Original Article

Under-reporting of energy intake affects estimates of nutrient intakes

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Under-reporting of energy intake is a common problem in nutritional epidemiological studies. The aim of the present study was to determine the effect of under-reporting of energy intake on the estimates of nutrient intakes. In this cross-sectional study, 901 subjects aged >16 y were randomly selected from participants of the Tehran Lipid and Glucose Study. Dietary intake was assessed by means of two 24-hour dietary recalls. Basal metabolic rate (BMR) was determined according to age, sex and weight. The ratio of energy intake (EI) to BMR was calculated. Under-reporting of energy intake was defined as EI:BMR<1.35 and normal-reporting of dietary intake as EI : BMR = 1.35 - 2.39. To obtain energy-adjusted amounts of macro- and micronutrients, the residual method was used. Under-reporting of energy intake was revealed in 31% of the subjects and was more common among females (40%) than males (19%, P <0.01). The mean age of females who under-reported was significantly lower than the normal-reporting females (32 ± 13 vs. 35 ± 14 y, P <0.05); however, the age difference between the two groups was not significant in men. Under-reporters had higher BMIs compared to normal-reporters in both genders. The absolute intakes of macro- and micronutrients (except for B12 in females and B6 and zinc in both genders) were lower in under-reporters, but following adjustment, no significant differences were seen. The results have revealed that under-reporting of energy intake affects the estimates of nutrient intakes; thus in studies aimed at determining the association between a certain chronic disease and a nutrient intake, we suggest adjustments be made for energy intake.

Key Words: Under-reporting, energy intake, nutrients, diet, Iran.

Introduction

Accurate assessment of energy intake is particularly important in nutritional epidemiology. The search for the identification of a gold standard for assessing the validity of reported energy intake, lead to the introduction of Doubly Labelled Water (DLW) method as an accurate method for determining energy expenditure. However, because of the high cost and complexity involved in the use of this technique in large epidemiological studies, Goldberg *et al.*,[1] suggested the ratio of energy intake to basal metabolic rate (EI: BMR) for detecting misreporting of energy intake. Other investigators have confirmed this index.[2]

Several studies have assessed the accuracy of reported energy intakes at population levels and demonstrated that under-reporting of energy intake is more prevalent, particularly among obese people.[3-5] Others reported that some foods were under-reported more than others.[6-7] As obesity is the underlying cause of many of chronic diseases and under-reporting of energy intake is more prevalent among obese people, research on the issue of diet-disease relationship may not yield precise answers. When the research topic is the association between a macronutrient or micronutrient intake with a certain chronic disease, it should be kept in mind whether or not the estimates of that nutrient intake are affected by under-reporting of energy intake. Limited studies conducted on this issue have focused on macronutrients[8-10] and it remains unknown whether the estimates of micronutrient intakes are affected by under-reporting. This study was therefore conducted to assess the effect of under-reporting of energy intake on the estimates of macro- and micronutrient intake in a group of Tehranian participants of the Tehran Lipid and Glucose Study (TLGS).

Subjects and methods

Subjects

This cross-sectional study was conducted within the framework of the Tehran Lipid and Glucose Study (TLGS), a prospective study performed on residents of district 13 of Tehran with the aim of determining the prevalence of non-communicable disease risk factors and developing a healthy lifestyle to curtail these risk factors.[11,12] In the TLGS, 15005 people aged 3 years and over, living in district 13 of Tehran, were selected by the multistage cluster random sampling method. A subsidiary population aged 16-80 years old consisting of 901 subjects (390 males and 511 females) were selected randomly for dietary

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assessment. It should be kept in mind that this sample also includes those who were on a weight-reducing diet. The proposal of this study was approved by the research council of the Endocrine Research Center of Shaheed Beheshti University of Medical Sciences and informed written consent was obtained from each subject.

Methods

Subjects were interviewed privately, face-to-face. Interviews were conducted by trained dietitians using a pre-tested questionnaire. Initially information on socio-demographic variables was collected. Anthropometric measurements of weight and height were determined using a digital electronic weighing scale and tape meter while the subjects were lightly clothed and wearing no shoes or restrictive underwear. Weight was recorded to 100g and height to the nearest 1cm. All measurements were made by the same individual to reduce subjective error and maintain uniformity.[13] Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Obesity was defined as BMI≥ 30 kg/ m^2.

Trained nutritionists, who had at least 5 years of experience in the Nationwide Household Food Consumption Survey Project, collected dietary data using two quantitative 24-hour dietary recalls. The first recall was completed at the subject's home and the second at the TLGS Research Unit within 3 days after the first one by the same interviewer. Subjects were asked to recall all foods and beverages consumed during the preceding 24-hours. To assist subjects to recall accurately, household utensils were used. Mothers were asked about the type and quantity of meals and snacks when subjects were unable to recall. Food values were usually recorded as household measures in details. Portion sizes of consumed foods were converted to grams using household measures.[14] Each food and beverage was then coded according to the prescribed protocol and analyzed for content of energy and the other nutrients using the Nutritionist III software program modified for Iranian foods. The basal Metabolic Rate (BMR) was calculated based on weight, age and sex according to Schofield's equations.[15]

Goldberg *et al.*,[1] calculated the minimum requirement of energy based on measuring total energy expenditure by whole-body calorimetry and coefficients for physical activity levels suggested by FAO/WHO/UNU.[16]
They found that an EI: BMR <1.35 was not consistent with usual dietary intake. We therefore defined under-reporting of energy intake as EI: BMR <1.35. Since a cut-off point of EI: BMR ≥2.4 has been suggested by Black *et al.,* as over-reporting of energy intake, we used a range of 1.35-2.39 as normal-reporting of dietary intake.[1]

Statistical Methods

Findings are shown as mean ± SD. Student t test was used to detect any differences between quantitative variables. The residual method was used to obtain energy-adjusted amounts of macro-and micronutrient intakes; therefore total energy intake was considered as an independent variable and absolute amounts of macro- and micro-nutrients were considered as dependent variables in linear regression models. Pearson correlation coefficients were used to assess the relationship between quantitative variables. The qui-square test was applied for detecting differences in proportions. The *P* value was considered significant at <0.05. All statistical analyses were conducted using SPSS (SPSS, Inc. Chicago, IL: Version 9.05) for windows.

Results

Men were older (37±14 vs. 33±14 y, *P*<0.01) and had a lower BMI (25.0±4.4 vs. 26.0±5.4 kg/m^2, *P*<0.01) compared to women. Total energy intake (2747±616 vs. 2016±549 kcal/d, *P*<0.01) and EI: BMR (1.64±0.34 vs. 1.43±0.39, *P*<0.01) was higher in men than women. Men also had higher BMR than women (1674±206 vs. 1411±123 kcal, *P*<0.01). The body mass index was inversely associated with EI: BMR in both men (R=-0.45, *P*<0.01) and women (R=-0.49, *P*<0.01). Under-reporting (40% VS. 19%, *P*<0.01) and obesity (23% vs. 12%, *P* <0.01) was more prevalent among women than men.

General characteristics of under-reporters compared to normal-reporters are shown in Table 1. Female under-reporters were older compared to normal-reporters (35 ± 14 vs. 32 ± 13 y, *P*<0.05), whereas there was no significant difference between male under- and normal-reporters with regards to age. Under-reporters had a higher BMI compared to normal-reporters in either gender (males: 26.7±4.5 vs. 24.5±4.3 kg/m^2, *P*<0.01 and females: 27.7±5.4 vs. 24.8±5.1 kg/m^2, *P*<0.01). The prevalence of under-reporting of energy intake increased with BMI in both genders, such that the highest prevalence was seen among obese subjects (data not shown).

Table 1. General characteristic of under- and normal-reporters by gender

Variables	EI: BMR			
	Males		Females	
	<1.35 (n=77)	1.35-2.39 (n= 313)	<1.35 (n=209)	1.35-2.39 (n=302)
Age (y)	39 ± 14	37 ± 14	35 ± 14	32 ± 13†
Weight (kg)	79 ± 13	71 ± 13*	69 ± 14	62 ± 12*
Height (cm)	172 ± 6	170 ± 6	157 ± 6	158 ± 6
BMI (kg/m^2)	26.7 ± 4.5	24.5 ± 4.3*	27.7 ± 5.4	24.8 ± 5.1*
Energy intake (kcal)	2014 ± 341	2926 ± 529*	1517 ± 323	2362 ± 387*
BMR (kcal)	1748 ± 207	1655 ± 201*	1441 ± 113	1391 ± 112*
EI: BMR	1.15 ± 0.13	1.77 ± 0.26*	1.05 ± 0.21	1.70 ± 0.26*

* *P*<0.01 and † *P*<0.05 compared to <1.35 group.

Table 2 shows absolute and calorie-adjusted amounts of macronutrient intakes in under- and normal-reporters. Absolute amounts of carbohydrate, protein and fat intake were significantly lower in under-reporters compared to normal-reporters, both in males and females, whereas calorie-adjusted amounts of these macronutrients were not significantly different between these two groups. This was also the case for most of the micronutrient intakes in males (Table 3) and females (Table 4). Absolute amounts of all micronutrient intakes, except for B2 intake in females and B6 and zinc intakes in both genders were lower in under-reporters than normal-reporters, while after controlling for the effect of energy intake, there was no significant difference between under- and normal-reporters with regards to micronutrient intakes.

Discussion

The present study, conducted in an urban population of Tehran, showed that under-reporting of energy intake affects estimates of macro- and micronutrient intakes. Under-reporting of energy intake was positively associated with body mass index and obese subjects had the highest rate of under-reporting. Absolute amounts of nutrient intakes were positively related to EI: BMR. Absolute amounts of macro- and micronutrient intakes were lower in under-reporters compared to normal-reporters, whereas after controlling for the effect of energy intake, there was no significant difference between under- and over-reporters with regard to nutrient intakes.

Table 2. Absolute and energy-adjusted amounts of macronutrients intakes in under- and normal-reporters

	EI: BMR			
	Males		Females	
	<1.35 (n=77)	1.35-2.39 (n= 313)	<1.35 (n=77)	1.35-2.39 (n= 313)
Absolute amounts (g/d)				
Carbohydrate	311 ± 62	432 ± 84*	277 ± 55	342 ± 65*
Protein	60 ± 15	84 ± 20*	46 ± 11	65 ± 13*
Fat	62 ± 18	99 ± 33*	49 ± 16	85 ± 27*
Energy-adjusted amounts (g/d)				
Carbohydrate	348 ± 11	351 ± 17	308 ± 14	307 ± 17
Protein	77 ± 6	76 ± 8	55 ± 8	57 ± 10
Fat	87 ± 11	88 ± 13	80 ± 12	79 ± 10

* *P*<0.01 compared to <1.35 group.

Table 3. Absolute and energy-adjusted amounts of micronutrients intakes in male under- and normal-reporters

Dietary intakes	EI: BMR (Absolute amounts)		EI: BMR (Energy-adjusted amounts)	
	<1.35	1.35-2.39	<1.35	1.35-2.39
Vitamin C (mg)	100 ± 60	130 ± 68*	120 ± 9	125 ± 4
Thiamine (mg)	1.4 ± 0.4	2.1 ± 0.6*	2.0 ± 0.07	1.9 ± 0.03
Riboflavin (mg)	1.1 ± 0.4	1.5 ± 0.6†	1.5 ± 0.07	1.4 ± 0.03
Vitamin B6 (mg)	0.5 ± 0.2	0.7 ± 0.3	0.7 ± 0.03	0.7 ± 0.01
Vitamin B12 (μg)	1.8 ± 1.4	2.3 ± 1.8†	2.3 ± 0.2	2.2 ± 0.1
Iron (mg)	21 ± 7	28 ± 8	27 ± 1	26 ± 1
Zinc (mg)	4 ± 2	5 ± 2	4 ± 1	5 ± 1
Calcium (mg)	598 ± 215	716 ± 253*	727 ± 31	685 ± 14
Phosphorus (mg)	644 ± 198	856 ± 298*	857 ± 33	805 ± 15
Magnesium (mg)	170 ± 40	135 ± 65†	135 ± 8	129 ± 4
Potassium (mg)	1955 ± 638	2427 ± 816†	2397 ± 100	2320 ± 43

* *P*<0.01 and † *P*<0.05 compared to <1.35 group.

Table 4. Absolute and energy-adjusted amounts of micronutrients intakes in female under- and normal-reporters

Daily dietary intakes	EI: BMR (Absolute amounts)		EI: BMR (Energy-adjusted amounts)	
	<1.35	1.35-2.39	<1.35	1.35-2.39
Vitamin C (mg)	98 ± 59	130 ± 63*	120 ± 5	114 ± 4
Thiamine (mg)	1.1 ± 0.3	1.6 ± 0.3*	1.4 ± 0.02	1.4 ± 0.02
Riboflavin (mg)	1.0 ± 0.3	1.3 ± 0.4	1.2 ± 0.03	1.2 ± 0.02
Vitamin B6 (mg)	0.5 ± 0.2	0.6 ± 0.2	0.6 ± 0.02	0.5 ± 0.01
Vitamin B12 (μg)	1.4 ± 1.2	1.8 ± 1.7†	1.5 ± 0.1	1.7 ± 0.1
Iron (mg)	15 ± 5	22 ± 6*	19 ± 1	19 ± 1
Zinc (mg)	3 ± 2	4 ± 2	4 ± 1	4 ± 1
Calcium (mg)	512 ± 210	636 ± 243†	603 ± 20	574 ± 16
Phosphorus (mg)	537 ± 177	736 ± 220*	649 ± 17	658 ± 13
Magnesium (mg)	99 ± 72	122 ± 50*	118 ± 5	109 ± 4
Potassium (mg)	1755 ± 586	2264 ± 686*	2121 ± 54	2011 ± 43

* *P*<0.01 and † *P*<0.05 compared to <1.35 group.

We used two 24-hour dietary recalls for collecting dietary data to obtain more detailed data for research purposes. Other epidemiologic studies such as the Ten State Nutrition Survey,[17] NHANES I[18] and the Multiple Risk Factor Intervention Trial[19] have used the recall method alone or in combination with other dietary assessment methods for gathering dietary data. Collecting dietary data for two days could provide more accurate estimates of dietary intake as compared to just for one day. The validity of data provided by this method has been reported previously[20] and it has been shown that estimates obtained from recalls are comparable to those obtained with more precise methods such as dietary records.[21,22]

In the present study, the ratio of EI: BMR has been used for assessing the accuracy of reported energy intake data. Goldberg *et al.,*[1] calculated the minimum requirement of energy based on measuring of total energy expenditure by whole-body calorimetry and coefficients for physical activity levels suggested by FAO/WHO/UNU[16] and found that an EI: BMR<1.35 was not consistent with usual dietary intake. Other studies also have used EI: BMR to identify under-reporters, but the difference between methods used in various studies for gathering dietary data and different equations for BMR and different cut- off points to identify under-reporters could lead to the difference in findings of these studies. Overall prevalence of under-reporting of energy intake in the TLGS using a cut-off point of 1.35 was 31% that was related to age, sex, obesity and smoking.[23] Therefore, under-reporters are not randomly distributed among our population and this phenomenon is exclusive to some special groups of the population.

In the present study, nutrient intakes were lower in under-reporters than normal-reporters, but the energy-adjusted amounts of these nutrients were not significantly different between these two groups. Voss *et al.,*[8] also showed that absolute amounts of macronutrients were lower in under-reporters compared to those with higher EI: BMR, but after controlling for the effect of energy intake, they have reported no difference between under-reporters and those with high EI: BMR with regard to macronutrients intake. Pryer *et al.,*[24] reported lower amounts of macronutrient intakes among under-reporters, whereas after adjusting for energy intake with the nutrient density method, they showed that under-reporters ate diets with a lower density of carbohydrate and higher densities of protein, starch, cholesterol, MUFA, PUFA and most micronutrients compared to normal-reporters. Similar findings were also reported by Samaras *et al.*,[25] Other investigators have suggested that after controlling for energy intake, under-reporters can be used in the analysis.[26]

Contradictory to our findings, Hirvonen *et al.,*[27] have shown that in Finnish subjects, after excluding under-reporters, the contribution of macronutrients to energy did not change significantly and they reported that an increasing prevalence of under-reporting does not necessarily distort dietary surveys. Such a finding has also been reported by Australian investigators.[28] However it should be kept in mind that different studies have used different methods of energy adjustment. Some studies have used the residual method and others used the nutrient density method for controlling the effect of energy. The nutrient density method is used as an absolute amount of nutrients divided by total energy intake. This method of adjustment is dependent on changes in energy intake,[29] such that calorie-adjusted amounts of nutrients obtained by using this method are still correlated with energy intake. Therefore, using the nutrient density method is not appropriate in studies looking for the diet-disease relationship and it is recommended that investigators use energy-adjusted amounts of nutrients by residual method in assessing this relationship, because these amounts are independent of total energy intake. The results of the present study also showed that the energy-adjusted amounts of nutrients are independent of the EI: BMR ratio.

As total energy intake is related to most chronic diseases and under-reporting of energy intake affects estimates of most nutrients, therefore, the method of obtaining energy-adjusted amounts of nutrients is necessary in studies looking for diet-disease associations.

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Original Article

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熱量攝取量低報影響營養素攝取的評估

熱量攝取量低報在營養流行病學的研究中是個普遍存在的問題。本研究的目的為評估熱量攝取量低報對營養素攝取量估計的影響。在這個橫斷性研究中，從「德黑蘭脂質及葡萄糖研究」中隨機選取 901 名年齡大於 16 歲的研究對象。採用兩次 24 小時飲食回憶評估飲食攝取量。依據年齡、性別及體重去估算基礎代謝率(BMR)，並計算能量攝取(EI)與 BMR 的比值。EI：BMR<1.35 定義為熱量攝取量低報，而 EI：BMR=1.35-2.39 為合理的飲食攝取估算。使用殘差法進行能量校正，計算出巨量及微量營養素的攝取量。有 31%的研究對象有低報熱量攝取量的現象，女性(40%)高於男性(19%，*P*<0.01)。低報熱量攝取量的女性其年齡顯著低於確實報告的女性(32±13 vs. 35±14 歲，*P*<0.01)；但是，在男性中兩組的年齡卻沒有顯著的差異。不論男女性中，低報者較確實報告者有較高的 BMI。低報者巨量及微量營養素的絕對攝取量均較低(女性的 B12 及男女性的 B6 及鋅)，但是經過校正之後則沒有顯著差異。本研究結果顯示出低報熱量攝取量會影響到營養素攝取量的估算，因此本研究建議當進行慢性疾病及營養素攝取量的相關性評估時，需校正熱量攝取量。

關鍵字：低報、熱量攝取量、營養素、飲食、伊朗。