

Assessing dietary intake: Who, what and why of under-reporting

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Abstract

Under-reporting of food intake is one of the fundamental obstacles preventing the collection of accurate habitual dietary intake data. The prevalence of under-reporting in large nutritional surveys ranges from 18 to 54 % of the whole sample, but can be as high as 70 % in particular subgroups. This wide variation between studies is partly due to different criteria used to identify under-reporters and also to non-uniformity of under-reporting across populations. The most consistent differences found are between men and women and between groups differing in body mass index. Women are more likely to under-report than men, and under-reporting is more common among overweight and obese individuals. Other associated characteristics, for which there is less consistent evidence, include age, smoking habits, level of education, social class, physical activity and dietary restraint.

Determining whether under-reporting is specific to macronutrients or food is problematic, as most methods identify only low energy intakes. Studies that have attempted to measure under-reporting specific to macronutrients express nutrients as percentage of energy and have tended to find carbohydrate under-reported and protein over-reported. However, care must be taken when interpreting these results, especially when data are expressed as percentages. A logical conclusion is that food items with a negative health image (e.g. cakes, sweets, confectionery) are more likely to be under-reported, whereas those with a positive health image are more likely to be over-reported (e.g. fruits and vegetables). This also suggests that dietary fat is likely to be under-reported.

However, it is necessary to distinguish between under-reporting and genuine under-eating for the duration of data collection. The key to understanding this problem, but one that has been widely neglected, concerns the processes that cause people to under-report their food intakes. The little work that has been done has simply confirmed the complexity of this issue. The importance of obtaining accurate estimates of habitual dietary intakes so as to assess health correlates of food consumption can be contrasted with the poor quality of data collected. This phenomenon should be considered a priority research area. Moreover, misreporting is not simply a nutritionist's problem, but requires a multidisciplinary approach (including psychology, sociology and physiology) to advance the understanding of under-reporting in dietary intake studies.

Introduction

Few people will dispute the fact that one of the most fundamental problems facing nutritional research is the inability to assess dietary intake accurately. Despite efforts to develop more

accurate methods and improve existing ones to assess dietary intake, we fail to escape the rudimentary problem of under-reporting. Whether this issue will ever be fully understood and resolved remains debatable. One expert recently commented "...dietary intake cannot be estimated without error and probably never will" (Beaton, 1994).

Perhaps of equal concern is the reluctance to acknowledge this problem openly; for while under-reporting is not a new issue in nutritional research, until recently it has been given little or no consideration in dietary studies. Garrow (1995) aptly described dietary under-reporting as the "nutritionists' guilty secret". Summarizing the issue, Garrow (1995) emphasized the reluctance to acknowledge the problem, by adding "... it is only whispered among nutritionists when we believe that we are unlikely to be overheard". It is important to clarify that although this review is about 'under-reporting', more accurately we should refer to 'misreporting' or 'invalid reporting' which could include both over- and under-reporting. It is recognized, however, that during this particular period in the last decade of the twentieth century, the most widespread and problematic issue is 'under-reporting' or 'low-energy' reporting. Accordingly, this will be the main feature of this review.

Early studies did draw attention to the problem of under-reporting, for example Hallfrisch *et al.* (1982) found that men and women reported energy intakes (based on 7-d food records) that were 500 kcal and > 900 kcal respectively lower than their energy requirements for weight maintenance. This paper, however, appeared to have little impact on the question of the reliability of dietary intake data. It was not until later publications, particularly by Goldberg *et al.* (1991) and Black *et al.* (1991), that interest and concern about under-reporting was heightened and began to be accepted more widely as a major problem.

Why is there such resistance to acknowledging this problem which is so fundamental and common to us all? The complex, confounding nature of under-reporting is clearly one of the reasons (Schoeller, 1990; Garrow, 1995; Klesges *et al.* 1995; Livingstone, 1995). Much more information is required to understand fully who is likely to under-report, what is being under-reported and most importantly why are they doing it?

There are many reasons why it is important to obtain accurate assessments of habitual intakes of foods consumed by populations or subgroups. A knowledge of habitual foods consumed is needed to obtain values for energy consumed, macronutrients and micronutrients. For individuals living a normal life the only practical way to obtain this information is some form of self-reporting and self-monitoring of food intake. People must therefore record and report all the food and drink they consume using either prospective (e.g. food diaries) or retrospective methods (e.g. 24 h recalls, food frequency questionnaires) (see Bingham, 1987). Why is this such a difficult task for human beings to carry out? Why are people reluctant to report the food they eat? The inability to report food intake accurately has created the problem of under-reporting and its many implications.

The need to understand under-reporting can be appreciated when relationships between nutrient intakes and health are considered. The aetiology of diseases related to nutrition is obviously dependent on the accuracy of dietary intake data. Obesity is a classic example of a phenomenon where dietary under-reporting still hinders understanding. For many years it was believed, based on self-reported dietary intake data, that obese individuals, on average, ate less than lean subjects. From these intake data it was assumed that obesity was caused by a metabolic defect resulting in lower energy expenditure, rather than excessive energy intake. With the development, however, of techniques to measure energy expenditure, particularly under free-living conditions, e.g. doubly labelled water (DLW), a number of studies found the converse of this assumption to be true (Prentice *et al.* 1986; Lichtman *et al.* 1992). The obese, rather than having lower levels of energy expenditure than lean subjects, actually had sig-

nificantly higher levels. Thus, doubt was cast on the accuracy of self-reported dietary intakes, especially among the obese. It is from these classic studies that real interest (and concern) has grown to understand the principles of under-reporting and the impact it is having on interpreting relationships between diet and disease.

The key questions, therefore, which will be considered in this review are *who* is under-reporting, *what* is being under-reported and *why* are they under-reporting? First, however, it is necessary to be clear about what is meant by under-reporting in order to determine the magnitude of the problem.

Processes involved in dietary under-reporting?

What is a valid dietary record? Black *et al.* (1991) describe it as “one in which the subject ate as (s)he would have done had (s)he not been under observation”. During a recording period an individual’s intake may naturally deviate from their habitual intake, resulting in an increase or decrease of intake. If this random variation is the only form of error, then it should balance out across the sample being studied. However, when bias is not random within the population but the error reflects a bias towards recording *below* the habitual intake, under-reporting becomes a serious problem. Invalid dietary intakes can arise from different forms of behaviour including:

1. food being eaten but deliberately NOT reported (intentional under-reporting);
2. food consumption being reduced, or certain foods being avoided, during the period of study (intentional alteration of diet);
3. food being eaten but genuinely forgotten (unintentional/unknowing under-reporting).

These processes are unlikely to be mutually exclusive, with each having an effect on under-reporting to varying degrees. Unfortunately, the detection of under-reporting does not automatically reveal the process responsible. These factors may play more or less significant roles depending on the method of dietary assessment (Bingham, 1991). Beyond the initial issue of detecting under-reporting is the motivation causing subjects to produce false dietary data. Why are some individuals reluctant to report their food intake accurately? Does this motivation vary among subjects with different characteristics? While under-reporting is not always the result of an individual’s deliberate intention to falsify their food records, it is this aspect of under-reporting which is particularly interesting and will constitute the main part of this review. Clearly much of the underestimation of intake is the direct result of inadvertent failure to make an accurate record inherent in the assessment method (see Bingham, 1987; Barrett-Conner, 1991; Bingham, 1991 for reviews).

One aspect of under-reporting that is common to all methods is the effect of observation itself. It has been referred to as the ‘Hawthorne’ or ‘experimenter’ effect (Rosenthal & Rosnow 1991) and is analogous to Heisenberg’s ‘uncertainty principle’. Individuals participating in studies are aware of being observed and this can be sufficient to cause an alteration in dietary behaviour. This issue will be explored later.

How is under-reporting detected?

Dietary under-reporting can occur in any method of dietary assessment. Moreover many of the factors contributing to under-reporting will be common to all methods; even the comparison of

dietary intake from several different methods is unlikely to reveal the true prevalence of under-reporting (Black *et al.* 1991). Often physiological measures are used as a reference against which intake can be compared. This review is concerned primarily with assessment of dietary reporting for energy and macronutrient intake under free-living conditions. Under-reporting of energy consumed can be detected using a variety of techniques ranging from changes in body weight during the recording period to direct measurement of energy expenditure. More specific biomarkers (e.g. urinary nitrogen) can be used to detect the accuracy of records of protein intake.

Changes in body weight during a study can be an indication of subjects' reduced food intake. During the collection of duplicate diets and weighed food records Stockley (1985) found that subjects lost an average of 1 kg weight over a 16 d recording period. The weight loss suggested that food intake was significantly reduced during the study period. However, using the change in body weight as a method for detecting under-reporting is not sensitive, as the measurement techniques used in short term assessments (e.g. 7 d) depend on gross imbalances between energy intake and expenditure. Furthermore, it cannot be assumed that intakes are typical just when no change in body weight occurs, for the subject may have eaten a similar total amount of food, but varied the items eaten or omitted to report everything eaten.

A number of studies have detected under-reporting by comparing energy requirements for maintenance of body weight with self-reported energy intakes (Lissner *et al.* 1989; Mertz *et al.* 1991; de Vries *et al.* 1994). Individuals in these studies first complete a food record, then they are fed diets adjusted in energy to maintain their body weight. Studies of this nature have found that the bias tends towards individuals reporting energy intakes below their energy requirements for weight maintenance. Based on 7-d food diaries, Mertz *et al.* (1991) reported that 81 % of the sample ($n = 266$) underestimated their habitual intake compared with only 8 % who overestimated their energy intake. It is generally accepted that the discrepancies in these measures are due to an underestimation of energy intake rather than an overestimation of energy expenditure.

The use of energy expenditure to verify energy intake depends on the fact that, for someone in energy balance the energy intake must equal energy expenditure. Therefore the accurate measurement of energy expenditure can be used as a marker to evaluate the validity of energy intakes. Under free-living conditions, total energy expenditure can be measured directly using physiological techniques such as DLW or computed from validated formulations for estimating basal metabolic rate (BMR) and assumptions about energy expenditure expressed as a multiple of BMR. The introduction of stable isotopes into nutrition made possible the technique of DLW. This allows the assessment of total energy expenditure (TEE) over a period of time (e.g. 1–2 weeks).

Studies using DLW have left no doubt about the existence of under-reporting in many groups within the population (Prentice *et al.* 1986; Livingstone *et al.* 1990; Schoeller *et al.* 1990; Black *et al.* 1991; Martin *et al.* 1996; Sawayer *et al.* 1996). While this technique provides confirmation of the inaccuracy of dietary intake, its use is precluded in large population studies owing to the cost (Livingstone, 1995).

With the limitations on the widespread use of DLW, a reference often used for dietary intake data in large studies is the ratio of reported energy intake (EI) to BMR (EI:BMR) (Black *et al.* 1991; Goldberg *et al.* 1991; Black, 1996). BMR can be calculated from standard equations, e.g. those of Schofield *et al.* (1985), although the accuracy of these equations has been recently questioned (Durnin, 1996; Shetty *et al.* 1996). It has been suggested that the equations tend to overestimate BMR in the general population, which in turn could overestimate the prevalence of under-reporting (using the EI:BMR ratio). Despite more information being

needed about the general application of these equations, the EI : BMR ratio is used as a convenient tool to detect suspected under-reporting.

The use of the EI : BMR ratio has been developed in a series of publications (Black *et al.* 1991; Goldberg *et al.* 1991), producing guidelines for cut-off values to identify suspected under-reporters (formulated from whole body calorimetry and DLW measurements). EI : BMR is based on the assumption that TEE is equal to EI and where $TEE = BMR \times PAL$ (physical activity level). It has been stated that an EI : BMR of 1.27 is the minimum value for survival and not compatible with long term health (WHO, 1985). Goldberg *et al.* (1991) confirmed these results, showing that it is virtually impossible to survive with an EI : BMR < 1.2. Since these initial reference points were proposed, cut-off limits for either habitual intakes (cut-off 1) or plausible intakes for the duration of the study (cut-off 2) have been established and extensively used to detect under-reporting (see p. 236) (Goldberg *et al.* 1991). The latter cut-off criterion tends to be more liberal, allowing for natural day-to-day variation in food intake. Using these ratios is clearly less accurate than measuring energy expenditure directly especially when little or nothing is known about individuals' physical activity levels. As a result a proportion of under-reporters will remain undetected using these ratios, but they still provide a useful reference point for large studies when not overinterpreted (Black, 1997).

Biomarkers are also used to confirm the validity of particular nutrients. One of the most commonly used biomarkers is urinary nitrogen, which allows the determination of the accuracy of recorded dietary nitrogen (i.e. protein) (Isaksson, 1980; Bingham & Cummings, 1985). Other biomarkers include, for example, adipose tissue fatty acids, urinary potassium, serum vitamin C and serum carotenoids, but these have not been validated as extensively or used as widely as urinary nitrogen (Johansson *et al.* 1992; Tjønneland *et al.* 1993; Bingham *et al.* 1995; Porrini *et al.* 1995; Bingham *et al.* 1997). The principle of biomarkers is to use biological specimens which are independent of subjects' perception or ability to provide accurate written dietary information (Bingham, 1991). Biomarkers, however, become less useful when individuals have altered their habitual intake as a result of taking part in a study. Biomarkers therefore accurately reflect what has been eaten, but the food eaten may not be typical of the habitual dietary intake.

The dilemma still facing researchers is what should be done with the data after a criterion has been established to identify suspected under-reporters? Should under-reporters be excluded from further analysis? Should they be included and their presence in the sample simply acknowledged? The debate hinges on the fact that we cannot be sure that suspected under-reporters identified by one of these techniques are the only people in the sample to be under-reporting. The situation is insecure because under-reporting can still occur among individuals with, for example, EI : BMR ratios which appear to reflect valid intakes (Macdiarmid & Blundell, 1997).

Although less likely to occur, the possibility of over-reporting cannot be dismissed (Goldberg *et al.* 1991; Black *et al.* 1997). Foods which have a positive health image may be over-reported to portray a healthy diet (see p. 244). In a meta-analysis of energy expenditure of free-living subjects, Black *et al.* (1997), found that 16% of men and 35% of women under-reported their intake while 15% of men but only 2% of women over-reported it.

Most of the work on dietary under-reporting continues to focus on physiological measurements for detection and still very little is known about the psychological processes which influence this type of behaviour (Mertz *et al.* 1991; Nelson, 1995). Few studies using qualitative methods have successfully detected under-reporting (Macdiarmid & Blundell, 1997; Mela & Aaron, 1997). Qualitative data have the added advantage of providing explanations or reasons why people under-report their intake (this issue will be discussed on pp. 246–249). It is clear

that a number of disciplines, including nutrition, physiology, epidemiology and psychology, need to work closely together to ensure accurate detection and understanding of dietary under-reporting.

What is the prevalence of under-reporting?

The prevalence of under-reporting has been estimated in a number of large national dietary surveys (Table 1). EI:BMR cut-off limits, suggested by Goldberg *et al.* (1991), have been typically used to identify suspected under-reporters in these large samples. The majority of studies used the second cut-off criterion to detect under-reporting (i.e. dietary intakes recorded during the study period that are too low to be considered plausible); the calculated cut-off values vary according to the design of the study. In the studies reported in Table 1 these values ranged from < 0.9 to < 1.14 (Heywood *et al.* 1993; Smith *et al.* 1994; Klesges *et al.* 1995; Briefel *et al.* 1997; Lafay *et al.* 1997; Price *et al.* 1997). The prevalence of under-reporting in these studies was found to range from 18 to 31 % of the sample. The first cut-off criterion, applied to long term habitual intakes (e.g. EI:BMR = 1.35; Goldberg *et al.* 1991), was only used in one of the reported studies and found that under-reporting ranged from 37 % in men to 45 % in women (Johansson *et al.* 1997). Alternative cut-off values to those suggested by Goldberg *et al.* (1991) have been used in a number of studies, based on the WHO (1985) value of $1.27 \times \text{BMR}$ as the minimum intake required for long term survival (see p. 235). In these studies the proportion of the sample falling below the criterion applied for long term survival ranged from 33 to 54 % (Gregory *et al.* 1990; Klesges *et al.* 1995; Fogelholm *et al.* 1996). The actual cut-off values ranged from 1.20 to 1.28 varying with the precise criteria chosen by the authors. Some of the variation in the prevalence of under-reporting between studies can be attributed to specific methodological errors that exist between different methods of dietary assessment (see Bingham, 1991). These studies also differ in that some include subjects who were on weight reducing diets during the study, e.g. NHANES, WSDS, DNSBA, while others excluded dieters from their analysis, e.g. NSHD (see Table 1). In an attempt to identify genuine under-reporters it would be reasonable to exclude dieters as these individuals are deliberately aiming to achieve a negative energy balance through under-eating (Ballard-Barbash *et al.* 1996). This highlights the importance of making adjustments for behaviours known to result in a reduction in energy intake.

An interesting aspect of these data is the trend in under-reporting over time, and how this might relate to changes in society. Part of the WHO MONICA study conducted in Finland recently reported an increase in the prevalence of under-reporting (Fogelholm *et al.* 1996). In 1982 39 % of men and 33 % of women were identified as suspected under-reporters (EI:BMR < 1.28); this increased to 43 % and 34 % respectively in the second assessment in 1992. It could be speculated that this rise is associated with an increasingly more diet conscious society containing individuals less likely to admit their true intakes.

It has also been claimed that the level of under-reporting (EI:BMR < 0.9) has decreased from 31 % in NHANES II (1976–80) to 23 % of the sample in NHANES III (1988–91) (Briefel *et al.* 1997). The authors suggest that the decrease in the level of under-reporting is due to improved methods of dietary assessment (e.g. the 24 h recall in NHANES III was more strictly controlled and detailed). More important however is the fact that NHANES III included Saturdays and Sundays, whereas assessments were only made from Monday through Friday in NHANES II. Higher energy intake would be expected by including weekend days as it has been shown that intake tends to be higher at the weekend compared to during the week (de Castro,

Table 1. The prevalence of dietary under-reporting (based on EI : BMR cut-off values) in national dietary surveys

Study	Authors	Dietary assessment	EI : BMR cut-off values	Prevalence of under-reporting (%)		
				All	men	women
NHANES II (1976–80)	Klesges <i>et al.</i> (1995)	24 h recall	<0.92 ¹	31	–	–
			<1.2 ³	54	–	–
NHANES III (1988–91)	Briefel <i>et al.</i> (1997)	24 h recall	<0.9 ¹	23	18	28
ANS (1983)	Heywood <i>et al.</i> (1993)	24 h recall	<0.9 ¹	18	12	24
CSFII (1985–6)	Ballard-Barbash <i>et al.</i> (1996)	4 × 24 h recall (women only)	<1.06 ¹	–	–	52
DNSBA (1986–7)	Gregory <i>et al.</i> (1990)	7 d WFR	<1.1 ¹	35	30	29
			<1.2 ³	38	29	47
NSHD (1989)*	Price <i>et al.</i> (1997)	7 d est FR	<1.1 ¹	21	19	23
MONICA (1982) (Finland)	Fogelholm <i>et al.</i> (1996)	3 d est FR	<1.28 ³	–	26	34
(1992)			<1.28 ³	–	42	47
FLVS (1993)	Lafay <i>et al.</i> (1997)	3 d est FR	<1.05 ¹	–	16	16
WSDS (1989–90)	Smith <i>et al.</i> (1994)	FFQ	<1.14 ¹	28	–	–
NORKOST (1993–4)	Johansson <i>et al.</i> (1997)	FFQ	<1.35 ²	–	37	45

¹ Cut-off criterion based on Goldberg *et al.* (1991) cut-off 2 values.

² Cut-off criterion based on Goldberg *et al.* (1991) cut-off 1 values.

³ Cut-off criterion based on WHO (1991) values.

* excluded dieters from the calculation of the prevalence of under-reporting.

ANS, Australian Nation Survey; CSFII, Continuing Surveys of Food Intake by Individuals; DNSBA, Dietary and Nutritional Survey of British Adults; est FR, estimated food record; FFQ, food frequency questionnaire; FLVS, Fleurbaix Laventie Ville Santé study; NHANES, National Health and Nutritional Examination Survey; NSHD, National Survey of Health and Development; WFR, weighed food record; WSDS, Western Sydney Dietary Survey.

1991; Tarasuk & Beaton, 1992; J. I. Macdiarmid *et al.* 1997 unpublished). Therefore, the apparently more reasonable intakes in NHANES III could be due to the inclusion of days of the week in which higher intakes were likely to occur anyway. These differences in the period of reporting make it extremely difficult to make meaningful comparisons between NHANES II and NHANES III.

A paradox—obesity increasing but energy intake decreasing?

An interesting paradox between the apparent trend in energy intake and the prevalence of obesity may be partly explained by under-reporting. Average energy intakes have been reported to be decreasing (MAFF, 1940–1995; Wrieden *et al.* 1994; Fogelholm *et al.* 1996), but the prevalence of obesity continues to increase steadily (Knight, 1994; Kuczmarski *et al.* 1994; Colhoun *et al.* 1996; Garrow, 1996; Seidell, 1997). One explanation is that energy expenditure is decreasing, a phenomenon for which there is evidence (Prentice & Jebb, 1995; Fogelholm *et al.* 1996). Another factor, however, which may also be contributing to this paradoxical

relationship between energy intake and obesity, is the trend to under-reporting. If, as proposed by the Finnish study, the prevalence of under-reporting is increasing (Fogelholm *et al.* 1996) the decrease in reported energy intakes may be a function of greater under-reporting rather than of genuine reductions in food intake. It is known that obese individuals are more likely to under-report their energy intake compared with their lean counterparts (Table 2). Therefore, it could be argued that as the prevalence of obesity increases the level of under-reporting is likely to increase at a similar rate.

From data in the literature there is no doubt about the existence of a high level of under-reporting. The next stage is to consider the nature of under-reporting in the context of who, what and why?

Who is under-reporting?

If it could be assumed that the bias in reporting dietary intake was randomly distributed within a population there would be less concern about its impact on interpretation of dietary data. All the evidence, however, suggests that under-reporting is not random but is likely to be more prevalent in particular subgroups (Table 2). Schoeller (1990) proposed that most people report intakes close to their perceived cultural or population norms rather than to their actual intake. What needs to be established is whether these perceived norms are uniform across subgroups of the population. An increasing number of studies has directly assessed 'who is under-reporting?' (Heitmann, 1993; Heywood *et al.* 1993; de Vries *et al.* 1994; Smith *et al.* 1994; Bingham *et al.* 1995; Klesges *et al.* 1995; Ballard-Barbash *et al.* 1996; Fogelholm *et al.* 1996; Briefel *et al.* 1997; Lafay *et al.* 1997; Price *et al.* 1997; Pryer *et al.* 1997). As a result various characteristics and behaviours have been associated with under-reporting. Consistent differences have been found between men and women and in groups with varying body mass index (BMI) (Tables 1 & 2). Under-reporting is typically more common among women and in individuals who are overweight or obese.

When comparing studies it should be noted that direct comparison can be problematic owing to differences in study design. Factors associated with under-reporting may vary as a result of different methods used for assessing food intake (e.g. food diaries, dietary recall). The method of identifying suspected under-reporters, for example the measurement or estimation of energy expenditure, varies between studies and this could influence those identified as under-reporters. Some studies set inclusion or exclusion criteria for subjects before analysing the data (e.g. the exclusion of individuals reporting to be on weight reducing diets). All these are important issues to be aware of when comparing studies to identify and characterize suspected under-reporters.

Gender difference—women tend to under-report more than men

In 11 of the 12 studies reviewed women were significantly more likely to under-report their dietary intake than men (Tables 1 & 2). Consistent differences between men and women have also been found in studies comparing reported energy intake with energy requirements to maintain body weight. For example, de Vries *et al.* (1994) found that 12% of women compared with only 8% of men under-reported their intakes. Among young adults Haraldsdóttir & Sandström (1994) found that women but not men reported energy intakes significantly lower than those needed to maintain a stable body weight. In a society where eating

Table 2. Characteristics and behaviours associated with dietary under-reporting

Authors	Dietary assessment	Under-reporting	Weight status	Sex	Smoking	Age	Education	Physical activity
Klesges <i>et al.</i> (1995)	24 h recall	EI: BMR < 0.92	overweight	women	-	NS	less educated	-
Briefel <i>et al.</i> (1997)	24 h recall	EI: BMR < 0.9	overweight	women	non-smokers	older	less educated	less physical activity (men only)
Ballard-Barbash <i>et al.</i> (1996)	4 x 24 h recall women only	EI: BMR < 1.06	overweight	-	NS	NS	less educated	NS
Heywood <i>et al.</i> (1993)	24 h recall	EI: BMR < 0.9	-	women	-	older (men only)	-	-
Lafay <i>et al.</i> (1997)	FFQ	EI: BRM < 1.05	overweight	NS	-	older	-	NS
Smith <i>et al.</i> (1994)	FFQ	EI: BMR < 1.14	overweight	women	-	NS	NS	NS
Fogelholm <i>et al.</i> (1996)	3 d est FR	EI: BMR < 1.28	overweight	women	-	-	-	-
Hirvonen <i>et al.</i> (1997)		EI: BMR < 1.27	overweight	women	-	older	more educated	-
Price <i>et al.</i> (1997)	7 d est FR	EI: BRM < 1.1	overweight	women	smokers (women only)	-	less educated (women only)	NS
Pryer <i>et al.</i> (1997)	7 d WFR	EI: BMR < 1.2	overweight	women	smokers	NS	-	-
de Vries <i>et al.</i> (1994)	3 d WFR	energy needs*	overweight (men only)	women	-	NS	-	-
Heitmann (1993)	diet history	UN:DN	overweight	NS	NS	NS	NS	NS
Bingham <i>et al.</i> (1995)	16 d WFR (women only)	UN/DN	overweight	-	-	-	-	-

* energy needs measured in a series of control trials to estimate energy intake required to maintain stable weight. - not reported or measured; est FR, estimated food record; FFQ, food frequency questionnaire; NS, not statistically significant; UN/DN, ratio of urinary nitrogen to dietary nitrogen; WFR, weighed food record.

small amounts has been associated with 'femininity' and where women often feel under social pressure to conform to such images, it is not unexpected that there is more under-reporting among women (Chaiken & Pliner, 1987; Mori *et al.* 1987). Furthermore, women tend to be more concerned about their body weight, food and eating than men. This gender specific behaviour may become less well defined with time as society places a greater emphasis on the body image of men. Studies have also shown that women have more ambivalent attitudes towards certain foods (e.g. sweet snacks) than men (Grogan *et al.* 1997). These authors found that mens' intentions to eat sweet snacks were only predicted by their attitudes while womens' intentions were predicted by both attitudes and social pressure. When these attitudes are combined with present day emphasis on slimness, particularly for women, in the Western world (Mori *et al.* 1987; Wardle, 1988), it would be surprising if there were not a high degree of under-reporting of dietary intake. With these pressures women are more likely to report an intake that they perceive as socially acceptable (Schoeller, 1990).

Body weight related to under-reporting

The other most commonly cited phenomenon associated with under-reporting is body weight and obesity. Overweight and obese individuals have frequently been identified as groups which under-report food intake (Table 2). Under-reporting was first confirmed in these groups when reported intakes were compared with measurements of total energy expenditure by DLW (Prentice *et al.* 1986). These authors found that lean women accurately reported their food intake while obese women did not. Their results have since been replicated in studies of similar design (Lichtman *et al.* 1992; Johnson *et al.* 1994).

While it is accepted that under-reporting is more prevalent among overweight and obese individuals, it must not be assumed that it is confined to this section of the population. Furthermore, not all studies have shown a consistent difference between obese and non-obese subjects in their frequency of under-reporting (Lissner *et al.* 1989) and others have observed this difference only in women (Johnson *et al.* 1994). Lissner *et al.* (1989) found that lean women underestimated their food intake to the same extent as obese women, which suggests that under-reporting was not restricted to obese subjects. However, since the magnitude of under-reporting is believed to vary as a direct function of the quantity of food consumed, this could be the reason for differences in reported dietary intakes between lean and obese subjects (Lissner *et al.* 1989)

When under-reporting is determined from calculations of EI : BMR, its prevalence is found to be consistently higher among obese compared with lean subjects (Table 2). Ballard-Barbash *et al.* (1996) reported the prevalence of under-reporting to be as high as 71 % in overweight women (BMI > 27.3). This was almost $1\frac{1}{2}$ times greater than for normal weight women (BMI = 19–27.3) and $2\frac{1}{2}$ times greater than for underweight women (BMI < 19). Similarly, in the DNSBA, under-reporting was almost 4 and 5 times higher in obese (BMI > 30) than in lean subjects (BMI = 19–21.9) for men and women respectively (Price *et al.* 1997).

An insight into understanding dietary under-reporting by obese individuals was revealed by Lichtman *et al.* (1992) who found a subgroup of obese subjects with a greater tendency to under-report. Two groups were studied, one with and one without a history of diet resistance (defined as an inability to lose weight despite a history of self-reported calorie restricted diet). Subjects in the diet resistant group significantly under-reported their intake compared with those in the non-diet resistant group. The authors concluded that "failure to lose weight despite a self-reported low calorie intake can be explained by substantial mis-reporting of food intake

and physical activity” (Lichtman *et al.* 1992). Self-deception may play a significant role in under-reporting, rather than a desire to deceive the experimenter.

In western societies obesity is a highly stigmatized condition, making the obese an obvious group within the population to be the object of social pressure to reduce weight. Yunker *et al.* (1995) state that obese individuals face a degree of social discrimination, which is equal to the medical consequences of the disease, from both the medical profession and the general population. It has therefore been described as the last remaining socially acceptable form of prejudice (Stunkard & Sobal, 1995). These attitudes in a society where dieting has been described as ‘a national obsession’ (Hill *et al.* 1992) could be driving overweight individuals to under-report their food intake. This is probably not just a reflection of dishonesty. It has been suggested that, when participating in dietary assessment studies, overweight or obese individuals may take the opportunity to diet and try to lose weight (Nelson, 1995).

Interestingly, there is some contradiction, which tends to be overlooked, in the effect that different assessment methods are likely to have on reported food intake. Nutrition scientists commonly use self-reported food records to assess ‘habitual’ intake, with claims that 7-d weighed food diaries are the ‘gold standard’ in dietary assessment (Black *et al.* 1991; Bingham *et al.* 1994). Exactly the same technique (completing food diaries), however, has also been used for years in a clinical setting as part of a behavioural modification treatment for obesity (Stuart, 1967). The first stage of the treatment involves instructing the patient to keep a food diary, which itself is sufficient to induce weight loss *via* a reduction in intake or a change in eating pattern (Stuart & Davis, 1972). Supporting this, subjects participating in dietary surveys have actually volunteered the information that “. . . it would be a good way to make someone diet” (Macdiarmid & Blundell, 1997). This raises an obvious question: how can the same methods be expected to assess habitual intakes when they are known to alter eating patterns and to reduce food intake in order to induce weight loss?

Other characteristics of under-reporters

In the quest to understand under-reporting, studies have revealed a number of other characteristics associated with under-reporting including smoking, age, education, social class, physical activity, dietary restraint and emotional states (Table 2).

Smoking. The relationship between smoking and under-reporting is equivocal. Pryer *et al.* (1997) and Price *et al.* (1997) (women only) found that smokers were more likely to under-report. Contrary to these results, in the NHANES III a higher frequency of under-reporting was found among nonsmokers (Briefel *et al.* 1997). Meanwhile, other studies have found no relationship between smoking and under-reporting (Heitmann, 1993; Ballard-Barbash *et al.* 1996). The impact of smoking needs to be considered in the light of the possible effect of nicotine on BMR and therefore the appropriateness of the BMR equations for smokers and nonsmokers (Perkin *et al.* 1996).

Age. An age difference was found in approximately half the studies (Table 2). Generally, where a difference in age was observed, under-reporting was associated with increased age (Heywood *et al.* 1993; Briefel *et al.* 1997; Hirvonen *et al.* 1997; Lafay *et al.* 1997). The true impact of this relationship is questionable as age tended to be associated with other characteristics, such as BMI, which may have a confounding effect on under-reporting. Further analysis is needed to draw more definitive conclusions from these data.

Education. In 4 of the 7 studies in which educational attainment was assessed, under-reporting was associated with lower levels of education (Klesges *et al.* 1995; Ballard-Barbash

et al. 1996; Briefel *et al.* 1997; Price *et al.* 1997). This finding is not surprising as most methods for recording food intake depend heavily on literacy. Even with the development of more sophisticated equipment to reduce the burden on subjects (e.g. PETRA; Bingham, 1987), the techniques can still prove to be difficult for some people. It is therefore important to take care in interpreting low dietary intakes of individuals with poor literacy skills. In contrast to these studies only one study found that under-reporting was associated with high levels of education (Hirvonen *et al.* 1997).

Social class. Differences between social classes were not consistently observed in studies of under-reporters. Pryer *et al.* (1997) found under-reporting most prevalent among men in manual social classes, while another study showed that women of low social class, but not men, were more likely to under-report (Price *et al.* 1997). In contrast, Lafay *et al.* (1997) found under-reporting greatest in higher social classes, and others found no relationship (Heitmann, 1993). To fully interpret these differences it is important to take into account factors that may confound the relationship between social class and under-reporting, for example, BMI and possible cultural differences.

Physical activity. Self-reported estimates of physical activity seem to have no significant relationship with under-reporting of energy intake. Only one study found a negative relationship (in men, but not women) between the level of under-reporting and recreational physical activity (Briefel *et al.* 1997). In the majority of these studies physical activity was based on a self-reported description of the frequency and duration of exercise; typically samples were categorized into groups ranging from sedentary to strenuous/heavy. However, self-reporting of physical activity is probably subject to similar errors to those in reporting food intake.

Dietary restraint. Restrained eating, the cognitive control of food intake, has been related to under-reporting in a number of studies (Black *et al.* 1995; Bingham *et al.* 1995; Macdiarmid & Blundell, 1997; Lafay *et al.* 1997; Mela & Aaron, 1997). Bingham *et al.* (1995), using the Three Factor Eating Questionnaire (Stunkard & Messick, 1994) for valid and invalid reporters, found that invalid reporters had significantly higher restraint scores. In another study only a subgroup of the under-reporters (classified by their reasons for under-reporting, i.e. they felt 'too embarrassed' to record everything they ate) had high dietary restraint scores (see p. 247) (Macdiarmid & Blundell, 1997). In a prospective study subjects were asked if they would alter their diet or misreport their intake as a result of completing a food diary (Mela & Aaron, 1997). Restrained eaters claimed that they were more likely than non-restrained eaters to eat less and alter their eating patterns. The reasons why restrained eaters produce invalid food records are likely to be similar to those discussed for women and overweight subjects (see pp. 238–241.).

Emotional states. Finally, a small number of studies have looked at the emotional state of individuals completing food intake records and the potential impact on under-reporting. Price *et al.* (1997) found that under-reporting was more common among women (but not men) who had had nervous or emotional trouble in the previous year which had stopped them from pursuing a normal routine. Obviously, disruption of routine can influence how much attention and detail is given to participating in a dietary survey which is known to be demanding.

What is being under-reported?

Is dietary under-reporting associated with specific foods or nutrients or with diet in general? Owing to the methods that are used to detect under-reporters (e.g. EI:BMR, DLW), it is

normally only possible to identify those who are reporting low total energy intake rather than any specific food or macronutrient. Urinary nitrogen can be used to estimate under-reporting of protein but, as yet, no acceptable techniques for detecting under-reporting of other macronutrients have been developed.

Some studies have attempted to determine whether under-reporting is specific to certain foods or nutrients. Anecdotally, one might predict that foods with a negative health image (e.g. high fat and high sugar foods) are more likely to be under-reported. Obtaining actual evidence for this is, however, extremely difficult.

The issue of 'what is being under-reported' can be divided into two sections; firstly is under-reporting macronutrient specific? Secondly, if it is macronutrient specific, are there certain identifiable foods that are contributing heavily? These questions have important implications for interpreting dietary intake and understanding diet-disease relationships.

Macronutrients or food?

Is under-reporting macronutrient specific?

Studies that have attempted to determine which, if any, of the macronutrients are more likely to be under-reported have shown inconsistent results (Table 3). Detection of macronutrient specific under-reporting has been based on the comparison of the differences in nutrient intakes (expressed as a percentage of energy) between suspected under-reporters and 'valid' reporters. Macronutrients are normally expressed as a percentage of energy since under-reporters have low energy intakes (by definition) and therefore lower absolute nutrient intakes (g/d) than valid reporters. Expressing nutrients in absolute terms will not provide meaningful comparisons. Most of the studies reviewed have identified suspected under-reporters using either an EI : BMR ratio or urinary nitrogen techniques (Table 3).

These studies have reported that protein, in contrast to carbohydrate and fat, is typically accurately reported or even over-reported (Heitmann & Lissner, 1995; Summerbell, 1996; Pryer *et al.* 1997). Carbohydrate (particularly sugar) tends to be under-reported in dietary studies (Lissner & Lindroos, 1994; Poppitt *et al.* 1995; Rutishauser, 1995; Summerbell, 1996; Briefel *et al.* 1997; Pryer *et al.* 1997). The accuracy of reported fat intake, however, is unclear with only three studies reporting differences; two suggested that it is over-reported (Summerbell, 1996; Briefel *et al.* 1997) and the other that it is under-reported (Poppitt *et al.* 1995).

Care should be taken in interpreting these data. Certain macronutrient intakes tend to be inter-related, especially when expressed as a percentage of energy intake, for example, in the frequently cited sugar-fat seesaw (McColl, 1988). Owing to the typical inverse relationships between some nutrients, it is difficult to prove whether under-estimation of one nutrient is the cause or the result of overestimation of another nutrient. It is virtually impossible to answer this without knowing more about the reasons why people under-report.

Is under-reporting related to specific foods?

One way to get a better understanding of macronutrient specific under-reporting is to try to determine whether specific foods are under-reported. For research purposes, diet is usually considered in terms of nutrients, but most people think of a diet in terms of food. This is an important distinction. Identifying certain foods or food groups as susceptible to under-reporting can increase our understanding of under-reporting in two ways. Firstly, it can clarify whether under-reporting is nutrient specific and hence provide better interpretation for relationships between diet and health. Secondly, it may be possible to draw conclusions about the reasons for

Table 3. Under- and over-reporting of macronutrient intakes (expressed as a percentage of energy intake)

Authors	Study	% Fat	% CHO (% sugar)	% Protein	% Alcohol
Lissner & Lindroos (1994)	men & women <i>lean</i> (n = 370) <i>obese</i> (n = 87)	NS NS	under (-) NS (-)	NS NS	- -
Bingham <i>et al.</i> (1995)	women (n = 160)	NS	NS (-)	NS	NS
Heitmann & Lissner (1995)	men & women (n = 323)	-	-(-)	over	-
Poppitt <i>et al.</i> (1995)	women <i>lean</i> (n = 15) <i>obese</i> (n = 18)	under under	under (-) under (-)	NS NS	under under
Rutishauser (1995)	men & women (n = 179)	NS	under (-)	NS	-
Summerbell (1996)	men & women <i>lean</i> (n = 157) <i>overwt</i> (n = 63)	NS over	NS (NS) under (under)	NS over	under NS
Briefel <i>et al.</i> (1997)	men & women (n = 7769)	over	under (-)	NS	under (women only)
Lafay <i>et al.</i> (1997)	men & women <i>lean</i> (n = 144) <i>obese</i> (n = 886)	NS NS	under (-) NS	over over	over NS
Pryer <i>et al.</i> (1997)	men & women (n = 1856)	NS	under (under)	over	under (women only)

CHO, carbohydrate; NS, not statistically significantly over- or under-reported; over, over-reported; under, under-reported; overwt, overweight subjects; -, not measured or reported.

under-reporting. Foods, for example, with a negative health image, e.g. high fat and sugar foods, are more likely to be under-reported while those with a positive health image, e.g. fruits and vegetables, may well be over-reported.

In the few studies that have attempted to deduce which foods are under-reported these suggestions have been supported. Under-reporters were found to record lower intakes of high fat sweet foods (e.g. cakes, biscuits, pastries, and other sweet foods) (e.g. sugar and confectionery), than valid reporters (Bingham *et al.* 1995; Pryer *et al.* 1997). Comparing the absolute intake of different food groups, Bingham *et al.* (1995) found that female under-reporters also consumed significantly less breakfast cereals, milk and milk products, eggs and fats, including butter. Intakes of meat, fish, vegetables, fruit and bread, however, did not differ between groups. Pryer *et al.* (1997) expressed food intake as a percentage of energy consumed, thereby adjusting for the lower energy intake of the under-reporters (by definition). In contrast, when intakes were adjusted for total energy, relative consumption of cakes, biscuits, pastries, sugar, confectionery, butter (women only) and fruit/nuts (men only) was lower, but meats, vegetables, salad, eggs, fried fish, white bread, refined cereals (women only) and rice, pasta (men only) were higher for under-reporters. These results were consistent with those of Hirvonen *et al.* (1997).

Subjects predicting how accurately they would report their food intake stated that cakes, pastries, confectionery and fatty foods were the main food groups they would under-report (Mela & Aaron, 1997). A third of this sample stated that they would reduce their intake of cakes, pastries and confectionery, while 19 % would reduce their intake of fatty food. Conversely, 43 % thought they would increase their intake of fruits and vegetables during the study period. These data provide further evidence that under- and over-reporting is related to the health image of foods.

Another aspect of food specific under-reporting was identified in a recent study using a photographic technique (de Castro, 1997). Subjects were asked to photograph their meals as well as recording them in a standard food diary. The inclusion of missing foods from the diaries, identified from photographs, increased the estimated energy intake by more than 8 %. Increases of 11, 9 and 4 % were found for fat, carbohydrate and protein respectively. Condiments were food items typically omitted from food diaries. While this is a good way to reduce the number of items forgotten in food records, it would not solve the problem of deliberate alteration of the diet consumed.

Differences in meal and snacking patterns

How do under-reporters alter their eating patterns? Do they under-report meals or snacks to a greater or lesser extent? Many authors have inferred that snack foods are particularly susceptible to under-reporting (Livingstone *et al.* 1990; Summerbell, 1996; Briefel *et al.* 1997). Firstly, it is suggested that snack foods tend to be associated with a negative image which leads to their omission from food records. Whybrow & Kirk (1997) proposed that if eating three meals a day is perceived as the 'correct' eating pattern, then deviation from this to include snacks may inhibit some individuals from accurately reporting intake of snacks. Secondly, the method used to record food intake may be a significant factor in under-reporting snacks. Eating snacks has been described as a secondary activity to eating meals; they are therefore either forgotten when recalling intake or often seen as too great an inconvenience to record in food diaries.

Many weight reduction diets have promoted the idea that snacking is associated with weight gain, despite conflicting evidence for this relationship (Green & Burley, 1996). If people believe this, snacks are likely to be under-reported, especially by weight conscious or overweight individuals. Summerbell (1996) showed a trend for overweight, but not lean, under-reporters to consume fewer snacks than valid reporters. In this study snacks tended to be higher in sugar (% energy) and lower in protein and fat, which was consistent with the composition of snacks (compared to meals) found by Whybrow & Kirk (1997) in a study of non-obese female students. Heitmann & Lissner, (1995) reported obese individuals under-reporting high fat, high sugar foods, which the authors interpreted as typically being snack foods. Subjects have also referred to having to weigh snacks as one of the most "irritating aspects of the procedure", which is likely to be a source of inaccurate reporting (Livingstone *et al.* 1990). In NHANES III, alterations to eating patterns were not restricted to snacks, with reduction in the number of meal and food items also reported (Briefel *et al.* 1997). A follow-up study of subjects who had completed 7-d weighed food records found that 21 % of subjects claimed to have reduced their intake of snacks compared with only 12 % who had reduced their intake of meals (J. I. Macdiarmid & J. E. Blundell, unpublished data). In this study women were significantly more likely to reduce their intake of snacks than men.

The inter-relationship between individual characteristics and eating patterns associated with under-reporting adds to the difficulty of unfolding the complex nature of under-reporting. In almost all the studies on under-reporting authors have concluded by speculating and hypothesizing *why* particular subgroups of the population under-report or *why* specific foods or nutrients are under-reported or *why* people alter their eating habits. The next stage of this investigation must be to make enquiries of the actual under-reporters themselves.

Why do people under-report?

In most studies this question remains unasked, at least of the suspected under-reporters. It would be naive to assume that such a question would always guarantee an honest answer or one more honest than the food record itself, but it provides a starting point. Understanding the psychology of under-reporting remains an area for much research.

Low energy intakes should not be ascribed solely to deliberate misreporting, as methodological issues can contribute significantly to inaccurate assessments of food intake. An outcome should not be interpreted as deliberate under-reporting until more information is obtained from subjects. Many methodological factors introduce errors which can reduce the accuracy of energy intakes, for example, using food tables, coding of dietary intakes, food weight estimates, day-to-day variations in intake and estimates of frequency of intakes (Bingham, 1991). Compared with errors introduced by individuals altering their dietary intakes, these types of methodological errors are unlikely to bias the results in a specific direction rather reduce the accuracy of the dietary intake. Since methodological aspects contributing to inaccuracies are not the principal focus of this paper and have been extensively reviewed in the literature (Stockley, 1985; Bingham, 1987; Barrett-Conner, 1991; Bingham, 1991; Beaton, 1994, de Castro, 1994), discussion of this will be taken no further. The main emphasis of this section will focus on the psychology and behaviour associated with under-reporting.

Psychology of under-reporting

“Diet questionnaires, though ultimately used to produce nutrient scores, are really cognitive and psychosocial test instruments.” (Hebert *et al.* 1995)

The discipline of psychology is not normally associated with dietary assessment. However, psychology is not only important in the generation of valid data but also in understanding the motivation behind accurate or inaccurate reporting. It is an area that is gradually becoming recognized; Nelson (1995) recently emphasized that “...the evaluation of psychological aspects of both subjects and interviewers may become increasingly important in establishing the validity of dietary assessment”. This is particularly relevant as the phenomenon of under-reporting is still poorly understood and little is known about the mechanism or true reasons for its common occurrence.

For simplicity, under-reporting can be broadly divided into two categories, intentional and unintentional under-reporting. These two forms of under-reporting while having very different origins are not mutually exclusive. Ultimately, however, the accuracy of all dietary methods is dependent on the compliance, motivation and ability of subjects taking part in a study (Livingstone *et al.* 1992; de Castro, 1994). It is, therefore, important to understand the nature of the individuals taking part in studies. Determining certain characteristics (see pp. 238–245)

provides some indication of a subject's motivation to under-report but much more information is needed to establish the true psychology behind this behaviour.

Intentional under-reporting

In a limited number of studies, subjects were asked directly about under-reporting or the likelihood of under-reporting (Macdiarmid & Blundell, 1997; Mela & Aaron, 1997). In these studies a high proportion of subjects admitted intentionally under-reporting or altering their food intake. Macdiarmid & Blundell (1997) asked subjects who had completed a 7-d weighed food record whether they altered their eating patterns or omitted any foods from the record during the study period. Almost half the sample (46%) admitted changing their diet in some way as a result of having to record their intake. An important aspect of this study is that people appear to be willing to disclose information about the truthfulness of their dietary intake records. The study also provided reasons (based on the subjects' own testimonies rather than on the speculations of investigators) for altering food records. These fell into two main categories. The first concerned individuals who admitted to being diet conscious or to 'feeling too embarrassed' to record all foods consumed. This rose from the impact of social desirability, social/peer pressure and social attitudes towards foods. These behaviours were particularly associated with individuals who were dieting and who had high dietary restraint scores. The second category was related to the inconvenience, 'hassle' and time consuming aspects of completing a food record. This highlights the demanding nature of recording food intake, which has been demonstrated in previous studies (Livingstone *et al.* 1990). Consequently, the two factors which caused subjects to make false records of their food intake were embarrassment and inconvenience.

Social Pressure. Pressure on individuals to conform to what 'society' defines as appropriate dietary behaviour has been identified as a major factor contributing to invalid dietary intakes. Bias in reporting can stem from individuals wanting to convey a socially desirable image, in line with perceived norms, to avoid criticism (Hebert *et al.* 1995). Social desirability has been described as one of the most common sources of bias affecting the validity of both experimental and survey results (Nederhof, 1985). The emphasis on diet, body image and health in society today makes the issue of social desirability a major obstacle in dietary assessment.

In a recent study measurement of social desirability was shown to correlate negatively with nutrient and energy intakes (Hebert *et al.* 1995). These relationships confirm that social influences are having significant effects on nutritional data. The comments of subjects who have completed 7-d weighed food records support these findings. One subject, for example, admitted reducing her meal portion sizes during the study because "I didn't want to look greedy" (Macdiarmid & Blundell, 1997). People possess firmly held ideas of what they think would be viewed by others as appropriate eating behaviour. This is called the 'subjective norm'. Subjects alter their intake to avoiding feelings of guilt or embarrassment which arise from deviating from the social norm. Although the impact of social desirability on behaviour occurs under many circumstances its effect will be exaggerated when the individual is aware of being observed. One is left asking what can currently only be a rhetorical question: how can dietary intake be assessed, within ethical boundaries, without the subjects knowing that they are being observed?

The influence of socially desirable behaviour varies across different groups of the population (Hebert *et al.* 1995). Groups wanting to purvey a socially desirable image tend to be women, overweight or restrained individuals (Macdiarmid & Blundell, 1997; Mela & Aaron, 1997). The desire to eat in a manner which is perceived as socially acceptable originates from

attitudes and beliefs about food and body image. As discussed previously (pp. 238–240) it is generally accepted that women have different eating patterns to men, since they have been socialized to eat in a more ‘feminine’ manner, and have more ambivalent attitudes towards foods than men. The commonly cited food conflict is the idea of certain foods being ‘naughty but nice’.

Sociocultural and psychological factors are vitally important in understanding under-reporting. It is now apparent that multidisciplinary investigations are needed to understand the psychology, sociology and physiology of dietary assessment.

Inconvenience. Completing food records is time consuming, hard work and can therefore be very inconvenient. This description echoes the feeling of many subjects who have taken part in dietary surveys. Weighed food records have been described as ‘invasive and burdensome’ (Livingstone, 1995). Having completed food records some subjects admit to not recording all the food eaten as “it was too much hassle” or “they were too busy” (Macdiarmid & Blundell, 1997). Subjects described finding alternative meal and snacking patterns, substituting foods which were easier to weigh or simply not recording some foods which were troublesome (e.g. condiments, snacks). Interestingly, individuals who reduced their recorded food intake because it was “too much hassle” or inconvenient had very different characteristics from those who admitted that false recording was due to social pressures (p. 247). The former subjects tended to have low dietary restraint scores, were younger and had significantly higher EI : BMR ratios than those who had altered their diet for social reasons. Interestingly, the EI : BMR ratio was significantly higher among these under-reporters than those who claimed *not* to have altered their intake. Additionally, many of the EI : BMR ratios of these under-reporters were above what would be generally classified as a valid intake, e.g. > 1.5 (Macdiarmid & Blundell, 1997). This casts doubt on the identification of under-reporters using EI : BMR estimates and confirms suspicions that under-reporting occurs at levels above many of the cut-off criteria used in studies. Therefore using EI : BMR as a cut-off criterion does not guarantee that the remaining intakes are valid.

The intrusive and demanding nature of dietary assessment, especially food diaries, is clearly another aspect contributing to under-reporting. Furthermore, it highlights the fact that under-reporting occurs in sections of the populations other than body weight and diet conscious individuals. Lifestyle is very important to the compliance of food studies. The dilemma here is how to balance the time consuming and intrusive nature of food recording with a busy lifestyle. Deliberate under-reporting needs to be accounted for in dietary studies as many people are likely to look for short cuts when recording their food intake.

Unintentional under-reporting

Aspects which tend to be out of the direct control of subjects, but will still contribute to under-reporting, can be generally referred to as unintentional under-reporting. For example, these include poor memory, poor attention and literacy problems. Furthermore, low energy intakes may reflect troublesome situations (e.g. illness, dieting, genuine irregular eating patterns) rather than deliberate falsification.

Many dietary methods rely heavily upon the recall of foods eaten recently, e.g. 24 h recall, or over an extended period, e.g. food frequency questionnaires. They depend on individuals having good medium- or long-term memories. Recalling this type of information can be demanding and in itself can introduce errors, contributing significantly to under-reporting of dietary intake (Smith, 1993). Recall can vary enormously even in subjects with extensive training in recording food intake. Acheson *et al.* (1980) studied 12 scientists, who jointly accumulated 1085 days of weighed food intakes. During the recording period they were asked

on 86 separate occasions to recall their previous 24 h intake. The accuracy of their recalled intake ranged from 32 % to 132 % of their total recorded energy intake.

Inaccuracies resulting in under-reporting can be a genuine function of honest people not remembering what or how much has been eaten. The evidence of food records have often surprised subjects about what they eat, described in statements such as "... it proved that I 'nibble' between meals" (Macdiarmid & Blundell, 1997). Despite the potential problems associated with heightening awareness of dietary intake, this type of comment illustrates that some people are quite unaware of their habitual eating patterns. These individuals are less likely to record food intake accurately when it is largely dependent on memory (e.g. 24 h recall).

Several authors have noted that the accuracy of dietary intake data is also heavily dependent on the intellectual capacity of the subjects (de Castro, 1994; Livingstone, 1995). Much of the data collected (see Table 2) suggests that under-reporting is more prevalent among subjects with lower educational attainment. This has the very obvious potential of skewing the data to include predominantly those individuals with the necessary literacy skills to complete the task. Areas that have been identified as problems include comprehension of questionnaires and computation of frequency of consumption, which are particularly observed when completing food intake questionnaires (Subar *et al.* 1997).

Summary

There can be little doubt about the magnitude and complexity of the problem of under-reporting in dietary intake studies. At the present time there are no obvious solutions to such a multi-dimensional problem. With, however, some recent studies beginning to investigate the processes behind under-reporting a significant step forward has been taken. In addition to increasing our knowledge about under-reporting, the issue is now being acknowledged more openly. Perhaps it can now be talked about rather than confined to a 'whisper' (Garrow, 1995). The importance of accurate dietary assessments cannot be overemphasized since much of our understanding of relationships between diet and health depends on the validity of the dietary data.

While it is not possible to propose simple solutions to deal with under-reporting, gradual improvements to dietary assessments can be made from the information available. Unreliable self-reports are known to be a feature of many situations in which human beings monitor various aspects of their own behaviour. Unlike many disciplines, nutrition has the advantage of physiological parameters which provide a guide to the plausibility of the self-report data. These parameters should not be overstated as studies have shown that they do not guarantee detection of inaccurate data. Physiological measurements used in conjunction with psychological parameters will provide a much greater understanding of under-reporting and will increase confidence in the dietary data. Much more work is needed to determine the psychological factors which contribute to under-reporting, for the validity of the data collected can only reflect the motivation, honesty and other psychological processes of the subjects involved.

Note: Jennie Macdiarmid is now working for the International Obesity Task Force, at the Rowett Research Institute, Aberdeen, AB21 9SB (email: JIM@rri.sari.ac.uk)

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