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# Secular trends in under-reporting in young people

K. L. Rennie*, S. A. Jebb, A. Wright and W. A. Coward

*MRC Human Nutrition Research, Elsie Widdowson Laboratory, Fulbourn Road, Cambridge, CB1 9NL, UK*

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National survey data show that reported energy intake has decreased in recent decades despite a rise in the prevalence of obesity. This disparity may be due to a secular increase in under-reporting or a quantitatively greater decrease in energy expenditure. This study examines the extent of under-reporting of energy intake in the National Diet and Nutrition Survey (NDNS) in young people aged 4–18 years in 1997 using published equations to calculate estimated energy requirements. It explores secular changes by comparison with the Diets of British School Children (DBSC) survey in 10–11- and 14–15-year-olds in 1983. In the NDNS, under-reporting (estimated energy requirements – energy intake) represented 21 % of energy needs in girls and 20 % in boys. The magnitude of under-reporting increased significantly with age ($P < 0{\cdot}001$) and was higher in overweight than lean individuals over 7 years of age. To compare reported energy intake in DBSC and NDNS, the estimated physical activity level from dietary records (dPAL = reported energy intake/predicted BMR) was calculated. If there were no under-reporting, dPAL would represent the subject's true activity level. However, dPAL from the NDNS was significantly lower than that from the DBSC by 8 % and 9 % in boys and girls for those aged 10–11 years, and by 14 % and 11 % for 14–15-year-olds respectively, reaching physiologically implausible levels in the 14–15-year-old girls (dPAL = 1·17). If activity levels have remained constant between the two surveys, under-reporting has increased by 8–14 %. The evidence supports a secular trend towards increased under-reporting between the two surveys, but the precise magnitude cannot be quantified in the absence of historical measures of energy expenditure.

**Energy: Intake: Under-reporting: Dietary surveys: Doubly labelled water**

The prevalence of obesity is increasing worldwide in both adults and children, and attempts to explain this phenomenon have frequently made quantitative comparisons of energy intake and energy expenditure. At face value, data from large-scale surveys suggest that energy intake has decreased in recent decades, implying that even greater decreases in energy expenditure are principally responsible for the excess weight gain. However, the measurement of dietary intake in man is complex, and the problem of systematic under-reporting of energy intake in adults is well documented (Livingstone *et al.* 1990; Black *et al.* 1993; Trabulsi & Schoeller, 2001). In young people, studies suggest that under-reporting of dietary intake increases with age (Livingstone *et al.* 1992; Bandini *et al.* 2003) and is positively associated with body fatness (Bandini *et al.* 1990; Perks *et al.* 2000). There has, however, been no consideration of whether under-reporting in young people has increased over time. This paper examines the extent of under-reporting of energy intake in data collected in the National Diet and Nutrition Survey (NDNS) of young people in 1997 and the Diets of British School Children (DBSC) survey in 1983 to evaluate whether levels of under-reporting might have increased between these two surveys.

## Methods

Data from the NDNS and DBSC surveys were obtained from the UK Data Archive, University of Essex.

The NDNS is a programme of cross-sectional surveys of different population age groups designed to be nationally representative. This analysis uses the NDNS sample of 2127 young people aged 4–18 years studied in 1997. There are no previous dietary intake data in Great Britain comparable to those of the NDNS across the entire 4–18-year age range. However, the DBSC provides a representative sample of young people in 1983 in two specific age groups recruited through schools (Department of Health, 1989). It includes 2092 10–11-year-old and 1266 14–15-year-old children, including children of minority ethnic origin. A total of 1035 boys and 982 girls in the 10–11-year age group and 623 boys and 596 girls in the 14–15-year age group with complete energy intake and anthropometry data were included in the present analysis. The sample design and methods for each survey have been described in more detail elsewhere (Department of Health, 1989; Gregory & Lowe, 2000). Table 1 illustrates the design and main methods used in the two surveys.

**Abbreviations:** DBSC, Diets of British School Children; DLW, doubly labelled water; dPAL, physical activity level from dietary records; EER, estimated energy requirements; NDNS, National Diet and Nutrition Survey; PAL, physical activity level; TEE, total energy expenditure.

* **Corresponding author:** Dr Kirsten L. Rennie, fax +44 1223 437515, email kirsten.rennie@mrc-hnr.cam.ac.uk

The NDNS sample was based on households rather than school based, as with the DBSC. Both surveys measured dietary intake from a 7 d weighed diet record, but there were some differences in the methods used, as described in Table 1. In both surveys, information from the dietary record was linked to a nutrient database that contained nutritional information on foods and drinks, prepared by nutritionists at the Ministry of Agriculture, Fisheries and Food and Office for National Statistics. The 1993 nutrient database included a greater range of foods. The dietary records were checked by nutritionists for completeness, and portion sizes were converted to weights. Energy intake (kJ) was calculated as the mean of the 7 d weighed measurements. In the DBSC, 4·5 % of subjects were excluded due to poor recording of dietary intake. In the NDNS, 20 % of subjects who agreed to participate did not complete the dietary record. There were no significant differences by social class or fieldwork wave between those who completed the dietary record and those who did not. However, completion of the dietary record was lower in young people aged 15–18 years than in other age groups. No further exclusions were made.

Weight and height measurements were made in both surveys using similar methods. The weight status of individuals in both the NDNS and the DBSC was calculated using the international reference standard to define overweight and obesity (Cole *et al.* 2000). This is based on average centiles, which equate to a BMI of 25 or 30 kg/m$^2$ at age 18 years for overweight and obesity respectively. Overweight is defined here as a BMI on or above the overweight cut-off and includes those classified as obese.

BMR was computed using published equations based on gender, age, weight and height (Schofield, 1985), and these values were used to calculate each subject's estimated physical activity level (PAL) from dietary records by dividing the reported energy intake by the estimated BMR (dPAL).

To assess the validity of self-reported energy intake, it is necessary to determine energy needs. For the NDNS, estimated energy requirements (EER) were calculated from published sex and age-specific equations (Institute of Medicine of the National Academies, 2002). These equations, derived from collated doubly labelled water (DLW) energy expenditure data, allow for four PALs – sedentary, low activity, active and very active – with a corresponding activity coefficient in the EER equations.

The validity of the EER values used in the NDNS to estimate under-reporting was examined using data from the NDNS Feasibility Study undertaken in 1996. This study assessed the feasibility and validity of the dietary methods to be used in the main survey (Gregory & Lowe, 2000) by comparing the reported energy intake with total energy expenditure (TEE) calculated from 10 d DLW measurements. Calculations of TEE from the DLW were those used by Davies *et al.* (1994) except that the internal precision of each estimate was calculated as described by Cole & Coward (1992) and Ritz *et al.* (1996). Complete data on TEE and food intake were available for seventy-four subjects from four geographical areas using standard procedures. The appropriate Local Research Ethics Committees for each selected area approved the NDNS Feasibility study.

PAL was calculated from the DLW data in the feasibility study (PAL = TEE/BMR), with BMR estimated from published equations (Schofield, 1985). Measured PAL corresponded to the active level ($\text{PAL} \geq 1{\cdot}6 < 1{\cdot}9$) in the published EER equations in all age groups and in both genders. This level was therefore used to calculate EER in the NDNS.

In the feasibility study, the EER was compared with the DLW-measured TEE. The correlation between EER and TEE was high in both boys and girls (Spearman's rho 0·81 and 0·76 respectively; $P < 0{\cdot}001$). However, since there was a wide range of energy expenditure values, the data were log-transformed to estimate any proportional bias

**Table 1.** Study design and methods of the National Diet and Nutrition Survey and Diets of British School Children survey

| | National Diet and Nutrition Survey | Diets of British School Children |
|---|---|---|
| Year of survey | 1997 | 1983 |
| Sampling frame | Households: multi-stage random probability design | Area, school and age group: multi-stage random probability design<br>Over-sampling of children from less-advantaged families |
| Response rate | 80 % | 75 % |
| Diet record | 7-day weighed diet record | 7-day weighed diet record |
| Weighing method | Digital food scales and household measures | Digital food scales and household measures |
| Leftovers | Weighed and recorded | Weighed and recorded |
| Food eaten outside the home | Recorded in a separate diary | Recorded in a pocket notebook |
| Food eaten at school | Composition and portion size of food and drink collected from school caterers | Weighing scales and record books available in school canteens |
| Procedure for checking diet records | Checking call within 24 h by a fieldworker, after 7 d records were checked and coded by fieldworker | Checking call within 24 hours by a fieldworker and further calls made if recording considered to be not very good, after 7 d records checked and coded by fieldworker |
| Nutrient database used | 1993 Ministry of Agriculture, Fisheries and Food nutrient database (6000 food and drink items) (Gregory & Lowe, 2000) | 1982 Ministry of Agriculture, Fisheries and Food nutrient database (1080 food items) (Department of Health, 1989) |
| Anthropometry | Height and weight | Height and weight |
| *N* with complete data | 1599 | 3236 |

between the measured TEE and EER (Fig. 1). The mean bias between the logged TEE and EER was small but statistically significant in girls (0·06, limits of agreement −0·26, 0·38; $P<0·05$) although not in boys (0·02, limits of agreement −0·28, 0·31; NS). Overall, the bias was significantly correlated with body weight ($r$ 0·231, $P<0·05$) and, in boys only, with age independently of body weight ($r$ 0·33, $P<0·05$).

Positive differences between EER and reported energy intake are described here as under-reporting. Results for anthropometric variables and PAL are expressed as means with their standard deviations and for non-parametric variables, such as estimated under-reporting (kJ/d), as medians with inter-quartile ranges. Inter-individual differences in the extent of estimated under-reporting were assessed using the Mann–Whitney U test. Kruskal Wallis one-way ANOVA was used to test differences between age groups. Differences between EER and measured TEE were compared using paired $t$ tests. Differences between the DBSC and NDNS in reported energy intake and anthropometry within each age group were analysed using Mann–Whitney U tests and $t$ tests respectively. Values of $P<0·05$ were regarded as statistically significant, and all statistical analyses were performed using SPSS source® (version 11.0) (SPSS Inc, Chicago, IL, USA.)

## Results

*Under-reporting in the NDNS*

In the NDNS, there was evidence of under-reporting in both girls and boys, expressed as the difference between EER and reported energy intake (kJ/d): girls 1885 (interquartile range 954–3140) boys 1864 (interquartile range 890–3581). This estimated under-reporting was not significantly different between the genders, equating to a median 21 % and 20 % of energy needs in boys and girls respectively. There was a significant trend of increasing estimated under-reporting with increasing age, reaching 34 % in both

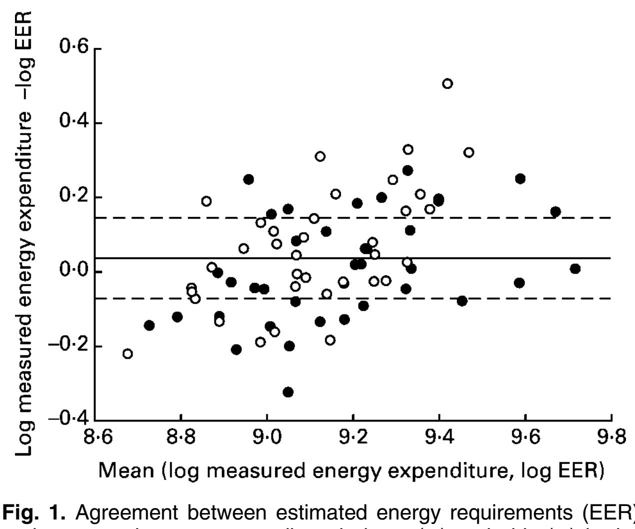


**Fig. 1.** Agreement between estimated energy requirements (EER) and measured energy expenditure in boys (●) and girls (○) in the National Diet and Nutrition Survey feasibility study ($n$ 74). The solid line shows the mean and dotted lines the 95 % CI.

boys and girls aged 15–18 years ($P<0·001$; Fig. 2). There was only a small increase in reported energy intake with age, with a median increase of 997 kJ/d in reported intake between the 4–6-year and 15–17-year age groups in girls and a median increase of 2613 kJ/d in boys. In contrast, EER increased by a median 3303 kJ/d in girls and 6346 kJ/d in boys.

In boys and girls over 7 years of age, there was no significant difference in reported energy intake between overweight and lean subjects. When expressed as the difference between EER and reported energy intake, the estimated median under-reporting of energy intake was 139 % and 38 % higher in overweight than lean boys and girls over 7 years of age respectively ($P<0·001$ in all groups except girls aged 7–10 years: where $P=0·02$; Fig. 3). Only forty-six girls (5·9 %) and twenty boys (2·5 %) reported that they were dieting at the time of the survey. Of those reporting to be dieting, 44 % of girls and 85 % of boys were defined as overweight. At the time of the survey, 160 girls (20 %) and 141 boys (17 %) reported feeling unwell. To investigate whether dieting or illness might confound the association, adjustment for self-reported general health and dieting was also made. Neither adjustment changed the extent of under-reporting in any of the above analyses (results not shown).

*Trends between NDNS and DBSC*

To assess the secular trends in under-reporting, comparisons of body weight, height, BMI and reported energy intake were performed for subjects in the DBSC 1983 survey and NDNS 1997 in two specific age groups. Median reported energy intakes were significantly lower (between 6 % and 11 %) in the NDNS 1997 compared with the DBSC. Conversely, mean body weight increased significantly between the two surveys, with weight differences of 2·6 kg and 1·8 kg in boys and girls aged 10–11 years, and 4·6 kg and 2·4 kg in boys and girls aged 14–15 years respectively ($P<0·05$ in girls, $P<0·001$ in boys, in all age groups; Table 2). Mean height also increased significantly in boys between 1983 and 1997, by 10 mm in those aged 10–11 years ($P<0·05$) and by 20 mm in those aged 14–15 years ($P<0·05$). BMI, adjusting for any secular increase in height, also significantly increased in both genders and age groups. However, the increase in the percentage of overweight only reached significance in 14–15-year-old boys. Estimated dPAL was significantly lower in the NDNS in 1997 than the DBSC in 1983, by 8 % and 9 % in boys and girls for 10–11-year-olds, and 14 % and 11 % for 14–15-year-olds, with a dPAL of 1·17 in 14–15-year-old girls.

## Discussion

This analysis suggests that there is a substantial under-reporting of energy intake in the NDNS, equating to approximately 20 % of energy needs. Furthermore, the level of estimated under-reporting rises significantly with age and is higher in overweight young people than those of a healthy weight. A comparison of data from the DBSC and NDNS suggests a secular trend towards

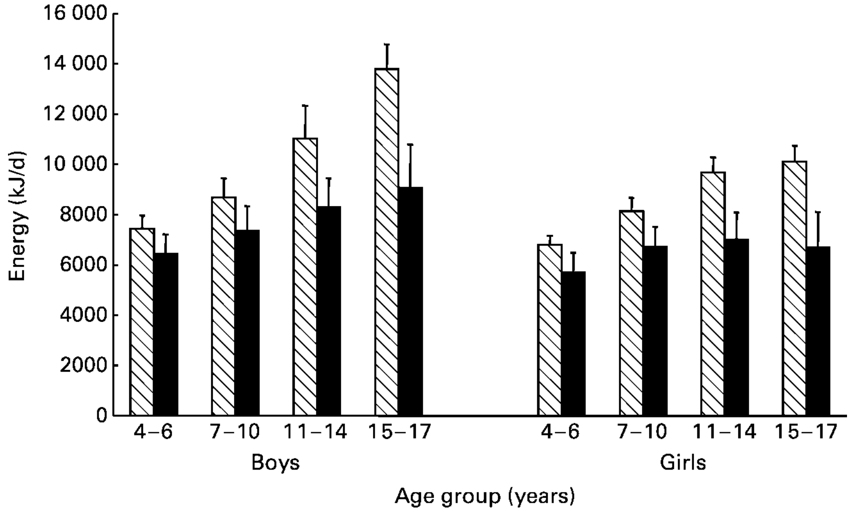


**Fig. 2.** Reported energy intake and estimated energy requirements in the National Diet and Nutrition Survey of young people (*n* 1599). (▧) Total energy expenditure; (■) Reported energy intake. Values are medians and interquartile ranges represented by vertical bars.

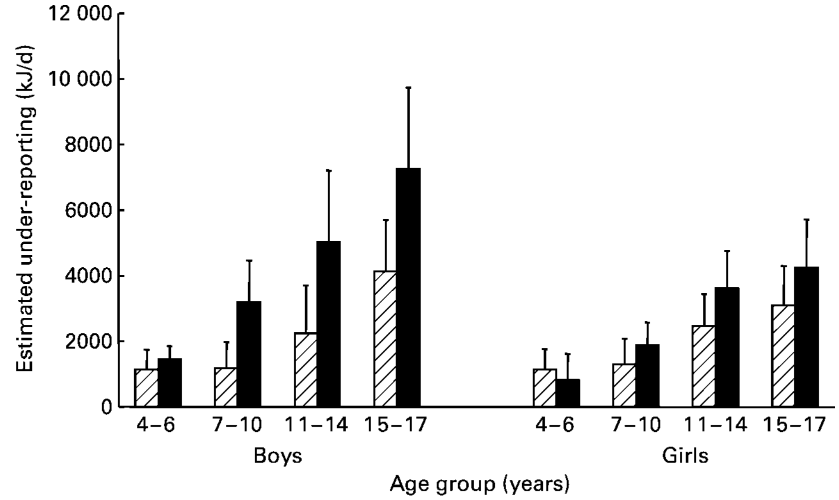


**Fig. 3.** Estimated under-reporting in overweight *v.* lean young people (4–17 years) in the National Diet and Nutrition Survey (*n* 1599). (▨) Lean; (■) Overweight.

increasing under-reporting in the 14-year period between the surveys.

The exact magnitude of a secular trend cannot be quantified in the absence of historical measures of energy expenditure. However, given the increase in body weight and BMI between the two surveys, it can be predicted that BMR was significantly higher among young people in the NDNS compared with the DBSC survey. Two scenarios can thus be considered to explain the decrease in reported energy intake. If it is assumed that there was no under-reporting of dietary intake and that the young people were in energy balance during the survey week, each subject's estimated PAL would equate to their dPAL, calculated from dietary records. Estimated dPAL by this method was significantly lower in the NDNS than the DBSC in girls and boys in both age groups, suggesting a marked decline in physical activity. With these assumptions, physical activity levels must have decreased between 1983 and 1997 by 8 % and 9 % in boys and girls respectively for 10–11-year-olds and 14 % and 11 % for 14–15 year-olds. Although there is no direct evidence of a secular trend of decreasing activity in young people (Livingstone *et al.* 2003), it is generally perceived that activity levels may have decreased in recent decades as a result of a decline in active transport, a decrease in school sport and a rise in sedentary leisure activities.

On the other hand, if it is assumed that activity levels were the same in the two surveys, under-reporting must have increased by 8–14 %. Support for the under-reporting hypothesis is provided by the implausibly low levels of absolute energy expenditure implicit in these reported dPAL values. Estimated dPAL in the NDNS 1997 was very low (1·17–1·44) and in older girls was on average below the estimated physiological minimum compatible with activities of daily living (Black, 1996).

It should, however, be noted that there were differences in the food-recording methods between the two surveys. In the NDNS, further information on food consumed at

**Table 2.** Reported energy intakes and anthropometry in 10–11-year-old and 14–15-year-old young people in 1983 and 1997
(Values are means and standard deviations; for energy intake the values are medians and interquartile ranges)

| | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Diets of British School Children (DBSC) | | National Diet and Nutrition Survey (NDNS) | | Diets of British School Children (DBSC) | | National Diet and Nutrition Survey (NDNS) | |
| *n*... | 1658 | | 250 | | 1578 | | 229 | |
| Energy intake (kJ/d)‡ | | | | | | | | |
| 10–11 years | 8437 (7518–9405) | | 7952*** (7054–8963) | | 7512 (6632–8479) | | 6951*** (6181–7787) | |
| 14–15 years | 10 014 (8542–11 583) | | 8888 (7629–10 346)*** | | 7630 (6390–8811) | | 6905 (5867–8245)*** | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Body weight (kg)§ | | | | | | | | |
| 10–11 years | 36·4 | 7·8 | 39·0 | 9·9*** | 36·9 | 7·7 | 38·7* | 7·8 |
| 14–15 years | 55·2 | 9·8 | 59·8 | 12·7 | 53·4 | 9·1 | 55·8* | 10·7 |
| Height (m)§ | | | | | | | | |
| 10–11 years | 1·43 | 0·06 | 1·44 | 0·07 | 1·43 | 0·07 | 1·44 | 0·09 |
| 14–15 years | 1·66 | 0·08 | 1·68 | 0·09 | 1·61 | 0·06 | 1·61 | 0·06 |
| BMI (kg/m$^2$)§ | | | | | | | | |
| 10–11 years | 17·8 | 3·1 | 18·6 | 3·6 | 18·0 | 3·0 | 18·7* | 2·9 |
| 14–15 years | 19·8 | 2·7 | 20·9 | 3·1 | 20·6 | 3·2 | 21·5* | 3·8 |
| Overweight (%)† | | | | | | | | |
| 10–11 years | 12·9 | | 17·9 | | 15·9 | | 21·2 | |
| 14–15 years | 11·1 | | 20·0 | | 13·3 | | 18·0 | |
| Dietary physical activity level§ | | | | | | | | |
| 10–11 years | 1·57 | 0·3 | 1·44 | 0·3*** | 1·55 | 0·3 | 1·41 | 0·3*** |
| 14–15 years | 1·48 | 0·3 | 1·27 | 0·3*** | 1·31 | 0·3 | 1·17 | 0·3*** |

DBSC, Diets of British School Children; NDNS, National Diet and Nutrition Survey.
Mean values are significantly different from those for DBSC 1983: $^{*}P>0·05$, $^{***}P>0·001$.
§ Body weight, dietary physical activity level:mean with standard deviation.
† Using International Obesity Task Force BMI cut-offs.

school, including cooking methods and portion sizes, was obtained from the school catering manager, and a greatly expanded food database was used compared with the DBSC. In the DBSC, scales and record books were provided in school canteens to weigh school meals, which may have improved the accuracy of the reported energy intake. These differences would not, however, introduce any significant systematic bias in the results. Completion rates of the dietary records were lower in the 15–18-year-old young people in the NDNS than in the DBSC. However, since this study was examining the extent of under-reporting within the surveys, such differences in methodology and completion rates are unlikely to explain such a large disparity in dPAL. We conclude that there has been a secular increase in under-reporting, although the data may in all probability be explained by a combination of an increase in under-reporting and a decrease in physical activity.

In large dietary surveys, precise measures of energy expenditure are not feasible, and therefore the extent of under-reporting can only be estimated. In our analyses, we have used predictive equations of energy requirements published in 2002 (Institute of Medicine of the National Academies, 2002) based on collated DLW energy expenditure data to estimate energy requirements in the NDNS survey. Unlike equations for energy requirements that are based on published dietary intake data, such as the earlier Food and Agriculture Organization/ World Health Organisation/ United Nations University (1985) equations, they are not subject to the same inherent errors as the survey's energy intake data. Although the data used to calculate the 2002 predictive equations were collected in non-randomly selected subjects, the data did include a wide range of children with respect to weight, height and activity levels. Unlike the Food and Agriculture Organisation/World Health Organisation/United Nations (1985) equations, the 2002 equations were based on studies largely in the United States and did not include studies from less-developed countries, thus making them more applicable to Western countries. There is nevertheless the possibility that these do not reflect the activity levels of young people in Great Britain in 1997. The equations allow adjustment for PAL, with four categories: sedentary, low active, active and very active. We used the NDNS Feasibility Study DLW data to develop age- and sex-specific PAL values to determine which PAL category was most appropriate for the 1997 NDNS. In each case, the 'active' category was selected. Since the subjects in the NDNS feasibility study were selected from a similar population base in the previous year, we think that this method of calculating under-reporting gives a good estimate of the extent of under-reporting in the NDNS.

We observed that estimated under-reporting increased with age. Studies in very young children (1·5–4·5 years) and pre-pubescents (5–8 years) in which reported energy intakes have been validated by comparison with energy expenditure by DLW suggest an appropriate reporting of energy intake in these age groups (Davies *et al.* 1994;

McGloin *et al.* 2002). However, small studies in older children have found significant discrepancies between reported energy intake and measures of expenditure (Bandini *et al.* 1990; Livingstone *et al.* 1992; Bratteby *et al.* 1998) and, prospectively, an increase in the under-reporting of energy intake with age throughout adolescence (Bandini *et al.* 2003). This could be because the parents and supervising adults of younger children record dietary intake more accurately than do older participants who record intake themselves. In older children, eating patterns may be less structured and may include more food eaten outside the home, particularly snacks, for which both quantity and composition are more difficult to estimate than they are for foods eaten at home; they are also more prone to be forgotten or deliberately missed out.

It is clear from this analysis that a much greater disparity exists between reported intake and estimated energy requirements in overweight young people than in those of healthy weight, as previously reported in adolescents (Bandini *et al.* 1990) and commonly observed in adults (Heitmann & Lissner, 1995; Pryer *et al.* 1997). An under-reporting of energy intake, especially among overweight subjects, implies an under-reporting of specific dietary components. A selective under-reporting of dietary fat (Voss *et al.* 1998; Goris *et al.* 2000), protein (Heitmann & Lissner, 1995) and snack items (Livingstone *et al.* 1990; Poppitt *et al.* 1998) has been reported in adults. This confounds attempts to understand the potential contributory role of specific dietary factors in the aetiology of obesity and other conditions. This systematic bias of reported dietary intake may either attenuate associations between dietary components and disease outcomes, leading to the acceptance of the null hypothesis, or alternatively imply spurious diet–disease relationships (Rosell *et al.* 2003).

This analysis is not able to distinguish between under-reporting and under-eating during the dietary record period, particularly among those who are trying to lose weight (Goris *et al.* 2000). One limitation of this study was that no measurements were made to determine any changes in body weight during the recording week, which could provide some insights into this phenomenon. In the NDNS, only a small number of subjects reported being on a diet at the time of the survey. Limiting the analysis to those who did not report being on a diet or feeling unwell and who might be expected to be under-eating did not alter the overall results.

We conclude that the extent of under-reporting in young people in the NDNS 1997 is approximately 20 % of energy needs, under-reporting increases with age and is greater in overweight than lean individuals. The extent of under-reporting may have increased since 1983, although the magnitude of this effect cannot be calculated in the absence of measures of energy expenditure at the time of the DBSC survey to determine secular changes in activity. The national nutrition surveys provide a wealth of information on food choice and eating habits from which public health strategies to tackle long-term health problems can be developed. However, the same caution given to under-reporting in interpreting dietary data from surveys in adults should also be applied to these data in young people. Biochemical measures of nutrient status are likely to provide a more robust estimate of the nutritional status of the population than assessments of reported dietary intake alone.


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## References


Bandini LG, Must A, Cyr HN, Anderson SE, Spadano JL & Dietz WH (2003) Longitudinal changes in the accuracy of reported energy intake in girls 10–15 y of age. *Am J Clin Nutr* **78**, 480–484.

Bandini LG, Schoeller DA, Cyr HN & Dietz WH (1990) Validity of reported energy intake in obese and nonobese adolescents. *Am J Clin Nutr* **52**, 421–425.

Black AE (1996) Physical activity levels from a meta-analysis of doubly labeled water studies for validating energy intake as measured by dietary assessment. *Nutr Rev* **54**, 170–174.

Black AE, Prentice AM, Goldberg GR, Jebb SA, Bingham SA, Livingstone MBE & Coward WA (1993) Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake. *J Am Diet Assoc* **93**, 572–579.

Bratteby L, Sandhagen B, Fan H, Enghardt H & Samuelson G (1998) Total energy expenditure and physical activity as assessed by the doubly labeled water method in Swedish adolescents in whom energy intake was underestimated by 7-d diet records. *Am J Clin Nutr* **67**, 905–911.

Cole TJ & Coward WA (1992) Precision and accuracy of doubly labeled water energy-expenditure by multipoint and 2-point methods. *Am J Physiol* **263**, E965–E972.

Cole TJ, Bellizzi MC, Flegal KM & Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* **320**, 1240–1243.

Davies PSW, Coward WA, Gregory J, White A & Mills A (1994) Total energy expenditure and energy intake in the pre-school child: a comparison. *Br J Nutr* **72**, 13–20.

Department of Health (1989) *The Diets of British Schoolchildren. Sub-committee on Nutritional Surveillance. Committee on Medical Aspects of Food Policy*. London: HMSO.

Food and Agriculture Organisation/World Health Organisation/ United Nations University (1985) Energy and protein requirements. *WHO Technical Report Series* no. 724.

Goris AHC, Westerterp-Plantenga MS & Westerterp KR (2000) Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake. *Am J Clin Nutr* **71**, 130–134.

Gregory J & Lowe S (2000) *National Diet and Nutritional Survey: Young People Aged 4 to 18 Years,* vol. 1. *Report of the Diet and Nutrition Survey*. London: Stationery Office.

Heitmann B & Lissner L (1995) Dietary underreporting by obese individuals – is it specific or non-specific. *Br Med J* **311**, 986–989.

Institute of Medicine of the National Academies (2002) Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington, DC: National Academies Press.

Livingstone MBE, Prentice AM, Coward WA, Strain JJ, Black AE, Davies PSW, Stewart CM, McKenna PG & Whitehead RG (1992) Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. *Am J Clin Nutr* **56**, 29–35.

Livingstone MBE, Prentice AM, Strain JJ, Coward WA, Black AE, Barker ME, McKenna PG & Whitehead RG (1990) Accuracy of weighed dietary records in studies of diet and health. *Br Med J* **300**, 708–712.

Livingstone MBE, Robson PJ, Wallace JMW & McKinley MC (2003) How active are we? Levels of routine physical activity in children and adults. *Proc Nutr Soc* **62**, 681–701.

McGloin AF, Livingstone MBE, Greene LC, Webb SE, Gibson JMA, Jebb SA, Core TJ, Coward WA, Wright A & Prentice AM (2002) Energy and fat intake in obese and lean children at varying risk of obesity. *Int J Obes Relat Metab Disord* **26**, 200–207.

Perks SM, Roemmich JN, Sandow-Pajewski M, Clark PA, Thomas E, Weltman A, Patrie J & Rogol AD (2000) Alternations in growth and body composition during puberty. IV. Energy intake estimated by the Youth-Adolescent Food-Frequency Questionnaire: validation by the doubly labeled water method. *Am J Clin Nutr* **72**, 1455–1460.

Poppitt SD, Swann D, Black AE & Prentice AM (1998) Assessment of selective under-reporting of food intake by both obese and non-obese women in a metabolic facility. *Int J Obes Relat Metab Disord* **22**, 303–311.

Pryer J, Vrijheid M, Nochols R, Kiggins M & Elliott P (1997) Who are the 'low energy reporters' in the dietary and nutritional surveys of British adults? *Int J Epidemiol* **26**, 146–154.

Ritz P, Cole TJ, Couet C & Coward WA (1996) Precision of DLW energy expenditure measurement: contribution of natural abundance variations. *Am J Physiol* **270**, E164–E169.

Rosell MS, Hellenius MB, Faire UH & Johansson GK (2003) Associations between diet and the metabolic syndrome vary with the validity of dietary intake data. *Am J Clin Nutr* **78**, 84–90.

Schofield W (1985) Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr* **39**, 5–41.

Trabulsi J & Schoeller DA (2001) Evaluation of dietary assessment instruments against doubly labeled water, a biomarker of habitual energy intake. *Am J Physiol Endocrinol Metab* **281**, E891–E899.

Voss S, Kroke A, Klipstein-Grobusch K & Boeing H (1998) Is macronutrient composition of dietary intake data affected by underreporting? Results form the EPIC-Potsdam Study. *Eur J Clin Nutr* **52**, 119–126.