



Under-reporting of energy intake in the 1997 National Nutrition Survey

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Abstract

Aims To estimate the level of under-reporting of energy intake by gender, age, ethnicity and body size (normal, overweight, obese) in the 1997 National Nutrition Survey (NNS97) in New Zealand.

Methods Data were from 4,258 participants (1,808 men and 2,450 women aged 15 years and over) who completed the 24-hour diet recall; the primary methodology used in the NNS97. Under-reporting was assessed using the ratio of reported energy intake to estimated resting metabolic rate (EI: RMR_{est}). Cut-off limits were used to identify percentages of under-reporters in the various subgroups.

Results Mean EI: RMR_{est} was 1.40 for all participants (1.51 for men, 1.30 for women, $p < 0.001$) with older age being associated with lower EI: RMR_{est} ($p < 0.001$). There were no significant differences in mean EI: RMR_{est} between ethnic groups for men. Mean EI: RMR_{est} for women were: Maori 1.46, European 1.29, and Pacific 1.37 ($p < 0.01$). A larger body size was associated with a significantly lower EI: RMR_{est} especially for women.

Percentages of 'definite' under-reporters (individual EI: RMR_{est} < 0.9) were as follows: men 12%, women 21%; Europeans 16%, Maori 23% and Pacific 26%; normal weight (11%), overweight (19%) and obese (27%) participants; and from 10% in the youngest to 23% in the oldest age group ($p < 0.001$ for all results).

Conclusion In this study, in agreement with the literature, women, older people and obese people under-reported more than men, younger people and non-obese people. Possible ethnic differences in under-reporting rates need further study. Care is needed in interpreting the energy intake data from the NNS97.

Under-reporting of total energy intake (hereafter referred to as 'under-reporting') is one of several potential sources of measurement error in all types of dietary surveys, and is a common and acknowledged problem. However, the extent of under-reporting in the 1997 National Nutrition Survey (NNS97)¹ and ethnic differences between European, Maori, and Pacific Islanders have not been studied.

The gold standard method for assessing the validity of reported total energy intake is through doubly-labelled water studies which can accurately assess total energy expenditure. However, because of the high cost of these studies, under-reporting of energy intake is most commonly measured by comparing reported energy intake with an individual's estimated basal metabolic rate (BMR) or resting metabolic rate (RMR).

There is a strong positive relationship between BMR, RMR, or total energy expenditure (all of which are very accurately measured) and weight or body mass index (BMI). In other words, the higher the body weight, the more energy is used to

maintain that weight.² However, the results of many dietary studies show either no relationship, or a negative relationship, between self-reported energy intake and weight or BMI.^{3,4} Since energy intake equals energy expenditure (at weight maintenance), there must be significant under-reporting of energy intake by people in the higher weight and BMI range.

Goldberg et al have suggested that while it may not be possible to improve on the quality of food intake data in dietary studies, what is important is that the possibility of bias (including bias due to under-reporting) is acknowledged and quantified, and that the data are examined and interpreted with this in mind.^{3,4} The aims of this study were to estimate the levels of under-reporting by gender, age, ethnicity, and body size in the NNS97 database.

Methods

The NNS97 survey was conducted by the University of Otago, using the primary methodology of multiple-pass 24-hour diet recall (24-HDR).^{1,5} For this analysis, data from individual participants were excluded if key variables such as height and weight were missing. Asians were excluded due to their small numbers. After these exclusions, a total of 4,258 participants (1,808 men and 2,450 women) aged 15 years and over remained for the analysis.

Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). A body size variable was created by grouping BMI into three categories: normal weight, overweight, and obese. The BMI ranges used were those suggested for New Zealanders of different ethnicities⁶ as follows: for Europeans: normal weight: $BMI < 25 \text{ kg/m}^2$; overweight: $25 \text{ kg/m}^2 \leq BMI < 30 \text{ kg/m}^2$; obese: $BMI \geq 30 \text{ kg/m}^2$; for Maori and Pacific people: normal weight: $BMI < 26 \text{ kg/m}^2$; overweight: $26 \text{ kg/m}^2 \leq BMI < 32 \text{ kg/m}^2$; obese: $BMI \geq 32 \text{ kg/m}^2$. Ethnicity was self identified.⁵

Resting metabolic rate (RMR_{est}) was estimated using several steps. Fat mass (FM, in kg) was calculated from BMI, using equations from Swinburn et al.⁷ These equations were different for New Zealand European, Maori, and Samoan males and females (Samoan equations were used for the whole Pacific ethnic group). Fat free mass (FFM, in kg) was calculated by subtracting fat mass from weight. Finally, RMR_{est} was calculated using an equation from Bogardus et al⁸ as follows: RMR_{est} (kilocalories per day) = $(22.8 \times FFM) + 489$. RMR_{est} in kilocalories per day was converted to kilojoules per day by multiplying by the standard conversion factor of 4.184.

The ratio between energy intake (EI) and RMR_{est} ($EI:RMR_{est}$) was calculated by dividing EI by RMR_{est} .⁴ Cut-off limits for identifying under-reporting were taken from the work done by Goldberg et al³ where they used basal metabolic rate (BMR), which is virtually identical to RMR. Cut-off values for evaluating energy intake using the ratio $EI:BMR$ vary according to the sample size and the number of days of diet intake records. The 95th percentile lower cut-off values for $EI:BMR$ based on 1 day of intake (as data were from a 24-HDR) were used to define 'definite' under-reporting in individuals and in population subgroups. Cut-off values for $EI: BMR$ based on 1 day of intake ranged from 0.9 for one person, to 1.53 for a group of 2,000 people.³ The 0.9 cut-off value was used to classify individuals, so that participants with an $EI:RMR_{est} < 0.9$ were considered 'definite' under-reporters. The group with an $EI:RMR_{est} \geq 0.9$ clearly contains a mixture of adequate reporters, under-reporters and over-reporters.

Because of unequal selection probabilities for participants, all statistical analyses took into account the sampling weights associated with the design of the study. Weighted means and standard errors of the mean (SEM) were calculated either unadjusted or after adjusting for potential confounders, using the statistical package STATA (StatCorp. 2001 Stata Statistical Software: Release 7.0. College Station, TX: Stata Corporation). The percentages of under-reporters calculated also took into account the unequal selection probabilities.

Table 1. Baseline characteristics of participants *

Characteristics		European	Maori	Pacific	All
Number	Male	1451	253	104	1808
	Female	1896	388	166	2450
Age (yrs), mean (SEM)	Male	43.2 (0.61)	34.8 (1.17)	34.2 (1.38)	41.9 (0.54)
	Female	44.6 (0.61)	35.3 (1.16)	34.9 (1.61)	43.1 (0.53)
Height (cm), mean (SEM)	Male	175.4 (0.25)	174.4 (0.47)	174.7 (0.85)	175.3 (0.23)
	Female	162.2 (0.21)	162.1 (0.41)	162.1 (0.61)	162.2 (0.18)
Weight (kg), mean (SEM)	Male	78.9 (0.46)	87.3 (1.66)	95.0 (2.29)	80.4 (0.45)
	Female	67.1 (0.43)	75.2 (1.13)	84.7 (2.45)	68.7 (0.41)
BMI (kg/m ²), mean (SEM)	Male	25.7 (0.13)	28.7 (0.53)	31.0 (0.63)	26.2 (0.13)
	Female	25.6 (0.16)	28.7 (0.43)	32.2 (0.86)	26.2 (0.15)
Body size, § n (%)**					
Normal	Male	607 (45.1)	85 (42.5)	†17 (14.7)	709 (43.7)
	Female	938 (52.2)	147 (39.0)	†43 (24.0)	1128 (49.5)
Overweight	Male	640 (41.9)	98 (29.8)	60 (59.7)	798 (41.1)
	Female	580 (30.3)	141 (33.0)	†50 (28.0)	771 (30.6)
Obese	Male	204 (13.0)	70 (27.7)	†27 (25.6)	30.1 (15.2)
	Female	378 (17.5)	100 (28.0)	73 (48.0)	551 (19.9)

BMI=body mass index, SEM=standard error of the mean.

*The unequal selection probabilities have been taken into account.

**Percentages relate to body size in each ethnic and gender subgroup (ie, males: % normal + % overweight + % obese = 100%).

†Limited sample size within that cell, n <50, and data should be interpreted with caution.

§See methods for definitions.

Table 2. Ratio of reported energy intake to estimated resting metabolic rate (EI:RMR_{est})*

Characteristics		Male		Female		All	
		mean	SEM**	mean	SEM	mean	SEM
All:		1.51	0.018	1.30	0.014	1.40	0.012
Ethnicity: †	European:	1.52	0.019	1.29 ^a	0.016	1.40	0.012
	Maori:	1.50	0.063	1.46 ^b	0.045	1.48	0.038
	Pacific:	1.37	0.074	1.37 ^a	0.075	1.37	0.053
Age (y): ‡	15-29:	1.64 ^a	0.039	1.42 ^a	0.034	1.53 ^a	0.026
	30-39:	1.61 ^a	0.041	1.35 ^a	0.031	1.48 ^a	0.025
	40-49:	1.54 ^a	0.038	1.27 ^b	0.028	1.40 ^b	0.024
	50-59:	1.38 ^b	0.031	1.22 ^c	0.025	1.30 ^c	0.020
	65+:	1.20 ^c	0.028	1.17 ^d	0.026	1.19 ^d	0.019
Body size: §	normal:	1.54 ^a	0.027	1.39 ^a	0.021	1.46 ^a	0.017
	overweight:	1.55 ^a	0.026	1.25 ^b	0.026	1.42 ^a	0.020
	obese:	1.31 ^b	0.036	1.15 ^c	0.025	1.23 ^b	0.022

*The unequal selection probabilities have been taken into account. ** Standard error of mean

†Adjusted for age and body size (and gender in the case of the last column 'all')

‡Adjusted for ethnicity and body size (and gender in the case of the last column 'all')

§Adjusted for ethnicity and age (and gender in the case of the last column 'all'). See methods for definitions

a, b, c, etc: Mean values for each population characteristic in the same column with different superscript letters are significantly different from each other, p<0.01.

Results

The baseline characteristics of the participants, 2450 women and 1808 men, are shown in Table 1. European men and women were 8–10 years older than the Maori and Pacific participants. The patterns of higher mean BMI and greater prevalence rates of obesity in Maori and Pacific people compared to European as shown here have previously been reported.¹

Mean values of EI:RMR_{est} (and SEM) for all participants, and for various subgroups, are presented in Table 2. Mean EI:RMR_{est} for all the participants was 1.40. Overall, females had a significantly lower EI:RMR_{est} than men (1.30 versus 1.51, $p < 0.001$, adjusted for age, ethnicity, and body size).

There were no significant differences in mean EI:RMR_{est} between different ethnic groups in men (adjusted for age and body size) but Maori women had a significantly higher mean EI:RMR_{est} compared to European and Pacific women ($p < 0.01$). Mean EI:RMR_{est} decreased with age (adjusted for ethnicity and body size). After adjustment for age and ethnicity, obese men and women had significantly lower EI:RMR_{est} compared to overweight and normal weight groups ($p < 0.001$), and in women the EI:RMR_{est} of the overweight group was also lower than that of the normal weight group ($p < 0.001$).

The mean EI:RMR_{est} values from Table 2 were compared to the cut-off values from Goldberg et al, as discussed in the methods.³ Cut-off values for one day of intake were used, and varied from a cut-off value of 1.47 for 104 Pacific men, to a cut-off of 1.53 for all 4258 participants. In all subgroups shown in Table 2, the mean EI:RMR_{est} was below the suggested appropriate cut-off value from Goldberg et al, except for the 15–29 year and 30–39 year age groups of men. The prevalence of ‘definite’ under-reporters, defined as a cut-off value for an individual’s EI:RMR_{est} of < 0.9 ^{3,9} was 12% in men and 21% in women.

Figure 1 shows the percentage of ‘definite’ under-reporters in the different ethnic groups. In contrast to the mean EI:RMR_{est} data, the ethnic differences from this analysis were statistically significant for men ($p = 0.0004$) but not for women. Figure 2 shows the percentage of ‘definite’ under-reporters in the different age groups. Differences between age groups in men, women and the total group were statistically significant ($p < 0.0005$). The percentage of ‘definite’ under-reporters in normal weight, overweight and obese groups is presented in Figure 3, with significant differences found across the groups in men and women ($p < 0.0001$).

Figure 1. Percentage of ‘definite’ under-reporters (EI:RMR_{est}<0.9) by ethnic group. Significant effects of ethnicity for men (p=0.0004) but not women.

(These percentages take the unequal selection probabilities into account)

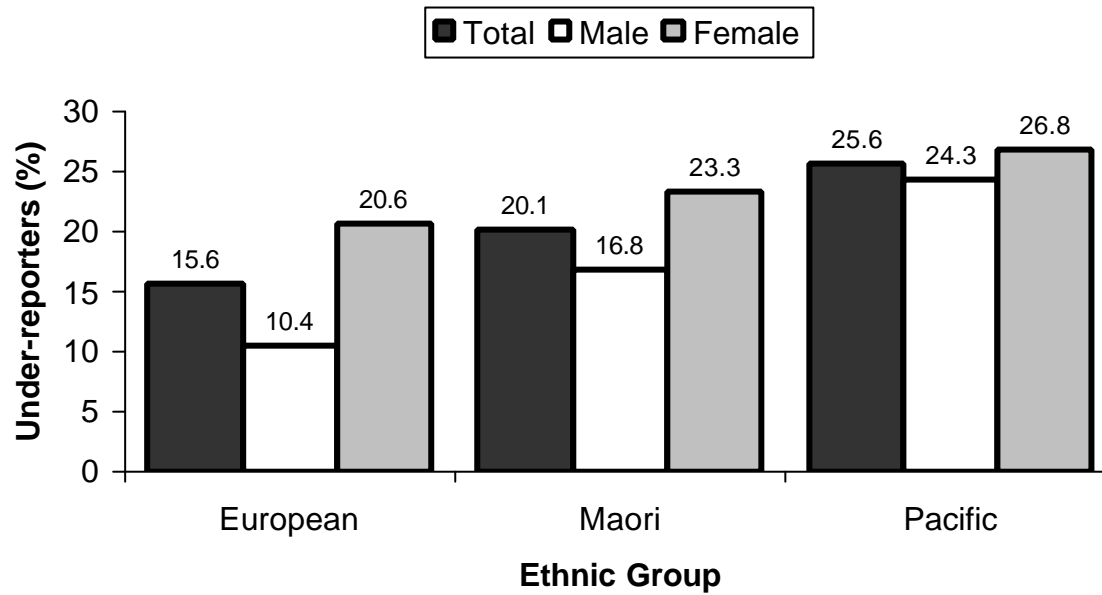


Figure 2. Percentage of ‘definite’ under-reporters (EI:RMR_{est}<0.9) by age group. Significant effects of age (p<0.0005) for both men and women.

(These percentages take the unequal selection probabilities into account)

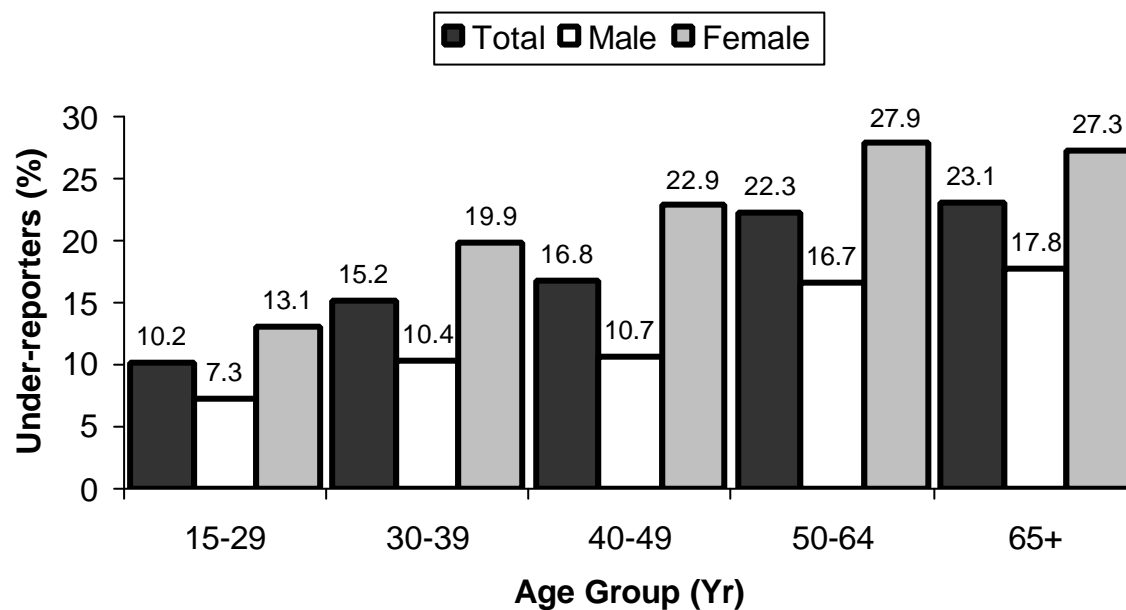
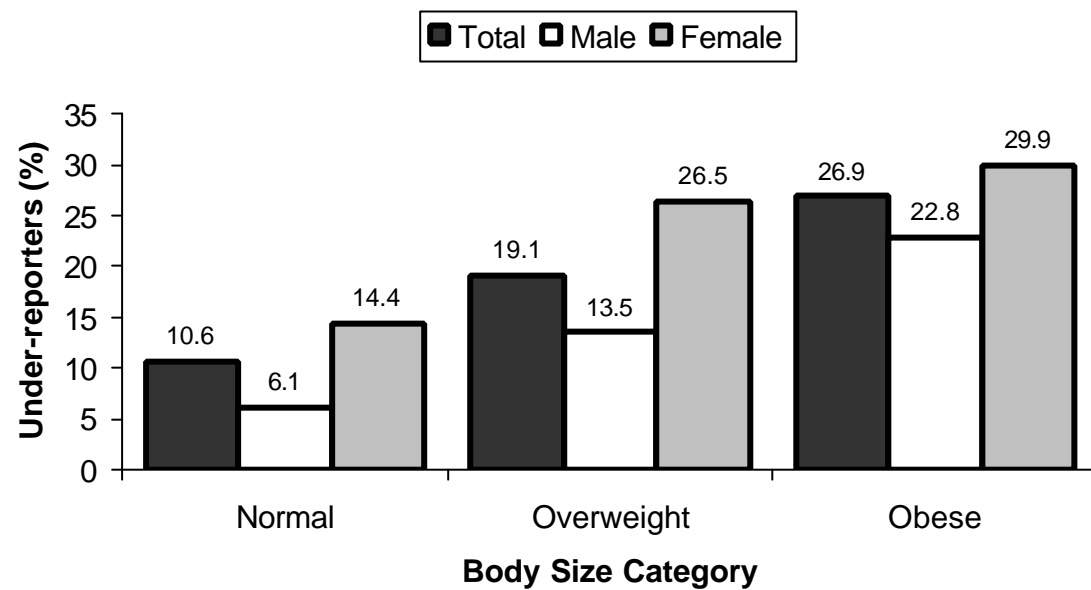


Figure 3: Percentage of ‘definite’ under-reporters ($EI:RMR_{est} < 0.9$) by *body size category*. Significant effects of body size ($p < 0.0001$) for both men and women.

(These percentages take the unequal selection probabilities into account)



Discussion

This study examined the extent of under-reporting in the 1997 National Nutrition Survey. We found a substantial level of under-reporting across most subgroups analysed. Overall, 12% of men and 21% of women reported energy intakes of less than 90% of their estimated resting metabolic rate (RMR_{est}) and were considered 'definite' under-reporters. In addition, under-reporting was significantly higher in older age groups, and those classified as overweight (women only) or obese. These patterns have been well described in other studies.⁹⁻¹²

There is some evidence in the literature suggesting that under-reporting may be more common in members of ethnic minority groups.⁹⁻¹¹ However, in the present study, the results from two different analyses of under-reporting by ethnic group gave mixed results. Using the mean $EI:RMR_{est}$ data, European and Pacific women seemed to have more under-reporting than Maori women. However using $EI:RMR_{est} < 0.9$ cut-off value, under-reporting seemed most prevalent in Pacific, lower in Maori and least prevalent in European women. Low numbers in the Maori and Pacific groups may be contributing to this uncertainty.

A re-examination of the distribution of $EI:RMR_{est}$ by gender and ethnicity showed that there were several very high individual values for $EI:RMR_{est}$ in Maori women, which caused a very positively skewed distribution, and this may explain the higher mean value of $EI:RMR_{est}$. The range of $EI:RMR_{est}$ values was also wider in Maori women. The median $EI:RMR_{est}$ for all three ethnic groups (in men and women) were slightly lower than the mean $EI:RMR_{est}$ values, but in Maori women the median $EI:RMR_{est}$ was much lower than the mean.

How does the level of under-reporting in the NNS97 compare with other surveys internationally? The NHANES III survey in the US also used 24-hour dietary recall methods. Briefel et al carried out an analysis of under-reporting in that survey.⁹ Their data analysis methods were similar to those used here, using the same cut-off value of 0.9 for $EI:BMR_{est}$ (or $EI:RMR_{est}$ as used here), derived from Goldberg et al.³ Mean values of $EI:BMR_{est}$ in their analysis (1.47 and 1.26 in men and women respectively) were lower than in the NNS97 and the percentages of 'definite' under-reporters were correspondingly higher (18% of men and 28% of women).

Comparisons with other large studies in the literature are more difficult to make, as the methods of assessment of dietary intake vary and include 7-day diet diaries, 3-day diet diaries, and food frequency questionnaires. In a meta-analysis by Black et al, a mean value for $EI:BMR$ of 1.43 (for men and women combined) was calculated for all the studies analysed (all methods), while the mean value for studies using the 24-HDR method was 1.31.⁴

The NNS97 investigators¹ felt that estimating under-reporting using the Schofield equations¹³ (which use body weight rather than fat free mass for estimating BMR) might not be appropriate for use in the New Zealand population. As the Schofield equations were developed in a normal weight population (up to 84 kg), but more than 25% of the NNS97 survey population had a weight exceeding 84 kg, the equations could not be assumed to be valid in this group. We have addressed this issue by using fat free mass to calculate RMR. Since New Zealand equations for estimating fat mass were available,⁷ fat free mass and then RMR could therefore be estimated.

Fat free mass has been shown to have a much tighter relationship than body weight with RMR, and is the best available determinant of energy expenditure, explaining about 80% of the variance observed between individuals.¹⁴⁻¹⁶ Several authors have strongly supported using prediction equations for BMR which incorporate fat free mass rather than body weight, as these would allow more accurate estimation of BMR, especially in population groups of varying body size and composition.^{17,18} As already discussed, RMR and BMR are virtually equivalent and may be substituted for one another. Other studies have used fat free mass in prediction equations for resting metabolic rate (RMR) and for 24-hour energy expenditure.^{8,14-16}

The limitations of this analysis can be considered in two broad groups, concerning firstly the methodology and the data collection in the NNS97 survey itself and secondly the methods used here to analyse the data. The NNS97¹ was linked to the concurrent New Zealand Health Survey.¹⁹ Of approximately 9,000 people who participated in the New Zealand Health Survey, and who were invited to participate in the linked NNS97, only 4,636 completed the 24-HDR in the NNS97—an overall response rate of only 50.1%.¹ The possibility of selection bias should therefore be borne in mind when interpreting the data.

An analysis of non-responders (people who took part in the New Zealand Health Survey but not in the NNS97) suggested that the NNS97 sample had similar characteristics to the New Zealand Health Survey sample.¹

The primary methodology used in the NNS97 was a 24-hour diet recall (24-HDR).^{1,5} The data from the 24-HDR have been analysed in this study. Other dietary assessment methods used in dietary studies include retrospective questionnaires of typical diet and prospective diet records (usually for 3 to 7 days, either weighed or quantified in some other way). All dietary assessment methods are subject to bias, usually towards underestimation of habitual energy intake, but the 24-HDR method tends to give lower intakes than other methods.⁴ Other issues for the 24-HDR method include intra- and inter-individual variability, day-to-day variability in food intake, weekday and weekend variability, and seasonal variability.

The gold standard method for measuring energy expenditure is to use the doubly-labelled water (DLW) technique.^{4,20-22} The rationale for doing a DLW validation study as part of a nutrition survey is enable assessment of the accuracy (or level of inaccuracy) of the dietary intake data with a greater degree of certainty than merely by calculating the ratio of $EI:BMR_{est}$ or $EI:RMR_{est}$. Energy expenditure can then be compared with self-reported energy intake, and an assessment of the degree of under-reporting can be made. The DLW method has been used in several small New Zealand studies^{23,24} but is expensive. No DLW validation study was performed in the NNS97; however the recently completed New Zealand Child Nutrition Survey included a DLW study.

Since the early 1990s, various authors have recommended that the data collected in dietary surveys should include information regarding physical activity level (PAL), dieting and weight-consciousness^{4,20,25-29} as well as DLW studies, in order to be able to assess the validity of the survey results and the level of under-reporting. Black has recently concluded that in order to assign the correct Goldberg cut-off values³ to subjects in dietary surveys, sufficient information on their level of activity is essential.^{27, 28}

Conclusions

This study highlights the difficulties of accurately measuring dietary intake through self-reporting methodologies such as the 24-hour diet recall, and the need to acknowledge and to attempt to measure the bias inherent in dietary assessment methods. Analyses such as the present one estimate the level of under-reporting and identify the subgroups with potentially greater levels of under-reporting—namely women, older people, overweight, and obese people. For more accurate estimates of under-reporting, validation studies using doubly-labelled water methodologies^{4,20–22} in those subgroups would be needed, as well as collection of information regarding physical activity level and dieting.^{25–29}

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