Black & Cole, 2001). Only chair-bound subjects or frail elderly persons are likely to have habitual PALs below 1.35 (Black & Cole, 2001). The 1985 FAO/WHO/UNU report calculated that a PAL of 1.27 (i.e. TEE = 1.27 x BMR) is the minimum 'survival requirement' which allowed for *'...minimal movement not compatible with long term health'* (Goldberg *et al.*, 1991). Due to the known variability in energy intake, the cut-off limits have to be more stringent if they are to be used to identify records that are likely to be incorrect estimates of the actual energy intake during the period of observation (Goldberg *et al.*, 1991). According to the Institute of Medicine (2002), the four categories of PAL of adults are as follows: sedentary (PAL ≥ 1.0 < 1.4), low active (PAL ≥ 1.4 < 1.6), active (PAL ≥ 1.6 < 1.9), and very active (PAL ≥ 1.9 < 2.5). Ideally, the PAL of an individual can be determined from DLW studies, however, in non-experimental situations, heart rate monitors, accelerometers and other devices as well as activity inventories can be used (Institute of Medicine, 2002).

2.3.5 Prediction of basal metabolic rate (BMR) from standard equations

The BMR is the minimal rate of energy consumption necessary to support all cellular functions and accounts for 50-70% of total energy expenditure in humans. BMR is used routinely by clinicians for estimation of energy requirements in patient care as well as by governmental agencies and health organizations in defining population energy requirements (Wong *et al.,* 1996).

The BMR describes the rate of energy expenditure which occurs in the post-absorptive state, defined as the particular condition which prevails after an overnight fast, the subject having not consumed food for 12 to 14 hours and resting comfortably, supine, awake and motionless in a thermoneutral environment. This standardized metabolic state corresponds to the situation in which food and physical activity have minimal influence on metabolism. The BMR thus reflects the energy needed to sustain the metabolic activities of cells and tissues, plus the energy to maintain blood circulation, respiration, gastrointestinal and renal processing (in other words the basal cost of living). In fact, BMR includes the energy expenditure associated with remaining awake (the cost of arousal), reflecting the fact that sleeping metabolic rate (SMR) during the morning is some five to ten percent lower than BMR during the morning hours (Garby *et al.,* 1987).

BMR is commonly extrapolated to 24 hours to be more meaningful and it is then referred to as basal energy expenditure (BEE), expressed as kilojoules per 24 hours. Resting metabolic rates (RMR), energy expenditure under 'resting conditions', tend to be somewhat higher (ten to 20 percent) than under basal conditions due to increases in EE caused by recent food intake (in other words by the 'thermic effect of food') or by the delayed effect of recently completed physical activities. Thus, it is important to distinguish between BMR and RMR and between BEE and resting energy expenditure (REE) (RMR extrapolated to 24 hours) (Institute of Medicine, 2002).

The BEE may be predicted from age, gender and body size. Prediction equations were developed for each gender by Schofield (1985) by pooling and analysing reported measurements made in 7 393 individuals. Henry (2000) recently re-evaluated all available data that has been performed that led to a new set of equations.

Several authors have questioned the use of the Schofield equations (Schofield, 1985) for the estimation of BMR (Cole *et al.,* 1996; Hayter & Henry, 1994; Price *et al.,* 1997; Shetty *et al.,* 1996).

2.4 Conclusion

As shown above, the methods used to determine EI (FFQ, 24-hour recall, diet history, food record / dairy and five-step multiple-pass method) may not always be fully reliable. Different methods exist to determine EE (whole-body calorimetry, DLW technique, PAL and prediction of BMR from standard equations). A full explanation and understanding of the above is needed in order to determine the method of identifying under and overreporters which will be explained in the next chapter.

CHAPTER 3: Identifying underreporting of energy intake

3.1 Introduction

Underreporting of EI is the most serious problem in dietary assessments today. The earliest indicator of bias to the underestimation of self-reported EI came from an 18 week metabolic study in which the EI reported by the subjects before entry into the study was 27% less than that required to maintain weight during the study (Hallfrisch *et al.,* 1982).

The DLW method remains the gold standard for the determination of EE (Scagliusi *et al.,* 2006). In view of the fact that this method is too expensive to be used as a routine validator of food intake measurements, cut-off limits are used to identify the most obvious implausible intake values (Goldberg *et al.,* 1991). The cut-off values used to identify under and overreporters are explored below.

3.2 Energy intake / basal metabolic rate ratio (EI/BMR ratio)

As discussed in the previous chapter, the best predictor of 24-hour energy expenditure is the BMR, as determined by indirect calorimetric measurement, which accounts for 65-70% of total 24-hour EE. The thermic effect of food (TEF) and PA account for the remaining 10-15% and 20-30%, respectively, of 24-hour EE. Because TEF and PA are highly variable from day to day and difficult to quantify, REE is most often used as an overall predictor of 24-hour EE. Usually, an individual's REE is multiplied by an activity factor to arrive at the 24-hour EE (Mifflin *et al.,* 1990).

When the ratio of EI to EE is calculated, the expected value is 1.0. Low values indicate underreporting. Values falling above or below the 95% confidence limits of the ratio were taken to indicate over or underreporting respectively by Black and Cole (2001). If the EI<TEE, the EI/TEE ratio is <1 and there is some level of energy underreporting. To validate reported EI against TEE, these researchers used the ratio of EI/TEE < 0.79 as a cut-off value defining energy underreporters. This value represents the lower 95% confidence limit of the ratio of EI to TEE (Samuel-Hodge *et al.*, 2004).

When energy underreporting is defined in terms of the ratio of EI to BMR, the Goldberg equation is generally used to establish the cut-off values. Because an individual's total energy requirement and BMR both vary with age, gender and body size, TEE may be represented in general terms as multiples of BMR (Samuel-Hodge *et al.*, 2004). The 'Goldberg cut-off' is based on the fact that EE can be represented as the BMR times an activity factor or PAL. A ratio of reported EI to calculated BMR (EI/BMR), also called the food intake level (FIL) (Johansson G *et al.*, 1998) that is less than this activity factor is suggestive of underreporting, or the cut-off under which reported intake is not valid (Goldberg *et al.*, 1991). The values defined by the Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU) are often used: the minimum survival level of 1.27, the sedentary level for women of 1.56 and the maximum sustainable lifestyle level of 2.0-2.4 (Okubo & Sasaki, 2004). It has been shown that among free-living persons EE levels below 1.27 BMR are rare, thus people whose EI were below this cut-off point were defined as underreporters. This cut-off point may be too low because at this level the PAL is equivalent to lying on a bed (Hirvonen *et al.*, 1997). A FIL cut-off level of 1.35 can also be used. This is the former Goldberg cut-off one level (Goldberg *et al.*, 1991) which is no longer recommended by Black (2000b). However, in the absence of good estimates of EE, this arbitrary value is still used. It is still true that PAL equal to 1.35 is the mean value of people staying in calorimeters and reflects a PAL value of an extremely sedentary lifestyle (Goldberg *et al.*, 1991). In a study by Johansson *et al.* (2001), two cut-off values were used to determine underreporters. A FIL of < 1.2 and < 1.35 was used. It corresponds to a PAL for a chair-bound or bed-bound person (survival limit), and to a PAL for the lowest possible free-living sedentary lifestyle, respectively. It was found that when FIL < 1.2 were applied as cut-off limit, the prevalence of underreporting was 44% for men and 47% for women, whereas the cut-off limit FIL < 1.35 would classify 61% of men and 72% of women as underreporters (Johansson *et al.*, 2001). This approach relies on the ability of the investigator to choose suitable physical activity factor values for each activity level (Black, 2000a).

3.3 Most common identified characteristics associated with energy over and/or underreporting

Goldberg *et al.* (1991) suggest four main reasons for low records of energy intake: 1) a simple failure to record everything eaten; 2) conscious or sub-conscious underreporting; 3) modification of eating patterns; and 4) the statistical uncertainty arising from the high level of day-to-day variability. The last of these will not threaten the overall credibility of intake measurements since it will generate overestimates of intake in as many subjects as it generates underestimates (Goldberg *et al.*, 1991). Individual results are clearly invalid if misleading information is given either from lack of motivation, alteration of food habits or misrepresentation (conscious or subconscious) of the true diet. If misrepresentation causes both over and underestimation, the mean results may still be valid but the precision of the measurement is reduced (Black *et al.*, 1991). The 'observer' effect, in other words, alterations made as a direct result of being under observation and wishing to appear in a good light probably remains whichever technique is employed (Black *et al.*, 1991).

Many studies have shown that underreporting is not random, but is related to characteristics such as obesity, smoking, dieting and psychological factors (Mendez *et al.*, 2004). Taren *et al.* (1999) also found that underreporting did not appear to be a uniform error, but rather one in which the amount of underreporting varied between the subjects. Samuel-Hodge *et al.* (2004) found that the most commonly identified characteristics associated with energy underreporting is high BMI, female sex, increased age and desire to lower body weight. In a recent in-depth review Maurer *et al.* (2006) provides a detailed discussion of published associations among psychosocial and behavioural characteristics and energy misreporting. According to these authors, past research suggests that higher social desirability and greater eating restraint are key factors influencing misreporting while a history of dieting and being overweight are more moderately associated, as summarised and reproduced in Table A1 (Addenda; 99).

Eating disinhibition, body image, depression, anxiety and fear of negative evaluation may be related but the evidence is insufficient. Factors associated with misreporting of energy intake are classified into nine distinct categories by Maurer *et al.* (2006), including demographics (for example age, gender), diet (for example macronutrient intake), eating behaviour (for example eating restraint), social desirability, dieting/weight history (for example number of previous dieting attempts), body image, psychology (for example depression), life status (for example socioeconomic status) and physical activity (see Figure 3.1). To these may be added perception of food size. Taren *et al.* (1999) found misreporting of dietary intake due to a generalized lack of awareness of food intake when one is maintaining typical fast-paced living patterns.

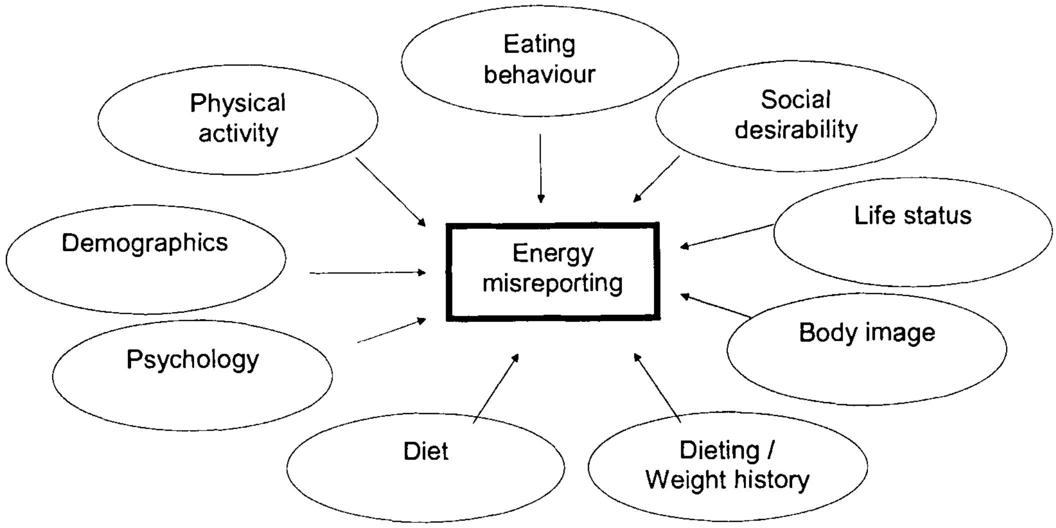

Figure 3.1 Categories related to misreporting self-reported energy intake (Maurer *et al.,* 2006)

Some of the most commonly found characteristics associated with energy over and/or underreporting will be discussed in more detail below.

3.3.1 Demographics

Correlation with BMI

One of the earliest studies to report a discrepancy between reported EI and measured EE was conducted by Prentice *et al.* (1986). In this study, 13 lean and nine obese women completed a seven day food record, with the obese group completing an additional seven day record. Lean subjects were found to have underestimated their dietary intake by two percent, whereas the obese subjects underestimated their intake by 34% (Prentice *et al.,* 1986). Additionally, the obese group tended to lose weight during the study, suggesting that the low self-reported intake was due to both undereating and underreporting (Prentice *et al.,* 1986). Goris *et al.* (2000) defined undereating as a consumption of less than the usual amount of food during the recording period. It is calculated from the loss of body weight during the study (Trabulsi & Schoeller, 2001). In a similar study, Platte *et al.* (1995) recruited ten normal-weight and ten obese women to complete a 14-day diet record. These authors found a larger magnitude of EI underreporting in the obese group compared with normal-weight women, 46% and two percent, respectively. Additionally, the obese subjects lost one kilogram of body weight during the recording period. The difference between reported EI and measured EE indicates that the obese group should have lost a total of 3.1 kilograms during the two week recording period, suggesting that this group not only underate but also underrecorded their true intake (Platte *et al.,* 1995). Trabulsi and Schoeller (2001) also found a tendency for obese subjects to reduce their intake and subsequently their body mass when food records are used to assess habitual dietary intake.

Other studies also showed that underreporting is more common among overweight than among people with normal body weight and this correlates with above mentioned studies (Hirvonen *et al.,* 1997; Novotny *et al.,* 2003; Tomoyasu *et al.,* 2000a). Novotny *et al.* (2003) found that for males and females combined, energy misreporting was correlated with percent body fat (higher percent fat was associated with greater likelihood to underreport EI). Tomoyasu *et al.* (2000a) concluded that BMI, waist circumference and fat mass were found to be significant correlates of underreporting, with the magnitude of underreporting increasing as these parameters increase. Similar results were found by Johansson *et al.* (2001) who found that the proportion of underreporters increased by BMI group (BMI < 25; 25-30; >30kg/m^2) from 33%, to 62% and 92% in women. In fact, it was found that the average FIL (0.89) for the 16 most obese subjects (BMI > 30kg/m^2) was lower than their estimated BMR (Johansson *et al.,* 2001).

Okubo and Sasaki (2004) found a significant correlation between BMI and EI/BMR. Strong predictors of underreporting included the following: year of study, gender, age, area, education and BMI. Among these BMI was the strongest factor (Hirvonen *et al.*, 1997). Samuel-Hodge *et al.* (2004) also found that underreporters had a significantly higher TEE and BMR (both related to higher BMI). In this study it was shown that energy underreporting increased with increasing degrees of overweight (Samuel-Hodge *et al.*, 2004). The inverse association between BMI and the degree of underreporting of EI has been demonstrated repeatedly, as exemplified by studies performed in different countries (Lichtman *et al.,* 1992, Mendez *et al.,* 2004, Prentice *et al.,* 1986, Tuschl *et al.,* 1990). In most dietary enquiries, obese subjects have been found to eat less than lean subjects, suggesting they are 'small eaters'. This suggestion does not fit in with EE measurements, which shows that obese expend more than lean subjects (Fricker *et al.*, 1992). Studies also show that this commonly believed thought that some obese people constantly ingest a low quantity of food and still remain obese is not scientifically supported (Fricker *et al.*, 1992).

It should be noted that the inverse relationship between BMI and reporting accuracy does not hold true for all segments of the population. For example, studies conducted in elite athletes have found large underreporting despite the fact that the subjects had low or average weights (Trabulsi & Schoeller, 2001). Edwards *et al.* (1993) found that the larger athletes had greater body image dissatisfaction, possibly related to athletic performance anxiety. This led to the speculation that an increase in underreporting with an increase in BMI or body weight may in fact be related to body image dissatisfaction (Trabulsi & Schoeller, 2001). This speculation is further supported by documented underreporting of EI by underweight women diagnosed with anorexia nervosa (Caper *et al.,* 1991). Black *et al.* (1991) suggested that weight-conscious individuals are likely to keep biased records and since such people may not be obese they cannot necessarily be identified by current BMI (Black *et al.*, 1991). All dietary assessment methods ultimately depend on the full cooperation of the subjects (Black *et al.*, 1991).

The study by Lissner *et al.* (1989) found no association between adiposity and underreporting. However, this study was not a population survey but an experimental study (Lissner *et al.,* 1989). Horner *et al.* (2002) also found no association between BMI and energy underreporting and suggested that, whilst there is no biologic reason that excess body fat would, in and of itself, cause women to underreport energy intake, the various measures of body size and adiposity must be serving as surrogates for psychosocial characteristics that result in underreporting energy, such as poor awareness of intake or portion sizes, deliberate underreporting and subconscious biasing toward intake that is perceived to be appropriate. These authors also observed several suggestive associations of psychosocial factors that were associated with underreporting such as that overweight people are more likely to be dieting or restricting food intake than other people, which may cause a low energy reporting (Horner *et al.,* 2002).

Gender

Studies have shown that women underreport more frequently than men (Hirvonen *et al.*, 1997). Goran and Poehlman (1992) recruited six women and seven men to complete a three day food record. They found that reporting accuracy differed significantly by gender ($P = 0.031$), with women underestimating their intake by 32% and men underestimating their intake by 13%. Asbeck *et al.* (2002) also found in their study consisting of 83 subjects that 49% of women but only 14.3% of men were classified as severe underreporters. Reilly *et al.* (1993) found similar results in their study with more women underreporting than men. They recruited ten healthy women to complete a three day weighed food record. Underreporting in their study was found to be 27% in women. Tomoyasu *et al.* (2000a) also quantified the degree of underreporting in men and women. Their sample consisted of 82 men and women, whose energy intake was determined from a three day weighed food record. The magnitude of underreporting of total energy intake for all subjects was 20% and, in contrast to findings by Goran and Poehlman (1992), was comparable between the two genders (Tomoyasu *et al.,* 2000a). Novotny *et al.* (2003) also found that underreporting by women was significantly of a larger magnitude than that of men. They found that 85% of the women underreported their EI (on average 2608.2kJ), whereas only 15% overreported their EI (on average 1276.8kJ). In contrast to above, Johansson *et al.* (2001) found that the reporting of food intake was unrelated to gender.

In a study by Tomoyasu *et al.* (2000b), 64 African-American men and women between the ages of 52-84 years were requested to complete a three day weighed food record. They found that the magnitude of misreporting was not affected by gender. Underestimation of intake amounted to eleven percent in the men and women. The authors speculate that a decreased preoccupation with body size and image in these older African-American men and women might have been responsible for the more modest underreporting found in this study (Tomoyasu *et al.,* 2000b).

Tooze *et al.* (2004) suggested that women had a fear of being negatively evaluated (defined as worry about being perceived in an unfavourable way by others or about doing the "wrong" things) that influenced subjects to underreport. The same association was not seen in men. One possible explanation for the gender difference is that women may be more self-conscious and worried about how they are perceived by others than their male counterparts. Support for this explanation can be found in the literature showing that another 'peer-driven' psychosocial factor, social desirability, influences underreporting in women (Maurer *et al.,* 2006).

Fricker *et al.* (1992) found that food intake reports could vary depending on the stage (luteal or follicular) of menses. EI is lower during the follicular phase (postmenstrual phase) than during the luteal phase (or premenstrual phase – 14 days before the onset of menses). Moreover, oestrogens decrease primarily fat and sweet intake in rats fed with a highly palatable diet. Thus, obese women may consume less energy, less fat and less sugars during the follicular phase than during the luteal phase (Fricker *et al.*, 1992).

Horner *et al.* (2002) found that postmenopausal women perceiving themselves to be thin underreported their energy intake more than those perceiving themselves to be heavy, even when the study was controlled for actual BMI (discussed in paragraph 3.3.5).

From the above, it appears that the physical, behavioural and psychological characteristics and/or profiles of study participants should be carefully considered as it may also provide insight into the reporting accuracy of dietary methodologies (Trabulsi & Schoeller, 2001).

Smoking

Several publications indicate lifestyle factors to be associated with dietary habits, such as smokers having different eating habits from non-smokers (Ballard-Barbash *et al.,* 1996; Birkett 1999; Block *et al.,* 1992; Morabia & Wynder, 1990; Walmsley *et al.,* 1999). However, besides the described relation between obesity and systematic underreporting (Bathalon *et al.,* 2000), limited knowledge exists on how or if lifestyle factors bias reporting of food intake, such as whether smokers and non-smokers report food intake in the same manner (Johansson *et al.,* 2001).

Johansson *et al.* (2001) found that smokers and former smokers had similar FILs, but both groups had lower FILs than non-smokers. Consequently, the proportion of underreporters was lower among non-smokers (37%) but interestingly, also among former smokers (44%) compared with smokers (68%). Smokers, former smokers and non-smokers had similar BMI, but smokers reported lower EI than former smokers and non-smokers. These authors concluded that underreporting of food intake was independently associated with smoking habit (Johansson *et al.,* 2001).

Age

Taren *et al.* (1999) investigated associations between reporting bias and physiological characteristics of participants. They found that reporting accuracy was inversely related to age (Taren *et al.,* 1999). A study by Horner *et al.* (2002) revealed that underreporting appeared to vary with participant characteristics, but was more evident among women who were younger. Johansson *et al.* (2001) contradicted this finding in their study using 94 men and 99 women in four age groups in Northern Sweden. They found that 26%, 58%, 45% and 54% underreported among the 30, 40, 50, and 60-year-olds, respectively. Thus, a high age was independently associated with underreporting of food intake in their study. This pattern remained largely the same when the genders were evaluated separately (Johansson *et al.,* 2001).

Educational level

Subjects with less than ten years at school had slightly lower average FILs than those with a higher educational level, but the proportion of underreporters did not differ significantly (50% and 40%

respectively) in the study of Johansson *et al.* (2001). Subjects with higher educational level were leaner than those with lower education, but their average recorded energy intakes were similar (Johansson *et al.,* 2001). Maurer *et al.* (2006) found that lower levels of education were associated with energy underreporting.

3.3.2 Diet

Samuel-Hodge *et al.* (2004) found that energy underreporters reported protein and fat intake significantly higher than non-URs, although Black *et al.* (1991) found an inverse relationship between energy intake and the percentage of energy derived from protein, suggesting also selective underestimation of fat and carbohydrate.

Bias on measurement of energy is likely to lead to bias on measurement of other nutrients closely correlated with total energy such as the B vitamins (Hirvonen *et al.*, 1997). There may not be bias on nutrients such as vitamin C, calcium or dietary fibre, which are derived mainly from low-energy foods (Black *et al.*, 1991).

Underreporters (FIL < 1.2) in the study by Johansson *et al.* (2001) reported a significantly higher intake of protein per energy unit, but a lower intake of fat and sucrose than subjects with a FIL > 1.35 ('plausible intake'). Underreporters reported significantly lower intakes of most evaluated sweet products, breads and high-fat products, such as sandwich spread, milk with 3% fat, cheese, sausages, bacon and crisps than in the plausible group (Johansson *et al.,* 2001). Underreporting women had significant fewer intakes of dairy products, potato/rice/pasta and alcoholic beverages.

3.3.3 Eating behaviour

The two main eating behaviours that have been associated with energy misreporting are eating restraint and eating disinhibition. Eating restraint has been defined as the conscious control/restriction of dietary intake to help assist in weight management (in other words loss of weight or prevention of weight gain) (Hill & Davies, 2001; Kretsch *et al.,* 1999). Eating disinhibition, often referred to as 'overeating', is defined as the loss of self-control over hunger and dietary intake (Tooze *et al.,* 2004). It has been suggested that eating restraint and eating disinhibition can occur concomitantly in some individuals, translating into repeated episodes of food restriction followed by binging or overeating (Lowe, 1993). It has been suggested that eating disinhibition may affect a person's ability or motivation to accurately report energy intake, while eating restraint directly reduces 'normal' intake, thereby contributing to underreporting (Kretsch *et al.,* 1999). In postobese subjects Black *et al.* (1997) found the magnitude of EI underreporting to be 26%. In this regard, the larger underreporting in the postobese women supports the idea that the underreporting may be related to dieting behaviours (Black *et al.,* 1997).

3.3.4 Social desirability

Social desirability is defined as the tendency to respond to questions based on a perception of what constitutes a socially appropriate response, regardless of truth (Maurer *et al.,* 2006). Higher social desirability, or a greater tendency to respond according to the "socially appropriate" response, has been associated with a higher incidence of energy underreporting. Novotny *et al.* (2003) found that social desirability presented as a predictor of underreporting only in women. Taren *et al.* (1999) explored the influence of psychological characteristics on reporting bias and also found that social desirability was found to be negatively associated with reporting accuracy. However, the 'observer' effect, defined as alterations made as a direct result of being under observation and wishing to appear in a good light, probably remains whichever technique is employed (Black *et al.*, 1991).

It is difficult to assess accurately how social desirability influences the intake of individual macro or micronutrients, since the intake of many of these nutrients is so highly interconnected (Maurer *et al.,* 2006). Maurer *et al.* (2006) found that in particular, participants in dietary intervention studies may be at an increased risk for providing self-reported dietary intakes that include higher amounts of 'socially desirable' foods and lower amounts of 'socially undesirable' foods in the context of study protocol dietary goals. In previous studies, low-energy reporters tended to report the consumption of 'socially desirable' or healthy foods such as fish, fruit and salad higher, whereas 'socially undesirable' or unhealthy foods such as snacks, cakes, sugar and fats were reported lower (Black *et al.*, 1991; Mendez *et al.,* 2004; Okubo & Sasaki, 2004; Taren *et al.,* 1999). Johansson *et al.* (1998) found that underreporters of energy intake reported consuming fewer foods rich in fat and sugar and reported higher vitamin C and fibre intakes than participants with a reported energy intake in the normal range. Goris *et al.* (2000), as well as Samuel-Hodge *et al.* (2004), found similar results with respect to fat intake. Stable weight obese 'small eaters' may report as much as 25% less than their estimated EE due to 'socially undesirable' foods (Fricker *et al.*, 1992; Okubo & Sasaki, 2004). Campaigns to reduce the consumption of fat and sugar may have particularly influenced the responses of small eaters, as suggested by their particularly low intake in these nutrients (Fricker *et al.*, 1992). It has been found that subjects report food intake more accurately while participating in nutrition studies (Taren *et al.,* 1999). These underestimations could lead to misinterpretation of nutritional epidemiological studies (Fricker *et al.*, 1992).

3.3.5 Dieting / weight history

Additionally, body dissatisfaction and the concept of a smaller body size than one's own as being healthier were also associated with a lower reporting accuracy (Taren *et al.,* 1999). Energy underreporting was also correlated with measures of body image, including having attempted weight loss in the past 12 months (Novotny *et al.,* 2003).

In a study by Muhlheim *et al.* (1998), participants admitted to having intentionally lied on self-reported food records. Deception of self and others is a common and adaptive process that plays an important role in the maintenance of both interpersonal relationships and of individual mental health (Muhlheim *et al.*, 1998). In this circumstance, the deception allows dieters to escape blame from a society that values thinness and believes that overweight people are responsible for their weight problems (Muhlheim *et al.*, 1998). Hirvonen *et al.* (1997) also found that the proportion of underreporting increased because of increasing health consciousness. Muhlheim *et al.* (1998) concluded that unsuccessful dieters may continue to overeat, but significantly underreport their EI and that helping them to acknowledge how much they are actually consuming is no simple matter. Even when directly confronted, participants continue to underreport their intake (Muhlheim *et al.*, 1998).

Novotny *et al.* (2003) found that underreporting was more present with people who considered themselves overweight. This was determined by asking the following question: 'Are you overweight, underweight, or the right weight?' They found that underreporting was more prominent with people that gained weight during the previous ten years. It was also found that a predictor of EI misreporting was more prominent with people that wish to weigh less (Novotny *et al.* 2003). Diet resistance, obesity and restrained eaters showed the largest magnitudes of underreporting bias of all studies included in the review by Trabulsi & Schoeller (2001), which confirms the above mentioned.

An example of poor accuracy in reported dietary intake was shown in a study by Lichtman *et al.* (1992). Subjects in this study were divided into two groups. Group one (with a mean BMI of 33.8) consisted of nine women and one man with a history of repeated failure to lose weight despite low caloric self-reported intake. The subjects were termed 'diet resistant' by these authors. Group two (with a mean BMI of 36.4) consisted of 80 men and women without a history of diet resistance. Energy intake was measured using a 14-day weighed food record. EE was measured in all group one subjects and in a subset of six group two subjects. The diet-resistant members of group one underreported EI by 58%, whereas group two subjects underreported intake by 36%. Group one's subjects were more likely to be using thyroid medication, had a stronger belief that their body weight was due to a genetic predisposition, had a series of failed diet attempts (some more than 20) and reported less hunger and more cognitive restraint compared to group two's subjects (Lichtman *et al.,* 1992).

3.3.6 Body image

Body image has been defined by Cash (2004) as 'the multifaceted psychological experience of embodiment, especially but not exclusively one's physical appearance'. Further, body image 'encompasses one's body related self-perceptions and self-attitudes, including thoughts, beliefs, feelings and behaviours' (Cash, 2004). The multi-dimensionality of body image makes the assessment and interpretation of the measured associations complicated. The relationship between body image and energy misreporting, while not well researched, could be a result of the stigma that overweight and obesity have in the general population (Schwartz & Brownell, 2004). Again, the idea of social desirability is a factor in this regard. A person whose body image is affected by the stigma of being overweight or obese may misreport (most likely underreport) EI to avoid ridicule for their 'overeating', leading to their overweight or obesity (Maurer *et al.,* 2006).

Taren *et al.* (1999) showed disparities reported from studies on free-living individuals, or in populations selected on the basis of their body size. Horner *et al.* (2002) found that postmenopausal women perceiving themselves to be thin underreported their energy intake more than those perceiving themselves to be heavy, even when the study was controlled for actual BMI.

In one of the largest studies to date evaluating psychosocial predictors of energy underreporting in adults, Tooze *et al.* (2004) found that body image, as assessed by Stunkard-Sorensen silhouettes and dieting / weight history emerged as significant factors associated with energy underreporting. Female URs perceived their body size and the discrepancy between perceived body size and healthy / ideal body size to be significantly larger than did accurate reporters. These same URs described a long-term pattern of weight loss and regain. Among male URs, discrepancy between perceived and ideal body size in conjunction with BMI were significantly greater than that of male accurate reporters. Male URs also reported a history of frequent dieting and weight loss (Tooze *et al.,* 2004). Maurer *et al.* (2006) concluded from a review that current body weight influences the relationship between body image, dieting / weight history and energy underreporting in men, whereas in women the relationship between body image and dieting / weight history and energy underreporting occurs irrespective of current adiposity.

3.3.7 Psychology

Sources of bias are several and include lapses of memory which could make it impossible for subjects to remember their true intake (Black *et al.*, 1991; Fricker *et al.*, 1992). Maurer *et al.* (2006) stated that depression and anxiety can influence reporting accuracy by impairing cognitive processes such as memory or triggering eating disinhibition. This may explain why Taren *et al.* (1999) found that reporting accuracy was inversely related to age. Alternatively, depression and psychological distress may be associated with the true causes of energy misreporting (for example fear of negative evaluation or other attributes). Depression is often evaluated in research settings using the Beck Depression Inventory (BDI), which screens for the presence and severity of depression (Maurer *et al.,* 2006). Kretsch *et al.* (1999) found a strong positive correlation between a lower depression score on the BDI (a score of 0 to 9 is indicative of minimal depression) in obese women and underreporting. It was found that specifically obese women with a BDI score of three and/or below, energy underreporting was estimated between 1400 to 1800 kcal, whereas those who scored four or above, reported energy intakes within ±600 kcal of measured EI (Kretsch *et al.,* 1999). This is interesting because depression has been shown to be prevalent in obese women (Palinkas *et al.,* 1996). A possible explanation offered by Kretsch *et al.* (1999) revolves around the possibility that scores of 3 or less on the BDI are indicative of depression in people actively in denial of their depression (Joiner *et al.,* 1994).

Sources of bias also include: knowingly omitting items from the record (Black *et al.*, 1991; Fricker *et al.*, 1992) and inability to focus attention on the dietary inquiry and misperception of size of food (Fricker *et al.*, 1992). Perception of food size was shown to be different in patients with anorexia who showed an exaggerated perception of food size, which may be a psychological phenomenon involved in their decrease of food intake (Fricker *et al.*, 1992). On the other hand, Fricker *et al.* (1992) found that obese women perceived food items as being smaller than their real size or than neutral objects; for their part, normal-weight controls had previously shown a normal perception of food size. Thus, misperception of food size in obesity mirrors that in anorexia and could be involved in the underestimation of EI usually shown by obese subjects (Fricker *et al.*, 1992).

3.3.8 Physical activity

Briefel *et al.* (1997) found that subjects with a high recreational PAL were also associated with a higher mean EI: BMR (estimated), but this varied according to population subgroup. The use of the same prediction equations for physically active and inactive persons of the same age group and gender may alter results because physically active persons would have greater lean body mass and greater true energy expenditure than would inactive persons of the same age group, gender and body weight (Briefel *et al.,* 1997). Additionally Tooze *et al.* (2004) found that a person's perceived activity level may be more closely related to underreporting than his or her actual activity level. URs may less accurately perceive their activity levels as well as their diets (Tooze *et al.,* 2004).

3.4. Conclusion

Researchers should not simply accept that energy under and overreporting occur, but should also develop the means for identifying at risk populations and account for the influence of energy on under and overreporting in the assessment of nutrition, health and disease relationships (Maurer *et al.,* 2006). Thus, underreporting of total intake should be considered along with data on body weight, smoking, behavioural and other dietary issues in interpreting information from dietary surveys. Briefel *et al.* (1997) recommend that all dietary surveys should collect height and weight information (preferably measured because self-reported weight status is subject to reporting bias) to allow interpretation of dietary data.

In Chapter 4, the results from a study done to assess characteristics associated or not associated with underreporting will be explored in the article format. The manuscript was prepared according to the author's instructions of Public Health Nutrition.

CHAPTER 4: Underreporting in the POWIRS study

The characteristics of underreporting women in the POWIRS II study

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Abstract

Objective: Underreporting is a common problem in dietary surveys. This investigation is done to determine whether specific subject characteristics contribute to underreporting and whether there is an association between the metabolic syndrome and underreporting.

Design: A multi-disciplinary cross-sectional case-control study was carried out with 115 apparently healthy Caucasian women. Dietary intake was measured using the quantitative food frequency questionnaire (QFFQ). The ratio of energy intake (EI) to basal metabolic rate (BMR) was calculated from the reported EI and estimated BMR. Underreporters (URs) were identified using the Goldberg equation, which compares EI with energy expenditure, both expressed as multiples of the BMR. URs had reported energy intakes <1.27 x BMR and non-URs ≥1.27 x BMR. Total energy expenditure (TEE) was calculated (n=115) and measured in a subgroup (n=63) by using the Actical accelerometer. Physical activity was also divided into three groups by using the Yale physical activity questionnaire.

Setting: The POWIRS II (Profiles of Obese Women Suffering from the Insulin Resistance Syndrome) study was performed in the Metabolic Unit of the North-West University, Potchefstroom, South Africa.

Subjects: The study was done with 115 apparently healthy Caucasian women.

Results: Most of the women were overweight (45.8%) and 29.2% were obese but only 20 subjects presented with the metabolic syndrome. The prevalence of underreporting women with a food intake level (FIL; reported EI divided by estimated BMR) below 1.27 was relatively low (21%). Overreporting (FIL >2.4) was also low (6.7%). The prevalence of metabolic syndrome did not differ between URs and non-URs (12.5% and 18.7%, respectively). Most subjects were younger than 35 years (mean=33.2), highly educated and received a high monthly income. The subjects fell mostly into the low activity category. URs had a statistically significantly ($p<0.05$) higher percentage energy intake from fat but lower from carbohydrates (37.4% and 42.9%, respectively) when compared to non-URs (33.5% and 47%; respectively). The mean intakes of most micronutrients were statistically significantly lower in the URs. However, expressed per energy unit, intakes of URs were significantly higher for potassium, selenium and vitamin E. When the food group intakes of URs and non-URs were compared no significant differences were found. Measured TEE was significantly higher in URs and non-URs (13 036kJ and 13 805kJ; respectively) compared to calculated TEE (10 105.8kJ and 10 220.3kJ; respectively). Measured TEE was also significantly higher than reported EI ($p<0.01$).

Conclusions: No specific subject characteristics were related to underreporting. Considering the low reported EI compared to the measured TEE, the cut-off values to identify URs might have been too low.

Introduction

The identification of underreporting, indicated by a low ratio of energy intake (EI) to basal metabolic rate (BMR)[1] is necessary to obtain reliable dietary data from food records, quantitative food frequency questionnaires (QFFQ) and/or 24-hour recalls. Factors influencing reliability include misreporting because assessments of dietary intake are mostly obtained by self-report, large day-to-day variations in food intake may reduce reliability if only 24-hour recall questionnaires are used and subjects may change their habitual dietary habits during a given study period[2]. An underestimation of energy intake by ~20% is common[3] and can be as high as 50% in obese subjects[4]. Although body mass index (BMI) plays a role in underreporting[5], other factors like restrained eating[6,7], old age[8], smoking[8], certain nutrients[9,10,11], method of dietary assessment[12], dissatisfaction with body image[5] and socio-economic status[12] also seem to contribute in this respect. The method (definition or cut-off value) used to classify underreporters (URs) is a great determinant of the variation of underreporting[13].

The purpose of this sub-study of the multi-disciplinary cross-sectional POWIRS II (Profiles of Obese Women Suffering from the Insulin Resistance Syndrome) study was to determine the proportion of underreporters (URs) and the subject characteristics which played a role in underreporting. The reported energy intake (EI) was compared with measured and calculated total energy expenditure (TEE) and basal metabolic rate (BMR)[1].

Data are represented comparing the reported dietary composition of URs versus non-URs. In addition a description of the relationship between energy underreporting and demographic factors, metabolic syndrome and BMI are included. Data on the correlation between underreporting and the metabolic syndrome are scarce, especially in South Africa.

Material, methods and subject selection

The POWIRS II study was a follow-up study with a case-control cross-sectional study design including 115 Caucasian female volunteers between the ages of 19 and 56 years from the North West Province, South Africa. In general, a BMI of 25 or more indicates overweight and obesity and an increased risk of developing health problems. For the description of subjects, a BMI 30 – 34.9 was used for obesity class I, whereas a BMI > 34.9 was used for obesity class II[14]. The calculated BMR was determined by using Schofield's equations[15], namely adults 18 to 30 years: BMR = 0.057*weight (kg) + 1.184*height (cm) + 0.411; and adults 31 to 60 years: BMR = 0.034*weight (kg) + 0.006*height (cm) + 3.530[15].

Pregnant and lactating women and those with oral temperatures above 37° C were excluded. Patients with chronic diseases were included if they were stabilized on chronic medication.

The study was approved by the Ethics Committee of the North-West University (project number 03M03). After the procedure of the study was explained to all the subjects, they were requested to sign an informed consent form. Subjects were accommodated overnight and received supper and breakfast in the Metabolic Unit. A short report with their health information was given to the subjects after blood sample analysis. Subjects identified with diabetes, hypercholesterolaemia or other abnormalities were referred to local clinics, hospitals or their physicians.

Organisational procedures

Each afternoon, for a period of three weeks, ten subjects reported at the Metabolic Unit Facility (consisting of ten single bedrooms, two bathrooms, a living room and a kitchen). Each subject had to complete a demographic and medical background questionnaire during the course of the evening. Dietary questionnaires were administered by three experienced, registered dieticians. All anthropometric measurements were taken during the afternoon except weight and height measurements. The same light supper was served around 20:00 for all subjects. From then on no food or beverages were allowed to enable subjects to be in a fasting state the next morning. Subjects had to go to bed no later than 23:00.

From 06:00 the following morning resting blood pressure, weight and height measurements were taken. Blood pressure was recorded in duplicate using a sphygmomanometer (Tycos®, Arden, NC, USA) with adjustable cuffs. The first and fifth Korotkoff sounds were recorded in subjects lying in bed for at least ten minutes. Fasting venous blood samples were taken by registered nursing sisters for the measurement of various biochemical parameters which will not be reported here. Subjects then received breakfast and were allowed to go home.

Questionnaires

To determine physical activity, the Yale Physical Activity Survey (YPAS) questionnaire[16] was completed. The validity of the YPAS questionnaire was previously verified[17]. With the help of the YPAS questionnaire, the physical activity of the subjects could be divided into the three ranges, namely, low, moderately and highly active[16]. A physical activity index (PAI) of ≤ 47 was classified as low, between 48 and 67 as moderately and ≥ 68 as highly active[18].

The subjects' dietary intakes were measured using a culture sensitive validated QFFQ comprising 145 food items[19,20]. To assist subjects in reporting the correct amount of food eaten, a food portion photograph book (FPPB) was used containing photographs of three portion sizes of the most commonly eaten foods. In a validation study by Venter *et al.*[21], it was found that the FPPB is an acceptable and convenient visual aid to estimate portion sizes. Food models, household utensils and food packages further improved the quantification of food intakes. Analysis of nutrient intakes was done with a computer programme (Food Finder 2) based on the South African Food Composition Tables[22].

Anthropometrical measurements

All anthropometrical measurements were done by a level III (instructor level) anthropometrist. The subjects' weight, height, hip and waist circumference were recorded by standard methods. Height was measured using an Invicta IP stadiometer (London, UK) to the nearest 0.1cm. The subjects were barefoot, wearing light clothing and with the head in the Frankfort plane. Weight was measured to the nearest 0.1 kg on a portable electronic scale (Precision Health scale, A&D Company, Tokyo, Japan). Waist circumference was measured using a Lufkin-steel measuring tape to the nearest 0.1cm. A complete body composition profile was done using the BOD POD system (Life Measurement Inc., Concord, CA). The BOD POD body composition system is a valid, reliable standard that can be used by dieticians and clinicians for the assessment of body composition[23].

Two hours before BOD POD measurements were taken, subjects were not allowed any food or liquids as well as any physical activity. Subjects wore tight-fitting underclothes and swim caps only. The instrument was calibrated each day before measurements. Body density was determined with body mass and body volume. The women's weight was determined on the BOD POD's electronic scale and body volume with the help of the BOD POD by air displacement. The SIRI 1961-equation was used to calculate fat percentage of subjects with normal weight. For obese subjects the Brozek-equation was used[24,25].

Other measurements

In addition to the YPAS, accelerometers were also used to determine the physical activity levels objectively and, therefore, energy expenditure of a subgroup of 63 subjects (Actical, MiniMitter, Oregon, USA). Activity monitors predict resting energy expenditure (REE) by using an equation that includes age, sex, height and weight and give estimates to TEE by combining the estimate for REE with an estimate for energy expended in physical activity[26]. The subjects in this study wore the accelerometer around their waist, above the right hip, for 24 hours. This was given to the subjects to wear upon leaving the metabolic unit. Subjects then returned the accelerometer after 24 hours for examination of the data.

To calculate the TEE, the BMR was multiplied with 1.55. This value was decided upon as the mean EI: BMR ratio of all the subjects corresponded with PAL values of minimum and maximum habitual energy expenditures compatible with a normally active lifestyle, namely 1.35 – 2.0 for women[27]. Only chair-bound subjects or frail elderly persons are likely to have habitual PAL below 1.35[27].

Metabolic syndrome was identified according to the new definition of the International Diabetes Federation[28], namely central obesity (waist circumference ≥ 80cm) plus any two of the following factors: raised triglyceride (TG > 1.7 mmol/L), reduced HDL cholesterol (< 1.29 mmol/L), raised blood pressure (BP): systolic BP ≥130 or diastolic BP ≥85mm Hg, or treatment of previously diagnosed hypertension and/or raised fasting plasma glucose (> 5.6 mmol/L) or previously diagnosed type 2 diabetes, if above 5.6 mmol/L[28].

Statistical analysis

To identify subjects who underreported, use was made of the methodology described by Goldberg *et al.*[1], which derives cut-off limits for plausible EI. Using this methodology, EI/BMR ratios were calculated with BMR estimated by the Schofield equation[15]. The cut-off value of EI <1.27 x BMR was used to identify URs. Plausible and overreporters were grouped together with EI ≥1.27 x BMR. The 1995 FAO/WHO/UNU report[29] calculated that a PAL of 1.27 (i.e. TEE = 1.27 x BMR) is the minimum 'survival requirement' which allowed for '...minimal movement not compatible with long term health' and made no allowance for '...the energy needed to earn a living or prepare food'.

Statistical analysis of the data was done with the software computer package SAS[30]. Means, minimum and maximum values and standard deviations were calculated. A two-way frequency table was used to determine the statistical significance between the subjects who underreported compared to the rest. Statistical significance was then determined by means of the chi-square test. To determine whether this was a practical significant result the phi-coefficient was calculated. A phi-value was seen as practically significant where the value exceeded 0.5. T-tests were also performed to compare the means of the food groups and nutrient intakes between the over and underreporters. An analysis of covariance (ANCOVA) with group as factor and adjusted for age, BMI, marital status, education level, activity level, smoking status and level of income was done. A stepwise linear regression, employing TEE measured versus TEE calculated, was performed. Tukey's standardised range test was also used whenever the means of more than two groups were compared.

Results

Subject characteristics

In this study 21% subjects were classified as URs (n=24). Overreporting defined as EI/BMR > 2.4 was also found in this study. However, only ten subjects (6.7%) overreported. From the total group of subjects only 20 were diagnosed with metabolic syndrome of which only 15% were classified as

URs. As shown in Table 1, the majority of both URs (63%) and non-URs (66%) fell in the age group <35 years. The mean age of the URs was somewhat higher (33.2 years) than the non-URs (30.8 years). Most URs (65%) and non-URs (74%) fell in a higher education level (grade 12 as well as tertiary education). Most subjects (87%) were non-smokers, only 15 subjects smoked. Most URs were married (46%) whereas the non-URs were mostly never married (51%). Almost a third of URs and non-URs had an income of more than R 5000 per month.

Anthropometry

Of the 115 subjects 25% were of normal weight, 45.8% were overweight, 16.7% obese class 1 and 12.5% obese class 2. No subjects were underweight. The mean body mass (± standard deviation) of all the subjects was 81.4 ±22.0kg. The mean body mass of the URs was 80.7 ±24.0kg, which did not differ significantly from non-URs (81.6 ±21.3kg). The mean BMI of the groups was similar (URs=28.4 ±6.4; non-URs=28.5 ±7.4kg/m^2). Most of URs and the non-URs were classified into the overweight/obese class (75% and 61% respectively).

The mean waist circumference of all the subjects (87.6 ±15.2cm) was somewhat more than that of the URs (86.1 ±15.0cm) and less than that of the non-URs (88.0 ±15.4cm). More URs than non-URs fell in the <88cm group (p<0.05). It was found that URs with the metabolic syndrome (n=3) had a significantly smaller waist circumference (86.5 ±2.1cm) compared with the non-URs with the metabolic syndrome (n=17) (104.8 ±9.6cm; p<0.001). The mean waist to hip ratio (WHR) for all the subjects was 0.77 ±0.1 and the same values were found for the URs as for the non-URs. However, the waist to hip ratio of the URs with the metabolic syndrome (0.82 ±0.10cm) did not differ significantly from the non-URs with the metabolic syndrome (0.83 ±0.06cm). The mean fat percentage of all subjects was 36.4 ±10.4% with no difference between the groups.

Energy expenditure and -intake

The mean activity index (PAI) of all the subjects was low (43.9 ±22.0). This is also evident in the percentage values: 62.5% URs and 64% non-URs fell in the low PAI category. The BMR between URs and non-URs did not differ significantly.

However, the mean EI/BMR ratio or food intake level (FIL) of the URs was significantly lower than that of the non-URs (1.1 versus 1.9 respectively, p<0.01). The total EI (reported) of the URs (7291 ±1428kJ) differed significantly from non-URs (11925 ±3164kJ; p<0.01) (see Table 1). Calculated mean TEE of all the subjects (n=115) was lower than the measured TEE (n=63 subjects) (10 122

±1707kJ versus 13 598 ±3758kJ respectively, p<0.01). Physical activity was measured in a sub group of 63 subjects by means of an accelerometer. Calculated mean TEE (n=115) of the URs was lower than the measured TEE (10 106 ±1291kJ versus 13 036 ±2543kJ respectively, p<0.01). The same tendency can be seen in the non-URs with calculated mean TEE being lower than the measured TEE (10 220 ±1580kJ versus 13 805 ±3731kJ respectively, p<0.01).

Table 1 Characteristics of the study population

	Energy intake <1.27*BMR (n=24) Mean (±SD)	**Energy intake ≥1.27*BMR (n=91) Mean (±SD)**
Age years (n=115)	33.2 (±11.1)	30.8 (±8.6)
< 35y (n=75)	63% (n=15)	66% (n=60)
≥ 35y (n=40)	37% (n=9)	34% (n=31)
Education level (n=113)		
Grade 12 (n=31)	35% (n=8)	26% (n=23)
Grade 12 + Tertiary education (n=82)	65% (n=15)	74% (n=67)
Smoking status (n=115)		
Smoker (n=15)	12.5% (n=3)	13% (n=12)
Non smoking (n=100)	87.5% (n=21)	87% (n=79)
Marital status (n=114)		
Never married	42% (n=10)	51% (n=46)
Married	46% (n=11)	44% (n=40)
Divorced	12% (n=3)	2.5% (n=2)
Widowed	0	2.5% (n=2)
Income level		
R 1000 – 2000	15% (n=3)	20% (n=16)
R 2000 – 3000	15% (n=3)	10% (n=8)
R3000 – 4000	20% (n=4)	15% (n=12)
R4000 – 5000	15% (n=3)	16% (n=13)
> R5000	30% (n=6)	38% (n=30)
Student	5% (n=1)	1% (n=1)
Body mass (kg) (n=115)	80.7 (±24.0)	81.6 (±21.3)
BMI (n=115)	28.4 (±6.4)	28.5 (±7.4)
Normal weight (BMI < 25) (n=41)	25% (n=6)	38.5% (n=35)
Overweight (BMI 25-29.9) (n=32)	46% (n=11)	23% (n=21)

	Energy intake <1.27*BMR (n=24) Mean (±SD)	Energy intake ≥1.27*BMR (n=91) Mean (±SD)
Obese (BMI ≥30) (n=42)	29% (n=7)	38.5% (n=35)
Waist circumference (cm) (n=115)	86.1 (±15.0)	88.0 (±15.4)
< 88cm (n=60)	71%* (n=17)	47%* (n=43)
≥ 88cm (n=55)	29% (n=7)	53% (n=48)
Waist to hip ratio (n=115)	0.8 (±0.1)	0.8 (±0.1)
BOD POD fat % (n=115)	36.9 (±10.4)	36.2 (±10.5)
Activity level (n=115)	42.5 (±17.3)	44.2 (±23.3)
Low (n=73)	62.5% (n=15)	64% (n=58)
Moderate (n=23)	25% (n=6)	19% (n=17)
High (n=19)	12.5% (n=3)	17% (n=16)
BMR (kJ) (n=115)	6519 (±832)	6593 (±833)
EI:BMR (n=115)	1.1** (±0.2)	1.9** (±0.3)
Total EI - Reported (kJ) (n=115)	7291** § (±1429)	11925** § (±3164)
Total EE – Measured (kJ) (n=63)	13036‡ § (±2543)(n=17)	13805‡ § (±3731)(n=46)
Total EE – Calculated (kJ) (n=115)	10106‡ (±1291) (n=24)	10220‡ (±1580) (n=91)

[1]SD = standard deviation

* Significant difference between URs and non-URs (p<0.05)

** Significant difference between URs and non-URs (p<0.01)

‡ Significant differences within groups (p<0.01)

§ Significant differences within groups (p<0.001)

Nutrient intakes

Figure 1 shows the percentage contribution to daily energy intake of the macronutrients. URs (n=24) reported a significantly lower percentage carbohydrate intake (42.9 ±8.8%) than non-URs (47.0 ±7.0%) and higher percentage fat (37.4 ±8.5% versus 33.5 ±2.4%; p<0.05). The URs also tended to have a higher percentage intake from protein (15.5 ±3.6% versus 14.7 ±7.1%) than the non-URs. There was no significant difference in alcohol intake in the URs (1.3 ±2.0%) compared to the non-URs (1.8 ±1.3%).

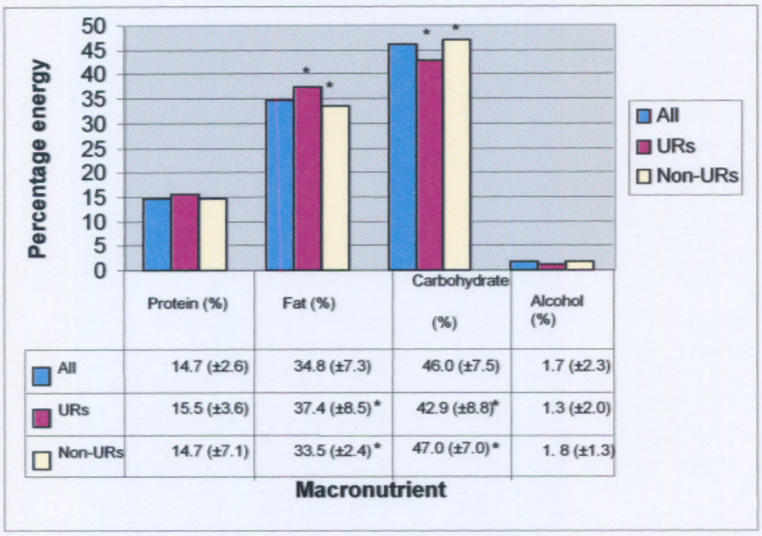
The mean total micronutrient intakes and intake per 10MJ are shown in Table 2. The mean intakes of most micronutrients were statistically significantly lower in the URs. However, expressed per energy unit (10MJ) the intake of potassium (p<0.05), selenium (p<0.01) and vitamin E (p<0.01) was significantly higher in URs compared to non-URs. The URs had a significantly lower intake of riboflavin ($p<0.05$) per energy unit when compared to non-URs.

Table 2 The mean micronutrient intake of all subjects, URs and non-URs, given in total and per 10 megajoule. (Non-URs = non-underreporters, URs = underreporters)

Nutrient	All (n=115)		URs (n=24)		Non-URs (n=91)	
	Total	**/10MJ**	**Total**	**/10MJ**	**Total**	**/10MJ**
Calcium (mg)	1109	976	610*	858	1174*	983
Iron (mg)	18.3	16.1	11.0*	15.5	18.9*	15.9
Magnesium (mg)	401	360	269**	375	427**	362
Phosphorus (mg)	1607	1429	1026**	1403	1718**	1446
Potassium (mg)	3961	3592	2857**	3955*	4221**	3569*
Sodium (mg)	2710	2446	1951*	2713	2891*	2420
Chloride (mg)	1787	1596	1366*	1805	1813*	1516
Zinc (mg)	14.2	12.6	9.7*	13.1	15.5*	12.9
Selenium (μg)	60.2	54.2	52.2	70.6**	62.8	52.6**
Iodine (μg)	49.9	44.3	36.7*	48.5	53.0*	44.3
Vitamin A (μg)	1610	1448	810*	1154	1786*	1492
Beta-carotene (mg)	5.4	4.9	2.6*	3.8	5.9*	4.9
Thiamin (mg)	1.6	1.4	1.0**	1.3	1.7**	1.5
Riboflavin (mg)	2.2	2.0	1.2**	1.6*	2.3**	2.0*
Niacin (mg)	26.3	23.6	18.5**	25.7	27.8**	23.4
Vitamin B_6 (mg)	2.2	2.0	1.4**	1.9	2.3**	2.0
Folate (μg)	287	256	173**	238	302**	256
Vitamin B_{12} (μg)	6.5	5.8	3.8	5.4	7.1	6.0
Vitamin C (mg)	166	152	110	164	182	156
Vitamin D (μg)	4.8	4.3	3.2*	4.2	5.2*	4.3
Vitamin E (mg)	2.2	2.0	1.9	2.6**	2.3	1.9**
Vitamin K (μg)	12.6	11.0	9.1	12.0	13.6	11.5
Dietary fibre (g)	24.3	21.9	15.4*	21.6	26.7*	22.9

* Statistically significant difference between URs and non-URs ($p<0.05$)

** Statistically significant difference between URs and non-URs ($p<0.01$)



	Protein (%)	Fat (%)	Carbohydrate (%)	Alcohol (%)
All	14.7 (±2.6)	34.8 (±7.3)	46.0 (±7.5)	1.7 (±2.3)
URs	15.5 (±3.6)	37.4 (±8.5)*	42.9 (±8.8)*	1.3 (±2.0)
Non-URs	14.7 (±7.1)	33.5 (±2.4)*	47.0 (±7.0)*	1. 8 (±1.3)

Figure 1 The percentage reported daily intake of macronutrients. (Non-URs = non-underreporters, URs = underreporters)

* Statistically significant difference between URs and non-URs ($p<0.05$)

Composition of diet at different levels of food intake

The mean FIL of the different physical activity (PA) groups, different age groups (< 35 or ≥ 35 years), smokers and non-smokers, different education levels and different income groups did not differ significantly from each other. However, FIL was highest in the student group (2.0 ± 1.4) with the lowest from the R2000-R3000 and the R3000-R4000 income levels (1.6 ± 0.5 and 1.6 ± 0.6, respectively).

Food groups

No statistically significant differences were found between URs and non-URs in terms of the percentage energy intake from eleven food groups (Figure 2) even when grouped as normal and overweight (data not shown).

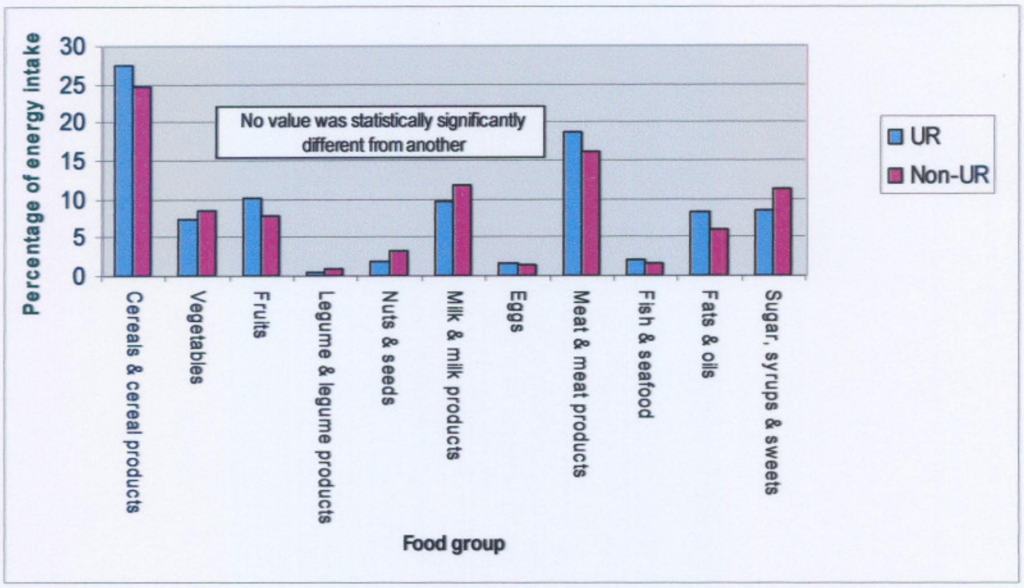


Figure 2 Percentage energy intakes from eleven food groups of the underreporters compared to the non-underreporters. (URs = underreporters; Non-URs = non-underreporters).

A stepwise linear regression, employing TEE measured versus TEE calculated, was done (Figure 3) which revealed an R^2 of 0.5037 between these two variables ($p<0.0001$).

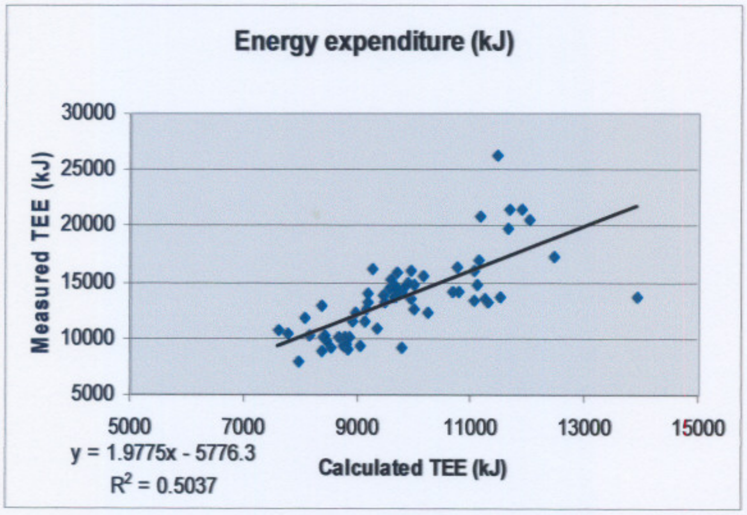


Figure 3 Linear regression curve of total energy expenditure measured versus total energy expenditure calculated.

Discussion

The objective of this study was to determine the proportion of URs and the characteristics which played a role in underreporting by subjects in a study on the metabolic syndrome. The overall percentage of URs was 21%. A tendency was found of overweight subjects underreporting (45.8%) when compared to normal weight subjects (25%). Previous studies showed that underreporting was associated with overweight[4,31,7,13,32,33]. However, Lissner *et al.*[34] found no association between adiposity and URs. Ballard-Barbash *et al.*[33] suggested that overweight subjects are more likely to be dieting or restricting their food intake than others, which may explain a higher prevalence of URs among overweight subjects compared to others. However, normal weight subjects also underreport. Asbeck *et al.*[6] found that 37% of normal weight subjects underreported severely.

The problem of overreporting was investigated by Mertz *et al.*[35] who found a total of 8% of subjects overreported their food intake compared to 81% of subjects who underreported. This suggests that overreporting is not a significant problem. Similar results were found as only ten subjects (6.7%) overreported.

Twenty subjects in this study suffered from the metabolic syndrome (17.4%). The prevalence of the metabolic syndrome did not differ between URs (12.5%) and non-URs (18.7%). Black *et al.*[3] found a higher prevalence of metabolic syndrome in male URs than in non-URs (18% and 9%, respectively, p=0.029).

The prevalence of underreporting in this study was rather low when compared to results from Pryer *et al.*[36] (women: 47%) and Ballard-Barbash *et al.*[33] (48% in normal weight and 71% in obese subjects), but not very different from Lafay *et al.*[7] (women: 15.8%). A possible reason for the difference in number of URs between studies might be due to the values used to define underreporting by EI/BMR. Goldberg *et al.*[1] stated that recorded energy intakes of below 1.35 x BMR either in individuals or populations are most unlikely to represent habitual intake. This is slightly higher than the 'survival' cut off limit of 1.27 x BMR[1]. The Goldberg cut-off can be used to evaluate the mean population bias in reported energy intake, but information on the activity or lifestyle of the population is needed to choose a suitable PAL energy requirement for comparison[37]. Subjects can then be assigned to low, medium or high PAL before calculating the cut-offs[37]. The EE within a subgroup (n=63) was measured and a low activity level was reported. For this reason 1.27 was used as a cut-off value to identify the URs. It can be argued that this cut-off point for URs in this study was too low, because this level of physical activity is equivalent to being sedentary or also to lying in bed. It has been shown that among free-living persons energy expenditure levels below 1.27 BMR are rare[31]. Hirvonen *et al.*[31] used the same cut-off value as in this study, whereas Pryer *et al.*[36] and Johansson *et al.*[8] used a cut-off value of <1.2 and Lafay *et al.*[7] used 1.05. Voss *et al.*[32] used 1.35 as cut-off and found approximately 40% of subjects to underreport. Lafay *et al.*[7] used 1.05 to determine that 16% of subjects underreported. The influence of the cut-off value used is also shown in a study by Okubo and Sasaki[10] where a cut-off of 1.56 yielded a total of 68% of subjects as URs, whereas 37% were URs with a 1.27 cut-off level.

The strength of this study lies in the measured physical activity (n=63) which allowed comparison of reported EI with calculated TEE (using the recommendations from the FAO/WHO/UNU[38]) and with TEE measured by means of accelerometry. The mean measured TEE was significantly higher than the calculated TEE. Furthermore, the mean reported EI was significantly lower than the measured TEE, which may indicate that the cut-off value used to identify URs might have been too low.

Vinken *et al.*[26] found that regression equations based on doubly labelled water (DLW) measurements of TEE appear to be more accurate than the recommended dietary allowances for predicting energy requirements in healthy, non-obese adults living in affluent countries. They found that measured PAL ranged from 1.21 to 2.57 with a mean of 1.80. This value is significantly higher than the mean adult energy requirements of ≥ 1.4 but < 1.6 times metabolic rate to qualify as being low active[39]. In a study by Ceesay *et al.*[40] it was found that mean sedentary EE was 1.38 times Schofield BMR or 1.35 times measured BMR. It is evident that measuring EE is more accurate than using estimation equations as these equations may estimate TEE lower. This can also be seen by the significant difference (p<0.01) between the measured and calculated TEE in all subjects, as well as URs and non-URs.

Sanuel-Hodge *et al.*[13] found when cut-off values were used based on data from TEE or BMR measured directly, a higher proportion of URs were found (93%) than using cut-offs based on methods using estimation (58%). This may also explain why this study yielded a lower percentage of URs when compared to other studies.

There is no single approach for estimating underreporting. A possible reason for discrepancies between studies could be the methods used to determine dietary intake. Methods may vary depending on dietary assessment techniques used. However, Black and Cole[27] stated that underreporting appears to be a function of individual characteristics rather than dietary methods. This is in line with results from Tooze *et al.*[41] who found underreporting to be prevalent with the use of both the QFFQ (variation was lowest) and the 24 hour recall when compared to the DLW method. Bedard *et al.*[12] found significant underreporting (35%) in 246 adults aged between 18-82 years when the semi-quantitative FFQ was used (in conjunction with photos of portion sizes of different foods and beverages). Macintyre *et al.*[19] found underreporting of 43% among black men and women using the same QFFQ that was used in this study. The fact that a lower percentage of URs (20.8%) was found in this study may be because the subjects were of Caucasian origin, had higher education and income levels and were of young age. Szabo[42] found a high prevalence of abnormal eating attitudes amongst young black South Africans. Thus, cultural differences may also partly explain the disparity.

As energy is provided by macronutrients it is self-evident that variations in absolute energy intake are directly related to absolute macronutrient intake. Therefore, it was necessary to investigate macronutrient intake independent of absolute energy intake. A frequently used method to express macronutrient intake relative to energy intake is to calculate the percentage of energy from a specific nutrient in the diet (nutrient density method)[32]. By use of this method it was found that macronutrient intake was associated with the ratio EI/BMR. URs had a lower percentage intake from carbohydrates ($p<0.05$) and a higher proportion of fat ($p<0.05$). However, various authors found that URs tend to underestimate the percentage energy intake from fat[2,32] possibly because of the well known relation between obesity and fat intake. More recently, high-carbohydrate diets became associated with obesity in the popular press. This may also explain why URs reported a lower intake from carbohydrates. In this study no relation was found between underreporting and consciously omitting food items considered "unhealthy" which opposes other study results[11], but confirms results of Black *et al.*[3]. There was a tendency for URs to have a higher percentage protein intake. Lafay *et al.*[7], Black *et al.*[3] and Voss *et al.*[32] found that URs reported a significantly higher percentage of energy from protein. Voss *et al.*[32] also found a lower percentage of energy from carbohydrates, which correlates with the findings in this study. Samuel-Hodge *et al.*[13] found no difference between reported intake of carbohydrates of type 2 diabetic URs and non-URs. All together, these data indicate that underreporting may be a major confounding bias in the assessment of macronutrient composition of the diet of subjects.

When an association between health and diet is studied, nutrient intakes are commonly adjusted for energy intake (EI). Nutrient densities are therefore a useful tool. The nutrient density of the diets of URs compared to non-URs was higher with respect to potassium, selenium and vitamin E but lower for riboflavin. Hirvonen *et al.*[31] also found that URs reported higher intakes of potassium and selenium ($p<0.001$) when compared to non-URs, but found a tendency towards lower intakes of vitamin E and higher intakes of riboflavin. Voss *et al.*[32] found that URs reported a significantly higher intake of fibre when expressed to energy intake. In this study the opposite was found, although this was not significant. Overall, these results indicated that there are few significant differences in energy related micronutrient intakes between URs and non-URs. With respect to food groups no significant difference was found in the intake of URs and non-URs. Pryer *et al.*[43] showed different dietary patterns in URs compared to non-URs.

Johansson *et al.*[8] indicated that smokers tend to underreport more often than non-smokers. This study included only 15 subjects who smoked and underreporting was not significantly higher among smokers. Age may also be related to underreporting. Sichert-Hellert *et al.*[44] found that underreporting increased positively with age. In this study a tendency was found of increased underreporting with younger age. This may be due to more pressure on younger people to be more health conscious. The subjects were from a higher income and education level which may possibly explain the lower percentage URs. Pryer *et al.*[36] found a greater degree of underreporting in subjects from a lower education level. However, Lafay *et al.*[7] showed that underreporting was lower among a higher education level. Additionally, this study showed no correlation between activity level and underreporting. This could be due to the fact that most subjects (URs as well as non-URs) fell in the low activity level.

Awareness of underreporting has become more common in recent years[31] and is a well recognized phenomenon that is unevenly distributed in populations. There is still debate as to how to deal with underreporting in dietary studies. Although it is suggested to improve the accuracy of data by excluding subjects with implausible low energy intakes from the analysis, this procedure leads to the exclusion of a high percentage of obese subjects and, therefore, might result in attenuated associations between exposure and outcome[44,32]. If this method was followed in this study, it would result in 11 obese, underreporting subjects (10%) being excluded. A possible solution may be to conduct larger studies. Discouraging results found that an underreporter on one occasion will remain an underreporter on other occasions and studies conducted among subjects who were highly motivated showed no guarantee of valid dietary reporting[27]. Sichert-Hellert *et al.*[44] concluded that the validity in dietary studies cannot be achieved by simply excluding URs. Also, it should be taken into consideration that different cut-off values are still used to define underreporting and this may result in potential missing of underreporting in subjects with energy intakes above the defined cut-off limit. During investigations concerning diet-disease relationships, studies need to include BMI or other methods of defining obesity. Considering the relation between underreporting and obesity, it seems to be a future task to find statistical solutions for this problem. Also, variables describing the composition of a diet in terms of the relative proportion of energy that is provided by a nutrient, absolute macronutrient intake values and total energy intake are influenced by underreporting which itself was associated with obesity.

Tooze *et al.*[41] suggested that using urinary nitrogen and doubly labelled water as biomarkers would be useful for adjusting the results of studies of diet and disease. It may be necessary to develop new instruments that discriminate better between URs and non-URs. For instance, additional information could be collected in dietary surveillance and epidemiologic studies of energy balance to identify URs and then to adjust for it[41]. Black and Cole[27] suggested measuring body weight before and after prospective records, as this may reveal dieting during a survey. Repeated dietary assessments will improve the precision of a measurement but it will not eliminate the bias.

In conclusion this study has found no specific subject characteristics that may point to URs. The homogeneous subject group (Caucasian origin, young women, high education and income level) may explain why only a small amount of subjects underreported when compared to other studies such as the one reported by Macintyre *et al.*[19] in a black African population. No association was found between metabolic syndrome and underreporting. Too few subjects that underreported were diagnosed with the metabolic syndrome (n=3) to be able to have statistical power. More research is necessary to determine the prevalence of underreporting in the South African population, which is known for its heterogeneity.

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CHAPTER 5: Conclusions and recommendations

5.1. Introduction

Numerous studies have shown that it is difficult to obtain a representative picture of what people usually eat, mainly because of large day-to-day variations in food intake, misreporting and changes in dietary habits during a given study period (Rosell *et al.,* 2003). Energy underreporting occurs in two to 85% and overreporting in one to 39% of various populations. Understanding why misreporting of energy intake occurs is complicated (Maurer *et al.*, 2006).

The identification of the psychosocial characteristics of energy misreporters is essential for the interpretation and understanding of the who, what and (most importantly) why of energy misreporting, which to date have been insufficiently described. Limited psychosocial inventories have been used to explore the association between psychosocial variables and energy misreporting (Maurer *et al.*, 2006).

Considering the impact that underreporting may have on dietary assessments, it is clear that the results and the inferences based on them might be seriously biased. Studies about underreporting should be conducted in developing nations because it is imperative to know the error associated with methods so widely used in population surveys, health policies, research and clinical practice. Until then, results obtained by means of these methods should be carefully considered and interpreted (Scagliusi *et al.,* 2006).

Although underreporting seems to be emerging in most populations, it is not extensively studied in the South African population. During this study, more light was shed on this phenomenon in a specific homogenous group of the South African population.

5.2. Summary of findings

Under conditions of energy balance, EI equals EE and the validity of EI may be determined by comparing these two measures. The DLW method is the gold standard for the determination of EE (Scagliusi *et al.,* 2006). However, conducting the DLW is expensive and in this study EE was calculated with standardized equations. URs were identified using the Goldberg equation, which compares EI with EE, both expressed as multiples of the BMR. The ratio of EI to BMR was calculated from the reported EI (by using the QFFQ) and estimated BMR. URs had reported energy intakes $<1.27 \times$ BMR and non-URs $\geq 1.27 \times$ BMR. TEE was calculated (n=115) and measured in a subgroup (n=63) by using the Actical accelerometer. Physical activity was also divided into three groups by using the Yale physical activity questionnaire.

Most of the women were overweight (45.8%) and 29.2% were obese but only 20 subjects presented with the metabolic syndrome. The prevalence of underreporting women with a food intake level (FIL; reported EI divided by estimated BMR) below 1.27 was relatively low (21%). Overreporting (FIL >2.4) was also low (6.7%). The prevalence of metabolic syndrome did not differ between URs and non-URs (12.5% and 18.7%, respectively). Most subjects were younger than 35 years (mean=33.2), highly educated and received a relatively high monthly income. The subjects fell mostly into the low activity category. URs had a statistically significantly ($p<0.05$) higher percentage energy intake from fat but lower from carbohydrates (37.4% and 42.9%, respectively) when compared to non-URs (33.5% and 47%; respectively). The mean intakes of most micronutrients were statistically significantly lower in the URs. However, expressed per energy unit, intakes of URs were significantly higher for potassium, selenium and vitamin E. When the food group intakes of URs and non-URs were compared no significant differences were found. Measured TEE was significantly higher in URs and non-URs (13 036kJ and 13 805kJ; respectively) compared to calculated TEE (10 105.8kJ and 10 220.3kJ; respectively). Measured TEE was also significantly higher than reported EI ($p<0.01$). It can be summarised that no specific subject characteristics were related to underreporting.

5.3. Limitations of the study

However few studies concerning underreporting have been conducted in developing nations and none of them has used DLW method (Scagliusi *et al.,* 2006) because of its expense. However, Coward (1998) stated that developing countries should make it a priority to consider the validation of dietary assessment methods by means of the DLW method. He also claimed that it would be difficult to monitor the effects of important interventions in developing countries (in other words interventions that focus on an increase in food supply and security without knowing the validity of the methods used to monitor food intake) (Coward, 1998). Therefore, the major limitation of this study was the method used to determine EE. The use of accelerometers together with equations and activity factors is an improvement but still not the most accurate method for identifying URs. The importance of DLW studies cannot be underestimated. Some authors suggest that the energy requirements of people from developing countries are lower than those of people from developed countries. If this is indeed the case, then the use of standard equations to calculate BMR may be even more inappropriate, since they may overestimate energy requirements of people from developing countries and, therefore, overestimate the number of individuals who underreport (Grillol *et al.*, 2005).

A further limitation of the study might have been the fact that the study group was a homogenous group. Although most of them were overweight or obese, the group consisted of only Caucasian women from a high education and income level. Dietary intake was ranked with more precision among subjects with these characteristics (Horner *et al.*, 2002). Most of the subjects in the present study had a low activity level and most were non-smokers. The FFQ was administered by experienced dieticians. This could explain in part the fact that a relatively low level of underreporting was found in this study. However, this could also point to characteristics that are not associated with underreporting.

The cut-off value used to determine URs was set at <1.27. It can be argued that the cut-off value was set too low and this may also have influenced the number of URs in the study. However, the ability of the Goldberg cut-off to identify individual URs remains limited. A more appropriate cut-off value may be set at 1.55, although it has been demonstrated that this approach identifies only ~50% of URs (Black, 2000a). A value lower than 1 is also not appropriate, as the absolute agreement between EI and EE is unlikely to happen. A cut-off value of 1.35 seems more appropriate as it was determined from studies with repeat DLW measurements and calculated as the 95% confidence limits of the distribution (Black & Cole, 2000). The cut-off value of 1.35 was taken as the mean of all of the very inactive calorimeter protocols in a study by Goldberg *et al.* (1991) and is slightly higher than the 'survival' limit of 1.27.

5.4. Recommendations for further research

The only way to advance knowledge in the field of dietary assessment methodology is to have researchers follow a careful methodology that overcomes the limitations of previously conducted studies (Scagliusi *et al.*, 2006). If dietary assessments are to be improved, there must be a full understanding of which foods and meals are misreported. More fundamentally, it needs be understood why people misreport food intake. Dieticians are trained mainly in the biological sciences and thus it is likely that they have failed to appreciate fully that dietary assessments depend on a complex interplay of cognitive and behavioural processes such as language, interpersonal communication and mutual understanding between subject and researcher. How do people think about and describe foods? How do people process information about the foods they eat? Is it possible to evaluate the comprehension and reporting abilities of the population? If the nature and the sources of bias in dietary reporting are to be identified, dieticians must go beyond the narrowly mechanistic focus of measurement of intake and examine the social, cultural and psychological context of such reporting. For example, a relatively unresearched area is the role that the investigators themselves play in enhancing or hindering the reporting process. General conduct toward subjects, unconscious body language, phraseology, voice intonation, unconscious attitudes and many other aspects of behaviour may unwittingly contribute to the problem. When better understanding of the how, why and what of dietary reporting has been achieved, then perhaps improved techniques for reporting food intake can be developed (Black & Livingstone, 2003).

The following objective measures of underreporting in future studies are suggested:

1. Using more diverse populations;
2. Taking into account undereating accompanied by a decline in body mass over the food-recording interval. Undereating is defined as [(body mass change in recording week x 30MJ / 7 days) / (EE)] x 100% (Livingstone & Black 2003);
3. Using additional biomarkers, such as urinary nitrogen, that could assist in determining whether underreporting varies by macronutrient source;
4. Comparing underreporting rates among several dietary assessment methods and verifying which method works better (or has lower over and underreporting ratios) for each type of person. However, observational studies found that subjects underestimated their food intake independently of the dietary assessment method used (Scagliusi *et al.,* 2006);
5. Using psychosocial measures to elucidate certain psychological characteristics associated with under and overreporting in the South African population;
6. Determining how psychosocial variables influence the accuracy of self-reported EI in different populations (e.g., ethnicity, gender, education, socioeconomic status and age) (Maurer *et al.,* 2006);
7. Incorporating the effect of psychosocial factors into the materials and methods used for collecting dietary data (Maurer *et al.,* 2006);
8. Establishing pertinent inclusion and exclusion criteria, avoiding the recruitment of individuals who are not in energy balance (such as undernourished, ill, or dieting individuals) (Scagliusi *et al.,* 2006);
9. Measuring the BMR by the indirect calorimetry method provides a valid measure of physical activity level, which could be a factor influencing underreporting;

5.5. Suggested methods to decrease over or underreporting

As the ability to identify underreporters of dietary EI improves, it may seem that the next logical step would be to address what to do about underreporters of true intake (Trabulsi & Schoeller, 2001). Practical guidelines on handling underreporting are necessary (Black & Cole, 2001). Proposed ideas to account for the reporting error have focused around two methods:

1. Removing the underreporters from the data set, or
2. Statistically correcting 'reported' intake to represent true intake (Trabulsi & Schoeller, 2001). Black & Cole (2001) suggest that if possible, means of validating the results should be built into dietary studies. Also, guidance from statisticians both in designing studies and analysing flawed data is essential (Black & Cole, 2001).

Underreporting is not random and a high prevalence of underreporting may lead to bias in associations between food intake patterns and certain health outcomes. In particular, associations between dietary intakes and obesity or obesity-related health problems may be affected (Mendez *et al.*, 2004). For this reason it is also not recommended to exclude underreporters from the data set as this introduces unknown bias into the data set and may also eliminate those subjects of greatest interest to the scientific questions posed (Livingstone & Black, 2003). Livingstone and Black (2003) suggest that all subjects should be included and energy adjustments should be made. However, this approach cannot eliminate bias due to selective underreporting of foods, nor does it provide corrected estimates of absolute nutrient intake.

In studies assessing the causes and consequences of misreporting, the identification of URs at the individual level is vital. Given the fact that the DLW technique measuring EE for EI validations is available to only a few research centres, alternative techniques for measuring expenditure such as heart rate monitoring, accelerometers or physical activity questionnaires need to be evaluated for their sensitivity and specificity for the detection of URs (Livingstone & Black, 2003).

A broader understanding of the psychosocial factors associated with energy misreporting would provide a basis for the adjustment of select confounders when necessary. The ability to make adjustments in study populations affected by energy under and overreporting would greatly enhance the reliability of research outcomes, reduce the risk of health or disease risk underestimation and overestimation and improve understanding between nutrition, health and disease relationships (Maurer *et al.*, 2006). It is, therefore, critical that researchers accept that energy misreporting exists in certain population groups and be certain before conclusions can be drawn out of data pertaining to disease relationships.

5.6. Conclusions

It is evident that the physical and psychological characteristics of study participants play a significant role in the underreporting bias observed in studies (Trabulsi & Schoeller, 2001). During an in-depth review by Maurer *et al.* (2006) several psychosocial factors were linked to the accuracy of self-reported EI. Higher social desirability and higher eating restraint had a clear association with underreporting. Energy misreporting was moderately linked to a history of dieting and being overweight (Maurer *et al.*, 2006). Thus, identifying persons who are likely to underestimate food intake may help to pinpoint those who are at risk for developing obesity or who may have particular difficulty in reducing body weight, as these persons are clearly less aware of their energy intake (Novotny *et al.*, 2003). Insufficient research exists to evaluate and describe the psychosocial associations with energy overreporting (Maurer *et al.*, 2006).

The fact that problems are associated with systematic bias in dietary assessments does not mean that dietary studies should be abandoned. The study of nutrition cannot be isolated from the reality of food intake. Nutritional health is ultimately dependant on the availability and composition of food and the choices made by the individual in the selection of his or her diet. Future cross-disciplinary research should establish the limits of dietary data such that valid conclusions about the relationships between nutrition and health can be drawn from a complete understanding of that data (Livingstone & Black, 2003).

This study found no relationship between underreporting and the characteristics which were considered. This is in line with findings from a review done by Scagliusi *et al.* (2006) that found no pattern of underreporting in developing countries. These authors quoted only one study that was done in South Africa to determine underreporting in a group of black South Africans (MacIntyre *et al.*, 2000a). This current study will be one of the first that was done on a Caucasian South African population. Considering the fact that there is a great deal of variability between and even within countries (Scagliusi *et al.*, 2006), it is evident that significant gaps exist in the understanding of over and underreporting specifically in developing countries such as South Africa, which suggests the need for continued research.

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Addenda

FOOD FREQUENCY QUESTIONNAIRE

INSTRUCTIONS: Circle the subject's answer. Fill in the amount and times eaten in the appropriate columns.

SUBJECT NO: ....

I shall now ask you about the type and the amount of food you have been eating in the last few months. Please tell if you eat the food, how much you eat and how often you eat it. We shall start with maize meal porridge.

Do you eat maize meal porridge? YES 1 NO 2
If YES, what type do you have at home now?

Brand name: ....
Don't know 2
Grind self 3

If brand name given, do you usually use this brand?
YES 1 NO 2 DON'T KNOW 3
Where do you get your maize meal from? (May answer more than one)

Shop	1
Employer	2
Harvest and grind self	3
Other – specify	4
Don't know	5

FOR OFFICE USE

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Maize meal porridge	Stiff ('pap')						e4225 4250	
Maize meal porridge	Soft ('slap pap')						e4225 4250	
Do you pour milk on your soft porridge? YES 1 NO 2 If YES, what type of milk (whole fresh, sour, 2 %, fat free, milk blend)? .... INSTRUCTION: Show subject examples.								
If YES, how much milk?								
Do you pour sugar on your soft porridge? YES 1 NO 2								
If YES, how much sugar?							9012	
Maize meal porridge	Crumbly (phutu)						e4225 4250	
Ting								
Mabella Coarse Fine Rice	Stiff						4082	
Mabella Coarse Fine Rice	Soft						4082	

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Do you pour milk on your mabella porridge? YES 1 NO 2 If YES, what type of milk (whole fresh, sour, 2 %, fat free, milk blend)? .... INSTRUCTION: Show subject examples.								
If YES, how much milk?								
Do you pour sugar on your mabella? YES 1 NO 2								
If YES, how much sugar?							9012	
Oats							4032	
Do you pour milk on your oats? YES 1 NO 2 If YES, what type of milk (whole fresh, sour, 2 %, fat free, milk blend)? .... INSTRUCTION: Show subject examples.								
If YES, how much milk?								
Do you pour sugar on your oats? YES 1 NO 2								
If YES, how much sugar?							9012	
Breakfast cereals	Brand names of cereals at home now: Don't know						4036	
Do you pour milk on your cereal? YES 1 NO 2 If YES, what type of milk (whole fresh, sour, 2 %, fat free, milk blend)? .... INSTRUCTION: Show subject examples.								
If YES, how much milk?								
Do you pour sugar on your cereal? YES 1 NO 2								
If YES, how much sugar?							9012	
Samp	Bought Self ground with fat without fat						4043	
Samp and beans							A014	
	Are the amounts of samp and beans the same as in the picture? YES NO If NO, do you use more beans than in the picture or less? MORE LESS							
Samp and peanuts							A013	
	Are the amount of samp and peanuts the same as in the picture? YES NO If NO, do you use more peanuts than in the picture or less? MORE LESS							
Rice	White Brown Maize rice						4040 4134 4043	
Pastas	Macaroni Spaghetti Other						4062	

FOOD		**DESCRIPTION**	*Amount*	**TIMES EATEN**				**CODE**	**AMOUNT/ DAY**
				Per day	**Per week**	**Per month**	**Seldom Never**		
You are being very helpful. Can I now ask you about meat? CHICKEN, MEAT, FISH How many times per day/week do you eat meat, fish or chicken? ....X/day ....X/week									
Chicken:	Boiled, nothing added							1521	
	Fried: in butter/crumbs Not coated							1634 1520	
	Roasted, grilled							1520	
	Stewed							1520	
	What vegetables are in the stew?								
	Don't know								
Do you eat chicken skin? ALWAYS 1 SOMETIMES 2 NEVER 3									
Chicken bones stew								A003	
Chicken feet		How do you cook it?						A004 1609	
Chicken offal		How do you cook it?						1610	
Red meat:		How do you like meat? With fat Fat trimmed							
Beef		Fried – with bone							
		Fried – without bone							
		Stewed – with bone						A001	
		Stewed – without bone						A001	
		Grilled – with bone							
		Grilled – without bone							
		Minced						1585	
Mutton		Fried – with bone						1522	
		Fried – without bone						1571	
		Stewed – with bone						1511	
		Stewed – without bone						1511	
		Grilled – with bone							
		Grilled – without bone							
		Minced						1662	

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Pork	Fried – with bone							
	Fried – without bone							
	Stewed – with bone							
	Stewed – without bone							
	Grilled – with bone							
	Grilled – without bone							
Beef Offal	Intestines: boiled, nothing added						161	
	Stewed with vegetables							
	Tripe						1546	
	Heart						1565	
	Lungs							
	Liver						1515	
	Kidneys						1518	
	Other specify:							
What vegetables are usually put into meat stews?								
Wors sausage	Fried Grilled						1526	
Bacon							1501	
Cold meats	Polony						1514	
	Ham						1564	
	Viennas						1531	
	Other specify:							
Canned meat	Bully beef						1535	
	Other specify:							
Meat pie	Home made Bought						1548	
Hamburger	Home made Bought						A015	
Dried beans, peas, lentils	How do you prepare them?							
Soya products e.g. Toppers	Brands at home now Don't know........ Show examples						3527	
Pilchards in tomato chilli brine	Whole						2557	
	Mashed with fried onion						A005	
Fried fish	With batter/ crumbs						2523	
	Without batter/crumbs						2509	
Other canned fish	Tuna							
	Pickled fish Other:						2562	
Fish cakes	Home made (describe) Frozen Bought						2531	

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	**Per week**	**Per month**	**Seldom Never**		
Eggs	Boiled poached Scrambled Fried						1001 1025 1003	
WE NOW COME TO VEGETABLES AND FRUIT How many times per day/week do you eat vegetables? ………….X/day ……………X/week								
Cabbage	How do you cook cabbage?							
	Boiled, nothing added							8066
	Boiled with potato and onion and fat							A006
	Fried, nothing added							A007
	Boiled, then fried with potato, onion							A006
	Other:							
	Don't know							
Spinach / morogo / other green leafy	How do you cook spinach?							
	Boiled, nothing added						8071	
	Boiled fat added						8209	
	Boiled with – onion, tomato & fat						A011	
	-onion, tomato & potato						8212	
	- with peanuts							
	Other:							
	Don't know							
Tomato and onion 'gravy'	Home made - with fat - without fat						 A012 A016	
	Canned (Is this the amount of pap you eat? How much more or less?)						8221	
Pumpkin	How do you cook pumpkin?							
	Cooked in fat & sugar						A010	
	Boiled, little sugar and fat						A009	
	Other:							
	Don't know							

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Carrots	How do you cook carrots?							
	Boiled, sugar & fat						8129	
	With potato/ onion						A008	
	Raw, salad Chakalaka						8015 A025	
	Other:							
	Don't know							
Mealies / Sweet corn	How do you eat mealies? On cob –with fat -without fat						8033	
	Off cob –with fat -without fat						8261	
Beetroot salad	Home made Bought						8005	
Potatoes	How do you cook potatoes?							
	Boiled/baked - with skin						8046	
	- without skin						8045	
	Mashed						8187	
	Roasted						8189	
	French fries						8048	
	Salad						8236	
	Other:							
Sweet potatoes	How do you cook sweet potatoes?							
	Boiled/baked - with skin						8057	
	- without skin						8214	
	Mashed						8058	
	Other:							
	Don/t know							
Salad vegetables	Raw tomato						8059	
	Lettuce						8031	
	Cucumber						8025	
Other vegetables specify:								
FRUIT: Do you like fruit? YES NO How many times per day/week do you eat fruit? ....X/day ....X/week								

FOOD	DESCRIPTION	Amount	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Apples/Pears	Fresh						7001	
Pears	Fresh Canned						7053 7054	
Bananas							7009	
Oranges / naartjies							7031	
Grapes							7020	
Peaches	Fresh Canned						7036 7038	
Apricots	Fresh Canned						7003 7004	
Mangoes	Fresh						7026	
Guavas	Fresh Canned						7021 7023	
If subject eats canned fruit: Do you have custard with canned fruit? YES 1 NO 2								
Custard	Home made Ultramel						0004	
Wild fruit / berries	Stamvrugte Noen-noem Klappers Maroelas Nastergals Other – specify						7070	
Dried fruit:	Types:							
Other fruit:								
BREAD AND BREAD SPREADS								
Bread Bread rolls	White						4001	
	Brown						4002	
	Whole wheat						4003	
Do you spread anything on the bread? ALWAYS 1 SOMETIMES 2 NEVER 3 If YES, what do you spread?								
Margarine	What brand do you have at home now? .... Don't know Show examples						6508 6521	
Butter	What brand do you have at home now? .... Home made Don't know						6502	

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Peanut butter							6509	
Jam/syrup/ honey							9008	
Marmite/Fray Bentos etc.							9501	
Fish/meat paste							1512	
Cheese	Type:						0010	
Atchar							3004	
Polony							1514	
Other spreads: specify								
Dumpling							4001	
Vetkoek							4057	
Provita, crackers etc.								
FATS: What fats do you use and where do you use them?								
Margarine	Where used: on bread							
	with vegetables** Number of spoons .... /number in family							
Butter	on bread with vegetables** Number of spoons .... /number in family							
Holsum / vegetable fat	Where used: Number of spoons .... /number in family						6508	
Oil	Where used: Number of spoons .... /number in family						6510	
Dripping	Where used: Number of spoons .... /number in family							
Mixed fat (makhuru)	Where used: Number of spoons .... /number in family							

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
Lard	Where used: Number of spoons ………. /number in family …………						6520	
Mayonnaise/ salad dressing	Number of spoons ………. /number in family …………						6573	
Cream	Fresh/Long life /canned Orley whip						6503	
DRINKS:								
Tea							9514	
Sugar/cup tea							9012	
Milk / cup tea	What type of milk do you use in tea?							
	Fresh / long life whole						0006	
	Fresh / long life 2%							
	Fresh / long life fat free						0072	
	Whole milk powder Brand …………						0009	
	Skimmed milk powder Brand …………						0008	
	Milk blend Brand …………						0068	
	Whitener Brand …………						0039	
	Condensed milk						0002	
	Evaporated milk						0003	
	None							
Coffee								
Sugar / cup coffee							9012	
Milk / cup coffee	What type of milk do you use in coffee?							
	Fresh / long life whole						0006	
	Fresh / long life 2 %							
	Fresh / long life fat free						0072	
	Whole milk powder Brand …………						0009	
	Skimmed milk powder Brand …………						0008	
	Milk blend Brand …………						0068	
	Whitener Brand …………						0039	

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per week	Per month	Seldom Never		
	Condensed milk						0002	
	Evaporated milk						0003	
	None							
Milk as such	What type of milk do you drink as such?							
	Fresh / long life whole						0006	
	Fresh / long life 2 %							
	Fresh / long life fat free						0072	
	Sour / Maas						0006	
	Buttermilk						0001	
	Whole milk powder Brand						0006	
	Skimmed milk powder Brand						0072	
	Milk blend Brand						0068	
Milk drinks Brand	Nestle Milo Other						0023	
Yoghurt	Drinking yoghurt Thick yoghurt						0044 0020	
Squash	Sweeto SixO Oros/Lecol - with sugar - artificial sweetner Kool Aid Other						9013 9013 9002 9013 9002	
Fruit juice	Fresh/Liquifruit/Ceres Tropica Concentrates e.g. Halls Nectars Flavour							
Fizzy drinks Coke, Fanta	Sweetened Diet						9001 9013	
Mageu/Motog o							9562	
Home brew							9516	
Tlokwe							9516	
Beer							9506	
Spirits							9510	
Wine red							9508	
Wine white							9518	
Liqueur							9517	
Other: specify								

FOOD	**DESCRIPTION**	***Amount***	**TIMES EATEN**				**CODE**	**AMOUNT/ DAY**
			Per day	**Per week**	**Per month**	**Seldom Never**		
SNACKS AND SWEETS:								
Potato crisps							4275	
Cheese curls Niknaks etc.							4067	
Peanuts	Raw Roasted						6001 6007	
Raisins							7022	
Peanuts and raisins								
Chocolates	Name						9024	
Candies	Sugars, gums, hard sweets						9009	
Sweets	Toffees, fudge, caramels						9014	
Biscuits	Type							
Cakes & tarts	Type							
Scones							4029	
Rusks							4160	
Savouries	Sausage rolls Samoosas Biscuits e.g. Bacon kips Other						1534 4196 4162	
PUDDINGS:								
Canned fruit	Type							
Jelly							9004	
Custard	Homemade Ultramel						0004	
Baked pudding							4181	
Instant pudding							4066	
Ice cream Sorbet							6507 6516	
Other: specify								
SAUCES / GRAVIES / CONDIMENTS:								
Atchar							3004	
Tomato sauce Worcester sauce							3027	
Chutney							9524	
Pickles							8176	
Packet soups							3046	
Others:								
INSECTS:								
Locusts								
Mopani worms								
Others:								

FOOD	DESCRIPTION	*Amount*	TIMES EATEN				CODE	AMOUNT/ DAY
			Per day	Per Week	Per month	Seldom Never		
WILD BIRDS OR ANIMALS (hunted in rural areas or on farms)								
MISCELLANEOUS: Please mention any other foods used more than once/two weeks which we have not talked about:								

Use of salt and vitamins:

What type of salt do you use? Fine iodised (1)............ Coarse (2).........

Do you add salt ro food while it is cooked? Yes (1) ...... No (2) ....

Do you add to you food salt at the table?Yes (1)...... No (2) ....

Do you eat salty food (salted peanuts, chips)? Often .....Seldom.....Never ......

(1) (2) (3)

Do you take any vitamin tablets or syrup, other than those supplied by the clinic?

Yes (1) .... No (2) ....

Table A1: Previous research investigating characteristics of energy URs.

Table 3.1 Previous research investigating characteristics of energy underreporters (Maurer *et al.*, 2006)

			Reported energy intake (kJ)		
Reference	**Subjects**	**Results**	**Non-URs**	**URs**	**Underreported kJ (% difference[*])**
		Demographics			
Briefel *et al.*, 1997	7769 M & F adults	URs more overweight, less educated compared with non-URs; weight status was largest predictor of underreporting.	F: 8455 ±84.1 M: 12100 ±158.5	F: 4096 ± 36.7 M: 5408 ±86.0	NR
Johansson *et al.*, 1998	3020 M & F adults	URs had higher BMI compared with non-URs; OR were younger and leaner than non-URs.			
Kretsch *et al.*, 1999	22 F adults	For normal weight females, BMI was inversely correlated with percent underreporting.	NR	NR	-282 ±632 (-9.7 ±24.8)
Lafay *et al.*, 1997	1030 M & F >15 years	URs were significantly more obese than non-URs	BMI< 27: 9470 ±2340 BMI> 27: 10150 ±2250	BMI< 27: 5520 ±1220 BMI> 27: 6400 ±1350	NR
Novotny *et al.*, 2003	98 M & F adults	Underreporting occurred more often in females and was correlated with % body fat in both genders	NR	NR	F: -479 ±548 M: -86 ±803
Price *et al.*, 1997	1898 M & F adults	Underreporting was associated with higher BMI	F: 8440 ±1490 M: 10950 ±2070	F: 5520 ±920 M: 7100 ±1060	NR
Taren *et al.*, 1999	37 F adults	Age and % body fat were the best predictors of reporting accuracy	9330 ±2710[†]	8250 ±2620[‡]	-12

Tooze *et al.*, 2004	484 M & F adults	Among both females and males, odds of underreporting increased with higher BMI	F: 9550[†] M: 11770[†]	F: 7910[‡] M: 10450[‡]	F: -17.2 M: -11.3
Diet					
Briefel *et al.*, 1997	7769 M & F adults	URs reported lower fiber and fat intake and higher carbohydrate intake compared with non-URs; number of foods recalled was best predictor of underreporting	F: 8455 ±84.1 M: 12100 ±158.5	F: 4096 ±36.7 M: 5408 ±86.0	NR
Johansson *et al.*, 1998	3020 M & F adults	URs consumed fewer foods high in fat and sugar but higher meat, potato and fish compared with non-URs.	F: 4000 ±1660 M: 12800 ±2200	F: 6400 ±1660 M: 8400 ±1200	NR
Lafay *et al.*, 1997	1033 M & F adults	URs consumed lower percentages of energy from fat and carbohydrates compared with non-URs due to reporting less consumption of butter, french fries, sugar, cakes and pastries; underreporting did not occur because of inaccurate portion estimation	F: 8600 ±100 M: 11200 ±100	F: 5100 ±200 M: 7400 ±200	NR
Poppitt *et al.*, 1998	36 F	The major cause for underreporting in the obese was the omission of snacks between meals; slight support for URs reporting less carbohydrates but not less fat or protein	15400 ±4800[†]	13300 ±4600[‡]	(-12.5)
Vuckovic *et al.*, 2000	73 F	Focus groups revealed that five factors influenced reporting of food/drink portion size: 1) role in meal, 2) type of food, 3)	NR	NR	NR

		personal preference for the food, 4) serving size of product and 5) comparison of personal serving size with that of others			
Dieting / Weight history					
Briefel *et al.*, 1997	7769 M & F adults	53% of female and 39% of male URs were trying to lose weight	F: 8455 ±84.1 M: 12100 ±158.5	F: 4096 ±36.7 M: 5408 ±86.0	NR
Heitmann *et al.*, 1993	323 M & F adults	There was more underreporting with a history of dieting and weight problems; dieters underreported more than others	NR	NR	NR
Johansson *et al.*, (1998)	3020 M & F adults	URs compared with non-URs were more likely to desire to reduce their weight; majority of ORs desired to increase body weight	F: 4000 ±1660 M: 12800 ±2200	F: 6400 ±1660 M: 8400 ±1200	NR
Lafay *et al.*, 1997	1030 M & F >15 years	Odds ratio for underreporting was 3.36 (2.47 when adjusted for age, sex, BMI and interactions) for those reporting having dieted at least once since the age of 14 years	BMI <27: 9470 ±2340 BMI >27: 10150 ±2250	BMI <27: 5520 ±1220 BMI >27: 6400 ±1350	NR
Novotny *et al.*, 2003	98 M & F adults	Underreporting was correlated with attempted weight loss/previous 12 months (β = -389 kcal underreport for attempting weight loss) and reported weight gain over the previous 10 years	NR	NR	F: -479 ±548 M: -86 ±803

Price *et al.*, 1997	1898 M & F adults	Underreporting was associated with more recent and longer duration of being overweight and more weight fluctuations	F: 8440 ±1490 M: 10950 ±2070	F: 5520 ±920 M: 7100 ±1060	NR
Tooze *et al.*, 2004	484 M & F adults	Among females, the likelihood of underreporting increased if person had lost ≥4.54 kg multiple times; among males the odds of underreporting increased as the number of previous diet attempts increased	F: 9550[†] M: 11770[†]	F: 7910[‡] M: 10450[‡]	F: -17.2 M: -11.3
Eating restraint					
Asbeck *et al.*, 2002	55 F, 28 M adults	High eating restraint was associated with a higher degree of underreporting.	F: 9374 ±1725 M: 13 046 ±2077	F: 6502 ±1080 M: 10053 ±1599	F: -5334 ±1141 M: -242 ±1248
Bathalon *et al.*, 2000	60 F postmenopausal	Compared with URs, REs reported diets lower in fat and energy density and higher in protein; energy intake was lower in REs	NR	NR	URs: -8 to +7 REs: -6 to -14
de Castro *et al.*, 1995	201 M, 157 F adults	Compared with low eating restraint, adults with high eating restraint reported less fat, cholesterol and carbohydrate intake; fat primarily suppressed by restraint; REs have lower energy requirements so their lower reported energy intake is not below what they need	NR	NR	NR

Hill *et al.*, 2001	Children and adults	REs underreported more than URs	NR	NR	NR
Kretsch *et al.*, 1999	22 F adults	No associations were found between eating restraint and underreporting	NR	NR	-282 ±632 (-9.7 ±24.8)
Lafay *et al.*, 1997	1030 M & F >15 years	Engaging in dietary restraint was significantly associated with underreporting regardless of weight, age or gender	BMI <27: 9470 ±2340 BMI >27: 10150 ±2250	BMI <27: 5520 ±1220 BMI >27: 6400 ±1350	NR
Poppitt *et al.*, 1998	36 F	URs consumed slightly more kilojoules compared with REs	15400 ±4800[†]	13300 ±4600[‡]	(-12.5)
Tooze *et al.*, 2004	484 M & F adults	Males scoring higher on the eating restraint scale, were more than three times as likely to underreport	F: 9550[†] M: 11770[†]	F: 7910[‡] M: 10450[‡]	(F: -17.2) M: -11.3
Eating disinhibition					
Asbeck *et al.*, 2002	55 F, 28 M adults	Eating disinhibition influenced underreporting in males only	F: 9374 ±1725 M: 13046 ±2077	F: 6502 ±1080 M: 10053 ±1599	F: -5334 ±1141 M: -242 ±1248
Physical activity					
Briefel *et al.*, 1997	7769 M & F adults	URs reported lower leisure physical activity	F: 8455 ±84.1 M: 12100 ±158.5	F: 4096 ±36.7 M: 5408 ±86.0	NR
Social desirability					
Herbert *et al.*, 1997	759 M & F adults	Underreporting was associated with social desirability among females.	NR	NR	NR
Herbert *et al.*, 2001	93 F adults	Underreporting was associated with social desirability among females.	NR	NR	NR

Horner *et al.*, 2002	102 F postmenopausal	Underreporting was associated with higher social desirability using the MCSDS	NR	NR	-1105 ±2452
Novotny *et al.*, 2003	98 M & F adults	Underreporting was associated with social desirability.	NR	NR	F: -479 ±548 M: -86 ±803
Taren *et al.*, 1999	37 F adults	Reporting accuracy was negatively associated with social desirability using the MCSDS	9330 ±2710†	8250 ±2620‡	(-12)
Tooze *et al.*, 2004	484 M & F adults	Reported intake from 24-hour recall underreporting was associated with social desirability in females	F: 9550† M: 11770†	F: 7910‡ M: 10450‡	(F: -17.2 M: -11.3)
		Body image			
Horner *et al.*, 2002	102 F postmenopausal	Underreporting was not influenced by body size dissatisfaction as assessed by Stunkard-Sorensen silhouettes	NR	NR	-1105 ±2452
Novotny *et al.*, 2003	98 M & F adults	Underreporting was correlated with dissatisfaction with current body weight.	NR	NR	F: -479 ±548 M: -86 ±803
Taren *et al.*, 1999	37 F adults	Reporting accuracy was negatively associated with body size dissatisfaction as assessed by Stunkard-Sorensen silhouettes	9330 ±2710†	8250 ±2620‡	(-12)
Tooze *et al.*, 2004	484 M & F adults	Among females, perceived body size from Stunkard-Sorensen silhouettes was significantly higher in URs compared with non-URs; among males, URs reported	F: 9550† M: 11770†	F: 7910‡ M: 10450‡	(F: -17.2 M: -11.3)

		more body size dissatisfaction compared with non-URs			
Psychology					
Kretsch *et al.*, 1999	22 F adults	For obese females, the lower the BDI score, the higher the chance for underreporting.	NR	NR	-282 ±632 (-9.7 ±24.8)
Tooze *et al.*, 2004	484 M & F adults	Reported intake from FFQ and 24-hour recall showed that underreporting was associated with fear of negative evaluation in females	F: 9550† M: 11770†	F: 7910‡ M: 10450‡	(F: -17.2 M: -11.3)

Male = M

Female = F

BDI = Beck depression index

MCSDS = Marlowe-Crowne social desirability scale

NR = Not reported

ORs = overreporters

REs = restrained eaters

*% Difference = Percent differentiation from estimated/measured energy expenditure; a negative value equals underreporting

†Measured or observed energy intake

‡Self-reported energy intake

(Maurer *et al.*, 2006)