2）身体活動の評価法

質問紙によって，扱っている身体活動・運動の内容や量的な換算法に差がみられる．また，こうした質問紙による評価法は，活動内容を区別する上では有用であるが，被験者の主観に左右され，必ずしも十分な妥当性があるわけではない[14]．加速度計法・歩数計法等の，より客観的な方法を用いる必要がある[15]．

3）対象特性や疾病の区別

今回，性や年齢階級，疾病別に基準値を決定するほどの根拠がなかったため，これらをまとめて検討した．また，基準値を決定する際に直接利用された日本人の研究は2件のみ[16,17]であった．

4）身体活動量の上限値

今回は，身体活動の上限値を決定する根拠は見当たらなかった．ただし，上限値の存在を示唆する報告もあり，「運動のし過ぎ」に関する検討も必要である．

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連載 肥満の評価と予防のためのエビデンス

8

肥満とエネルギーバランス

高田 和子

エネルギーバランスの考え方は，とても単純であり，エネルギーバランス＝(エネルギー摂取量)－(エネルギー消費量) で求めることができる．エネルギーバランスが正の状態が続くことによって肥満が生じることは，多くの人が納得するところであろう．エネルギーの消費と摂取のバランスがとれていれば，体重の変動はない．エネルギー摂取量がエネルギー消費量を上回れば，体脂肪として蓄積され，反対にエネルギー消費量がエネルギー摂取量を上回れば，体脂肪を動員して不足するエネルギーを補う．

実際には肥満に至るエネルギーバランスは1日当たりにすると意外と小さい．1カ月に1kgの体脂肪が増加する場合，体脂肪1g当たりのエネルギーは7kcalと考えられることから，1カ月で7,000kcalのエネルギー摂取量の過剰が生じていることになる．これは，1日当たりにすると約230kcal程度で，エネルギー摂取量として考えると，ご飯ならば小さい茶碗1杯，ビールならば約500mL，ドーナッツならば小さめの物1個ぐらいである．このようにエネルギーバランスの考え方は簡単であるが，自由に生活している状態のエネルギー消費量，エネルギー摂取量を正確に測定し，エネルギーバランスを評価することは難しい．

1．エネルギー摂取量の評価

エネルギー摂取量は，食事の摂取量を評価することによって知ることができる．食事の摂取量の評価方法には，食事を摂取する時に食べた物の記録をする食事記録法，食べた物と同じ物を提出してもらい分析する陰膳法，前日24時間に食べた物を思い出してもらう24時間思い出し法，決まった食品の摂取頻度を回答する食物摂取頻度調査法などがある．それぞれ，長所・短所があり，目的に応じて調査方法を選択している（表1）[1]．しかし，エネルギー摂取量の測定の精度は，コントロールした実験条件下で2～3％，自由な生活でさまざまな食事をしている時の精度は正確にはわかっていないが，24時間思い出し法で16％，食事記録法では20～30％の誤差があると推測されている[2,3]．

多くの場合，エネルギー摂取量は過小に評価されがちである．自由な生活条件で現時点でもっとも正確にエネルギー消費量を測定できるとされている方法である二重標識水（doubly labeled water：DLW）法を使用して，エネルギー摂取量調査の精度を評価した研究においては，多くの研究でエネルギー摂取量が過小に評価されることが報告されている．Toozeらはエネルギー摂取量が過小に評価される要因を図1[4] のようにまとめ

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表1 食事調査法のまとめ（文献1）

	食事記録法	24時間思い出し法	食物摂取頻度調査法
特徴	・対象者によって摂取された飲食物の食品名，摂取量，調理法などリアルタイムで記録を行なう ・摂取量については，秤量ないし目安量を記入する	・対象者に前日24時間の食事を想起させ，訓練を受けた面接者が食品名，目安量，調理法などを聞き取る ・目安量をフードモデル，写真，イラストなどを用いて推定する	・過去，一定の期間について，食品/料理の習慣的な摂取頻度あるいは目安量について，多くは自記式で回答する ・食品は50～60から120項目程度があげられている
栄養素等摂取量の算出	食品成分表	食品成分表	専用に開発された成分表
長所	①リアルタイムの記録なので，回答者の記憶をあてにしない ②記入漏れがない ③調査期間が明確である ④集団の摂取量の平均値や中央値が計算できる ⑤複数日の調査は，他の食事評価法のゴールドスタンダードとして利用される	①実施時間が短い ②調査期間が明確である ③調査することが習慣的食事パターンを変えない ④回答率が高い ⑤集団の摂取量の平均値や中央値が計算できる ⑥複数日の調査は，ほかの食事評価法のゴールドスタンダードとして利用される	①ほかの2法に比して簡便で費用が安い ②回答者の負担が小さい ③面接者を必要としない ④個人の摂取量のランク付けが可能 ⑤食事と疾病との関係が疫学的に解析できる
短所	①対象者の負担が大きい ②習慣的食事のパターンが記録の過程で変わるか，影響を受けることがある ③対象者に高い協力性が求められる ④データ集計には多くの人手，時間，コストがかかる ⑤1日調査では個人の習慣的な摂取量の推定はできない ⑥多人数，多数日の調査は難しい	①対象者の記憶に依存する ②訓練された面接者が必要 ③摂取量の正確性は高くない ④1日調査では，個人の習慣的な摂取量の推定はできない	①対象者の記憶に依存する ②思い出しの期間が漠然としている ③食物摂取量が厳密には算出されない ④調査票の精度を評価するための，妥当性研究を行なう必要がある
誤差，偏り	偶然誤差： 日差，週差，季節差 系統的誤差： 食品成分表，コード付け	偶然誤差： 日差，週差，季節差 系統的誤差： 食品成分表，コード付け，思い出し，重量推定	偶然誤差： 季節差，標本誤差 系統的誤差： 食品成分表，思い出し，頻度推定，重量推定

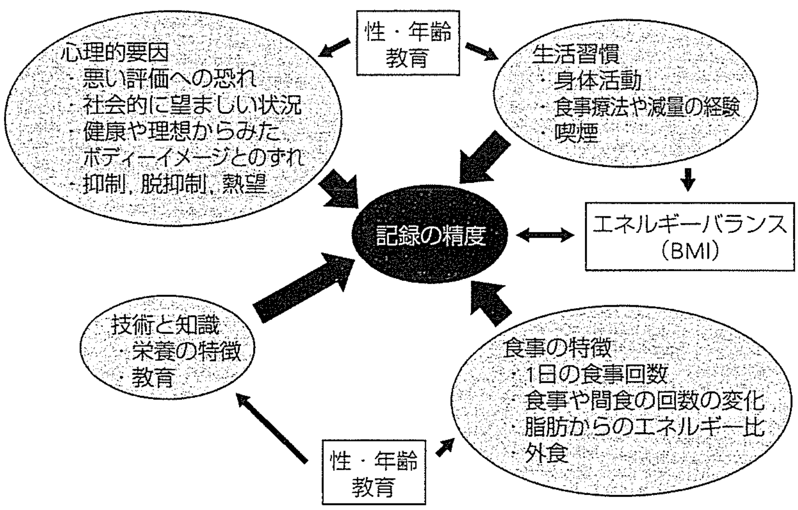

図1 過小評価の要因（文献4）

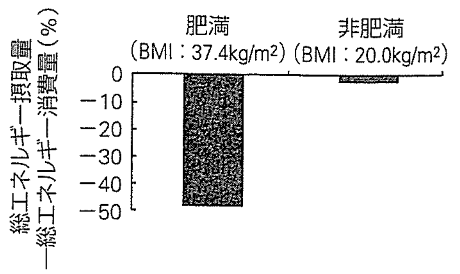

図2　エネルギー摂取量の過小評価の肥満度による違い（文献5）

ている．

エネルギーバランスを肥満との関連で検討する場合に問題となることとしては，エネルギー摂取量の過小評価の程度が，肥満者において大きい傾向にあることである．Platteらは肥満者（BMIが平均37.4kg/m^2）と非肥満者（BMIが平均20.0kg/m^2）のグループでDLW法で測定したエネルギー消費量と食事記録から求めたエネルギー摂取量を比較している（図2）[5]．肥満者のグループではエネルギー摂取量がエネルギー消費量に比べて約46％も低く調査された．エネルギー摂取量の調査が正確であれば2週間で3.1kgの体重減少を起こすはずであったが，実際には2週間で1kgの減少であり，食事の記録をすることにより，摂取量がやや減少してエネルギーバランスは負になっているものの，それ以上にエネルギー摂取量が低く評価されていた．

2. エネルギー消費量の評価

エネルギー消費量の評価方法にもさまざまな方法がある．対象者が記録するものとしては，行なった行動をすべて記録していく行動記録，主な活動の時間を回答する質問紙がある．また歩数計や加速度計などにより活動量を評価する方法，酸素の消費量を測定する方法，先に示したDLW法などがある（表2）[6]．エネルギー消費量測定の精度は，エネルギー消費量の評価方法ではもっとも精度が高いとされているヒューマンカロリーメータを使用した場合で2％程度とされているが，自由な生活条件での測定では，もっとも精度の高いDLW法でも3～6％，行動記録法で2～15％，加速度計では少なくとも10％，機器や活動内容によっては50％以上の誤差があると考えられている[6]．

3. エネルギー蓄積量の評価

エネルギーの移動は，消費と摂取だけでなく，体内のエネルギー蓄積量の変化も影響する．肥満はエネルギー摂取量の過剰分が体内に蓄積された状態であるから，体内の脂肪量，除脂肪量を測定することでエネルギーバランスを評価できる．体重は比較的正確に測定することが可能であるが，脂肪量・除脂肪量の測定は測定法により精度が異なる．体組成の評価方法のうち，精度の高いとされている水中体重測定や気体による体密度測定，二重エネルギーX線法（dual-energy X-ray densitometry）による測定誤差は1SD程度，約0.5kgとされている[3]．この測定誤差は，体脂肪量，除脂肪量の両方に起こるため，エネルギー蓄積量の誤差は約18MJ（4,300kcal）と考えられている．

4. エネルギーバランスの評価

1カ月での体脂肪1kgを増加しうるエネルギーバランスの乱れを把握するためには，最初に示したように1日当たりで230kcalの正のエネルギーバランスが確認できなければならない．しかしながら，実際的な方法としてエネルギー摂取量を食事記録で，エネルギー消費量を加速度計で把握しようとした場合，誤差は最小でもそれぞれ20％，10％ある．1日のエネルギー摂取量，消費量が2,000kcalの場合，誤差はそれぞれ400kcal，200kcalになり，230kcalのバランスを評価することは難しい．

Eliaらはエネルギー消費量の測定精度を3,5,10％（エネルギー量で0.36，0.6，1.2MJ/day）とし，エネルギー消費量の測定精度を3～15％（0.4～1.8MJ/day）とした時のエネルギーバラン

表2 調査方法と疫学研究での汎用性（文献6）

調査方法	適応年齢グループ	大規模研究での使用	低費用	短時間	対象者の所要時間が少ない	対象者の負担が少ない	行動への影響	対象者の受け入れ易さ	社会的な受け入れ易さ	特定の活動
調査										
活動特定記録	成人・高齢者	Y	Y	Y	N	N	Y	?	Y	Y
質問紙による思い出し	成人・高齢者	Y	Y	Y	Y	Y	N	Y	Y	Y
量的質問紙	成人・高齢者	Y	Y	N	N	N	N	Y	Y	Y
活動記録	成人・高齢者	Y	Y	Y	Y	Y	N	Y	Y	N
モニタ										
行動観察	成人・高齢者	N	N	N	N	Y	Y	?	?	Y
仕事の分類	成人	Y	Y	Y	Y	Y	N	Y	Y	Y
心拍数記録	すべて	N	N	N	Y	Y	N	Y	Y	N
心拍数とモーションセンサ	すべて	N	N	N	Y	Y	N	Y	Y	N
モーションセンサ	成人・高齢者	Y	N	Y	Y	Y	N	Y	Y	N
歩数計	成人・高齢者	Y	Y	Y	Y	Y	N	Y	Y	N
姿勢記録	小児・成人・高齢者	N	N	Y	Y	Y	N	Y	Y	N
加速度計	すべて	Y	Y	Y	Y	Y	N	Y	Y	N
水平方向モニタ	小児・成人・高齢者	N	N	Y	Y	Y	N	Y	Y	N
スタビロメータ	乳児	N	N	Y	Y	Y	N	Y	Y	N
直接法によるカロリーメータ	すべて	N	N	N	N	N	Y	N	N	Y
間接法によるカロリーメータ	成人・高齢者	N	N	N	N	N	Y	N	N	Y
二重標識水	小児・成人・高齢者	Y	N	N	Y	Y	N	Y	Y	N

Y：Yes N：No

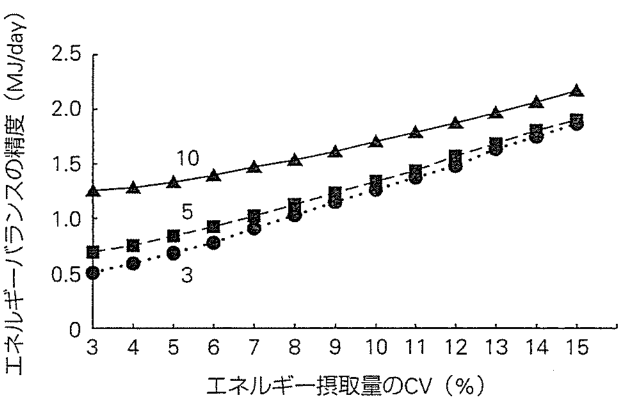

図3 エネルギー消費量（0.36（●…●），0.60（■—■），1.2（▲—▲）MJの3段階での精度）とエネルギー摂取量（0.4～1.8MJ/dayの精度）で別に測定した時に評価されるエネルギーバランスの精度（文献3）

スの測定精度の関係について図3のようにまとめた[3]．これによるとエネルギーバランスの測定精度は各条件によって0.5～2.0MJ/day（約120～478kcal/day）となり，肥満に至るエネルギーバランスの状態を日々，評価することが困難であることが示されている．

さらに1カ月の前後で体組成を測定した場合，エネルギー蓄積量に換算した誤差は4,300kcalと見込まれ，1日当たりにすると約140kcalになる．実際には，エネルギーのバランスは長期的な体組成の変化で確認するしかない．エネルギー蓄積量の誤差を1年間で検討する場合には，1日当たり12kcal程度の誤差になるため，1日のエネルギー摂取量，消費量が2,000kcalであれば，この誤差は0.6％にしかならず，エネルギー摂取量と消費

表3　ベースラインに比べて過食になって生じた変化（文献7）

	ベースライン	過食	過食—ベースライン	P †
エネルギー摂取量（MJ/day）	13.3±1.3	19.5±2.0	6.2±1.9	<0.001
体重（kg）	73.7±9.5	81.4±9.6 ‡	7.6±1.6 ‡	<0.001
除脂肪体重（kg）	57.4±4.0	60.7±4.2 ‡	3.0±0.9 ‡	<0.001
脂肪量（kg）	16.3±7.0	20.3±7.4 ‡	4.6±2.1 ‡	<0.001
CAL EE（MJ/day）	10.6±0.6	12.4±0.6	1.8±0.5	<0.001
CAL EE（kJ/kg/day）	146±17	154±15	9±4	<0.001
CAL A＋T（MJ/day）	3.3±0.2	4.2±0.4	0.9±0.4	<0.001
BMR（MJ/day）	7.3±0.5	8.2±0.2	0.9±0.4	<0.001
BMR（kJ/kg FFM/day）	128±9	137±9 ‡	9±10 ‡	<0.05
踏台昇降（kJ/30min/kg）	7.2±0.5	7.3±0.4	0.1±0.4	ns
自転車（kJ/30min/kg）	8.2±1.2	8.2±0.9	0.0±0.5	ns
DLW TEE（MJ/day）	13.2±1.2	14.8±1.6 ‡	1.4±2.0 ‡	ns
DLW TEE（kJ/kg/day）	187±35	186±35 ‡	−1±25 †	ns
DLW A＋T（MJ/day）	5.9±1.4	6.5±1.6 ‡	0.5±1.8 ‡	ns
TEE/BMR	1.8±0.3	1.8±0.2 ‡	1.7±0.2 ‡	ns
エネルギー／増加した体重（MJ/kg）	NA	28.7±4.4 §	NA	—

* $\bar{x}$ ± SD，特記以外 n ＝ 9（#807 を除く）．CAL EE：ヒューマンカロリーメータで測定した 24 時間のエネルギー消費量
BMR：基礎代謝　DLW TEE：二重標識水法で求めたエネルギー消費量　A ＋ T：活動と熱発生の計（CAL EE−BMR または DLW TEE − BMR から求めた）
† Paired と test　‡欠損値のために n ＝ 8　§欠損値のために n ＝ 7

量を比較してエネルギーバランスを評価することに比べれば，はるかに小さい誤差といえる．

5．エネルギーバランスの実際

エネルギーバランスを把握することは困難であっても，実験的には過剰のエネルギーバランスを崩すことで，体組成の変化を引き起こすことが確認されている．Diaz らは体重維持期のエネルギー摂取量より50％多い食事を6週間摂取し，その間の基礎代謝，1日のエネルギー消費量を測定して，体重増加に必要なエネルギー量を求めている（表3）[7]．この研究では，体重1kgの増加に要したエネルギー量は28.7 ± 44MJ/kgと計算され，この値は理論値である26MJ/kgとほぼ等しい．つまり，エネルギーの消費量，摂取量，体重のすべてが正確に測定できれば，エネルギーバランスも正確に評価することが可能である．

6．集団のエネルギーバランスの評価

集団のエネルギーバランスを評価するには，その集団の肥満者の割合や，エネルギー消費量，エネルギー摂取量に関連する指標の変化を比べることで推測するしかなく，実際のエネルギー消費量と摂取量を比較することは困難であろう．国民健康・栄養調査成績によれば，BMI25kg/m^{2}以上の肥満者の割合は，男性ではいずれの年齢階級でも増加し，女性では70歳以上を除いて減少傾向にある（図4）[8]．これは，エネルギーバランスからみれば，男性では正の状態になっている者が増加していると推測される．エネルギーバランスの乱れがエネルギー摂取量，消費量のどちらに起因しているかを検討すると，エネルギー消費量を推測するデータとして歩数は，各年代で300～400歩程度の減少傾向，運動習慣のある者は微増傾向にある．エネルギー摂取量は，過去のデータでは個人別の値がないため比較が困難であるが，平均値で比較すると大きな変化はない．これらのことから，近年の肥満者の増加は，どちらかというとエ

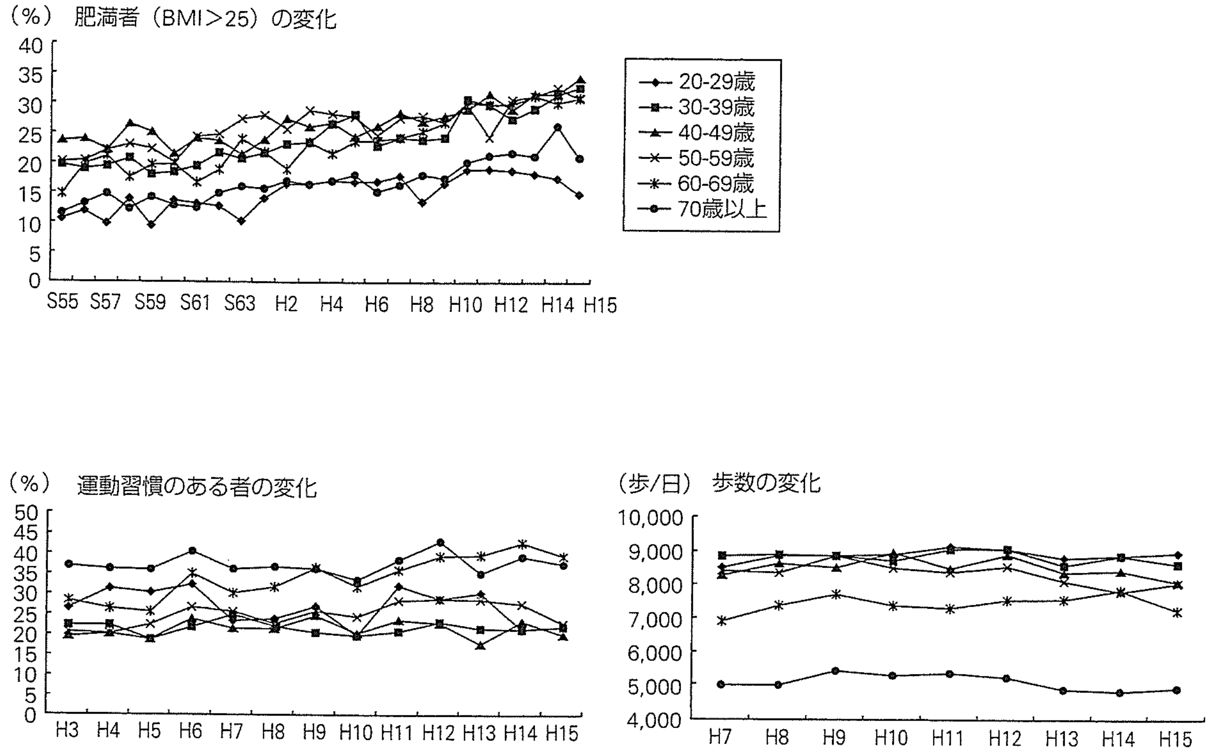

図4　日本人男性の肥満者，運動習慣のある者，歩数の変化（文献8より筆者作図）

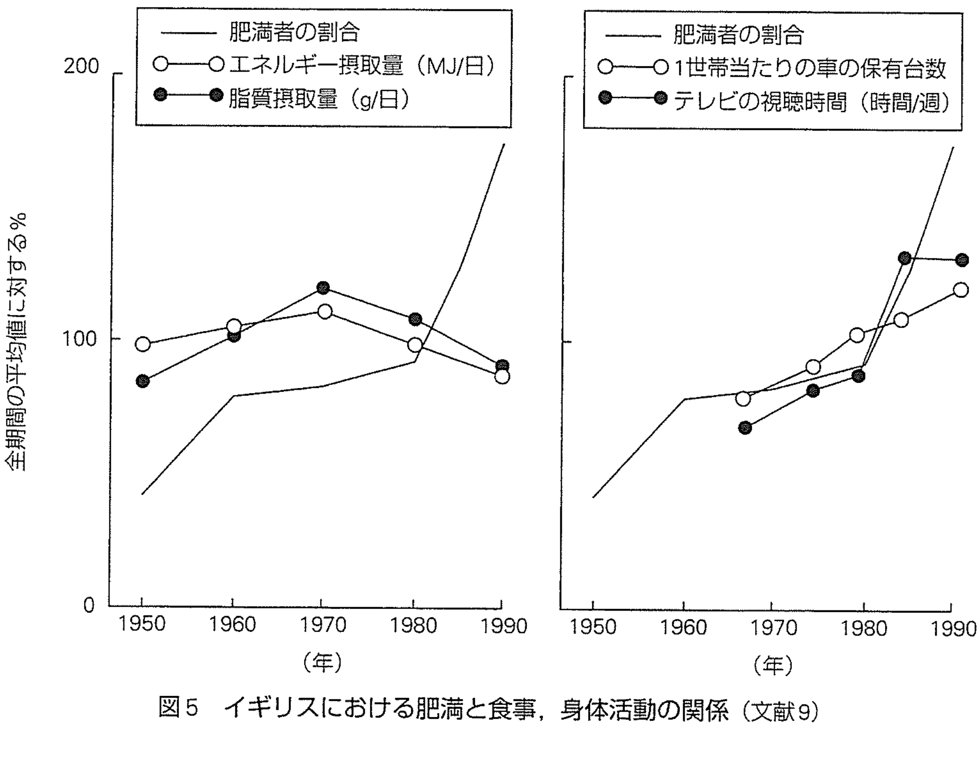

図5　イギリスにおける肥満と食事，身体活動の関係（文献9）

ネルギー摂取量の増加よりも不活動によると推測されている．

Prenticeらもイギリスにおいて各種の国民を対象とした調査から，肥満者の割合とその他の指標の年次変化を比較している（図5）[9]．肥満者の増加は，エネルギー摂取量や脂質の摂取量の変化と

の関連はほとんどみられないが，車の所有台数やテレビの視聴時間の増加との同じような動きをしており，エネルギー摂取量の過剰より不活動によるエネルギー消費量の減少によるエネルギーバランスの乱れが，肥満者の増加を招いたと推測している．

エネルギーバランスの考え方は単純であり，実験的に正確に把握した場合は，ほぼ理論通りのエネルギーの移動が観察される．しかしながら実際の自由な生活条件下では，長期的な体組成の変化としてのエネルギーバランスは評価できても，エネルギー摂取量とエネルギー消費量の差としてエネルギーバランスを評価すること，個人・集団のどちらを対象としても難しい．

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The influence of age and body mass index on relative accuracy of energy intake among Japanese adults

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Abstract

Objective: To examine relationships between the ratio of energy intake to basal metabolic rate (EI/BMR) and age and body mass index (BMI) among Japanese adults.
Design: Energy intake was assessed by 4-day semi-weighed diet records in each of four seasons (16 days in total). The EI/BMR ratio was calculated from reported energy intake and estimated basal metabolic rate as an indicator of reporting accuracy.
Setting: Residents in three areas in Japan, namely Osaka (urban), Nagano (rural inland) and Tottori (rural coastal).
Subjects: One hundred and eighty-three healthy Japanese men and women aged ≥30 years.
Results: The oldest age group (≥60 years) had higher EI/BMR values than the youngest age group (30–39 years) in both sexes (1.74 vs. 1.37 for men; 1.65 vs. 1.43 for women). In multiple regression analyses, age correlated positively (partial correlation coefficient, $\beta = 0.012$, $P < 0.001$ for men; $\beta = 0.011$, $P < 0.001$ for women) and BMI correlated negatively ($\beta = -0.031$, $P < 0.001$ for men; $\beta = -0.025$, $P < 0.01$ for women) with EI/BMR.
Conclusion: Age and BMI may influence the relative accuracy of energy intake among Japanese adults.

Keywords
Energy intake
Underreporting
Age
Body mass index
Japanese adults

Reliable dietary information plays a critical role in many aspects of human nutrition. Investigators have often relied on self-reported dietary data assessed by diet records, 24-hour dietary recalls and food-frequency questionnaires to interpret the associations between diet and disease. However, the results of various studies applying different assessment methods and investigating different populations have shown common problems such as reporting bias[1,2]. In particular, underreporting of energy intake is a serious threat to the validity of self-reported dietary assessment data. Studies using the doubly labelled water technique as an external biomarker of energy intake not only reveal underreporting of energy intake, but also identify the subject characteristics and factors associated with underreporting[3,4]. Moreover, other studies using the ratio of energy intake to basal metabolic rate (EI/BMR) as an alternative approach to identify the low energy reporters have shown similar results[5,6].

Most studies found a higher proportion of underreporting among women and older subjects[7,8]. Moreover, underreporting of energy intake was common among obese subjects[9–11], but was also observed in non-obese subjects[12,13]. Other factors such as body image, health consciousness, social desirability, educational level and smoking status also affected reporting accuracy[2,14,15]. However, all of these studies were conducted in Western countries. The only study conducted in Japan showed a significantly negative correlation between BMI and EI/BMR among women aged 18–20 years[16]. Thus the purpose of the present study was to examine the relative accuracy of self-reported energy intake among various age ranges in the Japanese population.

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Subjects and methods

Subjects

We selected three areas which have different geographical conditions in Japan: Osaka (urban), Nagano (rural inland) and Tottori (rural coastal). We invited 32 healthy married women aged 30–69 years from each of the three areas to distribute eight women equally in each age class of 30–39, 40–49, 50–59 and 60–69 years. The total number of women recruited was 96. Their husbands (aged 31–76 years) were also invited to participate in the study. None of the subjects was currently receiving or had recently received diet counselling from a doctor or dietitian, nor had a history of educational hospitalisation for diabetes. The subjects were not randomly sampled but asked by local study staff to participate in the study. Here, subject recruitment was continued until a sufficient number of subjects was obtained. Prior to the study, we held group orientations for the subjects where we explained the study purposes and protocol. All subjects giving written informed consent were finally considered eligible for the study.

Dietary assessment

The subjects completed 4-day semi-weighed diet records four times at 3-month intervals from November 2002 to August 2003. Dietary intake was assessed from four randomly assigned days, including one weekend day and three weekdays. A digital scale (Tanita KD-173; ± 2 g precision for 0–250 g and ± 4 g precision for 250–1000 g) was given to each couple to weigh all the foods eaten. When measurement was difficult, e.g. when eating out, we instructed them to record in as much detail as possible the size and quantity of foods they ate. For each recording day, the subjects were asked to fax the completed forms to the local staff (dietitians). The study staff checked the submitted forms and asked the subjects to add and/or modify the records as necessary by telephone or fax. In some cases, the responses were handed directly to the study staff rather than faxed.

All the collected diet records were checked by trained dietitians in each local centre and then in the study centre. The diet records were analysed for nutrient intake by trained dietitians using the food composition table of Japanese foods, 5th edition[17].

Physical activity level and anthropometric measurements

Physical activity level was obtained from a questionnaire which queried information about each subject's occupation and leisure-time activity. One answer was chosen from four categories, i.e. 'low', 'relatively low', 'moderate' and 'heavy' physical activity level. This classification was referenced to the recommended dietary allowance for Japanese, 6th edition[18]. The gross energy expenditure of each category was considered to require 1.3, 1.5, 1.7 and 1.9 times the BMR, respectively[18]. Therefore, we converted the categorical classification of physical activity level to the ratio of BMR based on above values, and expressed as it as a score for easy interpretation.

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with subjects wearing light clothing and no shoes. BMI was calculated as body weight (kg) divided by the square of body height (m^2). We classified BMI into four categories: $<18.5\,kg\,m^{-2}$, 18.5–24.9 $kg\,m^{-2}$, 25.0–27.9 $kg\,m^{-2}$ and $\geq 28\,kg\,m^{-2}$. Because the proportion of obese subjects (BMI $\geq 30\,kg\,m^{-2}$) was very low ($n = 1$ for men aged 40–49 years; $n = 0$ for women), BMI $\geq 28\,kg\,m^{-2}$ was used as the highest category instead of $\geq 30\,kg\,m^{-2}$ in the present analysis.

BMR was estimated for each subject using formulas based on body weight given by the Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU)[19] as follows.

- Men aged 30–60 years:
  $BMR = 0.0485 \times bodyweight(kg) + 3.67$.
- Men aged >60 years:
  $BMR = 0.0565 \times bodyweight(kg) + 2.04$.
- Women aged 30–60 years:
  $BMR = 0.0364 \times bodyweight\ (kg) + 3.47$.
- Women aged >60 years:
  $BMR = 0.0439 \times bodyweight\ (kg) + 2.49$.

Statistical analysis

We included 183 subjects (91 women and 92 men) with complete 16-day diet records living in the Osaka (29 women and 30 men), Nagano (31 women and 31 men) and Tottori (31 women and 31 men) areas in the present analysis.

We calculated the ratio EI/BMR to evaluate the relative accuracy of the reported energy intake. Subjects were allocated into quintiles of EI/BMR to compare 'low energy reporters' with 'high energy reporters'. Low ratios describe subjects reporting comparatively low energy intake relative to their energy requirement. To compare the relative degree of under- and overreporting, we temporarily used the values defined by FAO/WHO/UNU: the minimum survival level of 1.27, the sedentary level for men of 1.55 and women of 1.56, and the maximum sustainable lifestyle level of 2.0–2.4.

Results are given as mean ± standard deviation. Student's t-test and one-way analysis of variance (ANOVA) were used to test for differences between the groups. When ANOVA indicated a difference among the groups, Dunnett's t-test was applied to compare to the first group as a control. The chi-square test was used to test for proportionate differences between categories. Multivariate evaluation of the simultaneous effects of age, BMI, physical activity level and living area on EI/BMR was performed by a stepwise multiple regression analysis.

We also computed the partial correlation coefficients between each independent variable and EI/BMR adjusting for other independent variables.

All statistical analyses were performed using version 8.2 of the SAS software package (SAS Institute, Inc., Cary, NC, USA). A P-value of <0.05 was considered significant.

Results

Table 1 presents a summary of the physical characteristics of the subjects. Mean age was 52.8 ± 12.1 (range 31–76) years in men and 49.5 ± 11.4 (range 31–69) years in women. Mean values of EI/BMR were not different between sexes (1.55 for men vs. 1.48 for women, $P=0.12$). Men had a higher BMI (23.3 vs. 22.1 kg m^{-2}, $P<0.01$) and a higher proportion of overweight (21% vs. 11% for BMI of 25.0–27.9 kg m^{-2} and 10% vs. 2% for BMI ≥28 kg m^{-2}, $P=0.03$) than women. Men had a higher physical activity level than women (1.48 vs. 1.43, $P=0.02$), and 38% and 59% of women were classified into low and relatively low physical activity levels, respectively.

Table 2 presents a summary of the physical characteristics of men and women in the four age groups (30–39, 40–49, 50–59 and ≥60 years). Body height decreased with increasing age in both sexes. Body weight and BMR increased as age increased to 40–49 years, and then decreased with increasing age group in both sexes. Although BMI was lowest among the youngest age group in both sexes, a statistically significant difference between age groups was observed only for women ($P<0.01$). Energy intake was not different between age groups in either sex. On the other hand, mean EI/BMR became significantly higher with increase in age for men

Table 1 Characteristics of study subjects* ($n=183$)

	Men ($n=92$)	Women ($n=91$)	P-value†
Age (years)	52.8 ± 12.1	49.5 ± 11.4	0.06
Body height (cm)	168.0 ± 6.7	155.6 ± 5.9	<0.001
Body weight (kg)	66.2 ± 11.2	53.4 ± 7.2	<0.001
Reported EI (MJ day^{-1})	9.9 ± 1.8	7.8 ± 1.2	<0.001
BMR (MJ day^{-1})‡	6.5 ± 0.9	5.3 ± 0.4	<0.001
EI/BMR	1.55 ± 0.31	1.48 ± 0.24	0.12
BMI (kg m^{-2})	23.3 ± 3.1	22.1 ± 2.6	<0.01
<18.5	4 (4)	6 (7)	0.03§
18.5–24.9	60 (65)	73 (80)	
25.0–27.9	19 (21)	10 (11)	
≥28.0	9 (10)	2 (2)	
Physical activity level	1.48 ± 0.19	1.43 ± 0.11	0.02
Low	37 (40)	35 (38)	<0.001§
Relatively low	36 (39)	54 (59)	
Moderate	11 (12)	2 (2)	
Heavy	8 (9)	0 (0)	

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
* Values are expressed as mean ± standard deviation or n (%).
† Significant difference between sexes (t-test).
‡ BMR was calculated using formulas given by the Food and Agriculture Organization/World Health Organization/United Nations University (1985)[19].
§ Significant difference between sexes in all categories (chi-square test).

Table 2 Characteristics of study subjects according to age group in 92 men and 91 women†

	Men					Women				
	30–39 years‡ ($n=16$)	40–49 years ($n=24$)	50–59 years ($n=20$)	≥60 years ($n=32$)	P-value§	30–39 years‡ ($n=23$)	40–49 years ($n=22$)	50–59 years ($n=23$)	≥60 years ($n=23$)	P-value§
Age (years)	36.1 ± 2.2	44.0 ± 3.2	54.8 ± 2.3	66.4 ± 4.6	<0.001	35.7 ± 2.7	43.1 ± 3.2	54.1 ± 2.6	64.7 ± 3.0	<0.001
Body height (cm)	171.8 ± 5.7	171.0 ± 5.8	168.5 ± 7.0	163.7 ± 5.1***	<0.001	158.6 ± 5.7	156.1 ± 5.9	155.6 ± 6.0	152.0 ± 4.0***	<0.01
Body weight (kg)	64.7 ± 11.3	70.1 ± 12.7	69.3 ± 10.7	62.0 ± 9.0	0.02	51.2 ± 6.1	55.3 ± 7.0	55.0 ± 7.8	52.3 ± 7.2	0.14
Reported EI (MJ day^{-1})	9.3 ± 1.2	10.2 ± 2.5	10.5 ± 1.7	9.6 ± 1.3	0.15	7.7 ± 1.3	7.6 ± 1.3	7.9 ± 0.8	7.9 ± 1.2	0.76
BMR (MJ day^{-1})¶	6.8 ± 0.6	7.1 ± 0.6	7.0 ± 0.5	5.5 ± 0.5***	<0.001	5.3 ± 0.2	5.5 ± 0.3	5.5 ± 0.3	4.8 ± 0.3***	<0.001
EI/BMR	1.37 ± 0.21	1.44 ± 0.33	1.50 ± 0.28	1.74 ± 0.25***	<0.001	1.43 ± 0.23	1.39 ± 0.22	1.45 ± 0.14	1.65 ± 0.26***	<0.001
Physical activity level	1.50 ± 0.21	1.51 ± 0.23	1.48 ± 0.17	1.44 ± 0.15	0.59	1.44 ± 0.11	1.44 ± 0.10	1.42 ± 0.10	1.41 ± 0.12	0.82
BMI (kg m^{-2})	21.8 ± 3.0	23.9 ± 3.5	24.3 ± 2.8*	23.1 ± 2.7	0.07	20.3 ± 2.0	22.7 ± 2.9**	22.7 ± 2.2**	22.6 ± 2.7**	<0.01
< 18.5	1 (6)	1 (4)	1 (5)	1 (3)	0.27‖	5 (22)	1 (5)	0 (0)	0 (0)	0.03‖
18.5–24.9	13 (81)	14 (58)	9 (45)	24 (75)		18 (78)	16 (73)	20 (87)	19 (83)	
25.0–27.9	1 (6)	5 (21)	8 (40)	5 (16)		0 (0)	4 (18)	3 (13)	3 (13)	
≥ 28.0	1 (6)	4 (17)	2 (10)	2 (6)		0 (0)	1 (5)	0 (0)	1 (4)	

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
† Values are expressed as mean ± standard deviation or n (%).
‡ Significant difference compared with 30–39 year category between age groups within sex (Dunnett's t-test): *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$.
§ Significant difference between age groups within sexes (analysis of variance).
¶ BMR was calculated using formulas given by the Food and Agriculture Organization/World Health Organization/United Nations University (1985)[19].
‖ Significant difference between age groups within sexes in all categories (chi-square test).

Table 3 Anthropometric characteristics and lifestyle variables by quartile of EI/BMR ratio†

	Men					Women				
	First quartile ($n = 23$)‡	Second quartile ($n = 18$)	Third quartile ($n = 22$)	Fourth quartile ($n = 29$)	*P*-value§	First quartile ($n = 22$)‡	Second quartile ($n = 28$)	Third quartile ($n = 24$)	Fourth quartile ($n = 17$)	*P*-value§
EI/BMR	1.17 ± 0.12	1.41 ± 0.05	1.57 ± 0.05	1.90 ± 0.17		1.19 ± 0.09	1.42 ± 0.05	1.58 ± 0.05	1.83 ± 0.14	
Age (years)	44.8 ± 8.8	51.8 ± 10.3	54.6 ± 15.0*	58.3 ± 9.8***	<0.001	44.5 ± 9.8	47.2 ± 9.9	53.1 ± 118*	54.5 ± 12.5*	0.01
Body height (cm)	171.2 ± 4.8	168.8 ± 5.7	168.4 ± 6.7	164.7 ± 7.3**	<0.01	154.0 ± 5.4	156.9 ± 5.7	155.1 ± 5.8	156.0 ± 6.7	0.36
Body weight (kg)	72.0 ± 10.4	68.1 ± 7.4	64.5 ± 12.5	61.6 ± 11.0**	<0.01	53.7 ± 7.4	54.6 ± 6.5	54.1 ± 8.4	50.4 ± 5.5	0.27
EI (MJ day^{-1})	8.3 ± 1.0	9.5 ± 0.6*	9.9 ± 1.6***	11.4 ± 1.7***	<0.001	6.4 ± 0.7	7.6 ± 0.6***	8.3 ± 0.7***	9.1 ± 0.8***	<0.001
BMR (MJ day^{-1})¶	7.1 ± 0.6	6.7 ± 0.6	6.3 ± 0.9**	6.0 ± 0.9***	<0.001	5.4 ± 0.3	5.4 ± 0.3	5.3 ± 0.4	5.0 ± 0.4**	<0.01
Physical activity level	1.47 ± 0.19	1.41 ± 0.12	1.47 ± 0.18	1.53 ± 0.21	0.16	1.41 ± 0.10	1.43 ± 0.11	1.45 ± 0.09	1.42 ± 0.12	0.60
BMI (kg m^{-2})	24.5 ± 3.0	24.0 ± 2.8	22.6 ± 3.2	22.6 ± 3.0	0.06	22.6 ± 2.9	22.2 ± 2.4	22.5 ± 3.0	20.7 ± 1.7	0.11
< 18.5	0 (0)	0 (0)	1 (5)	3 (10)	0.34§	1 (5)	2 (7)	2 (8)	1 (6)	0.82§
18.5–24.9	13 (57)	11 (61)	14 (63)	22 (76)		17 (77)	22 (79)	18 (75)	16 (94)	
25.0–27.9	7 (30)	5 (28)	5 (23)	2 (7)		3 (14)	4 (14)	3 (13)	0 (0)	
≥ 28.0	3 (13)	2 (11)	2 (9)	2 (7)		1 (5)	0 (0)	1 (4)	0 (0)	

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
† Values are expressed as mean ± standard deviation or *n* (%).
‡ Significant difference compared with the first quartile of EI/BMR (Dunnett's *t*-test): *, $P < 0.05$, **, $P < 0.01$; ***, $P < 0.001$.
§ Significant difference between quartile within sexes (analysis of variance).
¶ BMR was calculated using formulas given by the Food and Agriculture Organization/World Health Organization/United Nations University (1985)[19].

($P < 0.001$). Although women aged 40–49 years had the lowest EI/BMR among the women, the trend of the relationship between mean EI/BMR and age was almost the same as that of men ($P < 0.001$).

Table 3 presents the mean values of anthropometric characteristics by quartile of EI/BMR. Age and reported energy intake increased significantly with the increase in EI/BMR in both sexes (all $P < 0.001$ except for age in women, where $P < 0.01$). However, with increasing EI/BMR quartile, body height and body weight decreased significantly in men (both $P < 0.01$), as did BMR in both sexes ($P < 0.001$ for men, $P < 0.01$ for women). BMI was slightly lower in the lowest category of EI/BMR than in the other categories in men, although it was not significant.

Table 4 shows the results of multiple regression analyses with EI/BMR as the dependent variable to examine the prediction for relative accuracy of reporting. For men, age and physical activity level correlated positively (partial regression coefficient, $\beta = 0.012$, $P < 0.001$ and $\beta = 0.377$, $P = 0.01$, respectively), and BMI and living area (urban) correlated negatively ($\beta = -0.031$, $P < 0.001$ and $\beta = -0.114$, $P = 0.045$, respectively), with EI/BMR. On the other hand, age and body height correlated positively ($\beta = 0.011$, $P < 0.001$ and $\beta = 0.011$, $P = 0.01$, respectively) and BMI correlated negatively ($\beta = -0.025$, $P < 0.01$) with EI/BMR for women. All the independent variables explained 35.7% and 25.7% of the variation in EI/BMR for men and women, respectively.

Figures 1a and 1b show the joint effect of age and BMI on EI/BMR values by cross-classifying subjects by both variables. Compared with subjects classified into the lowest BMI and oldest age group, subjects in the highest

Table 4 Results of stepwise multiple regression analyses with EI/BMR ratio as dependent variable*

Independent variable	β†	SE‡	*P*-value	Partial R^2 (%)§
Men ($n = 92$)				
Age (years)	0.012	0.002	<0.001	17.9
BMI (kg m^{-2})	−0.031	0.009	<0.001	9.9
Physical activity level	0.377	0.145	0.01	4.8
Living area (rural coastal area as reference)				
Urban	−0.114	0.056	0.05	3.1
Women ($n = 91$)				
Age (years)	0.011	0.002	<0.001	12.1
BMI (kg m^{-2})	−0.025	0.009	0.005	7.0
Body height (cm)	0.011	0.004	0.01	6.6

EI – energy intake; BMR – basal metabolic rate; BMI – body mass index.
*Age (as a continuous variable), BMI (as a continuous variable), height (as a continuous variable), physical activity level (as a continuous variable) and area of living (rural coastal, rural inland, urban) were entered into the model as independent variables.
† Partial regression coefficient; change in the dependent variable related to a one-unit change in the independent variable.
‡ Standard error of the regression coefficient.
§ Explained variance; adjusted R^2 and *P*-values are for independent variables in multiple regression analysis. R^2 value for EI/BMR was 35.7% and 25.7% for men and women, respectively, when all variables were included in the model.

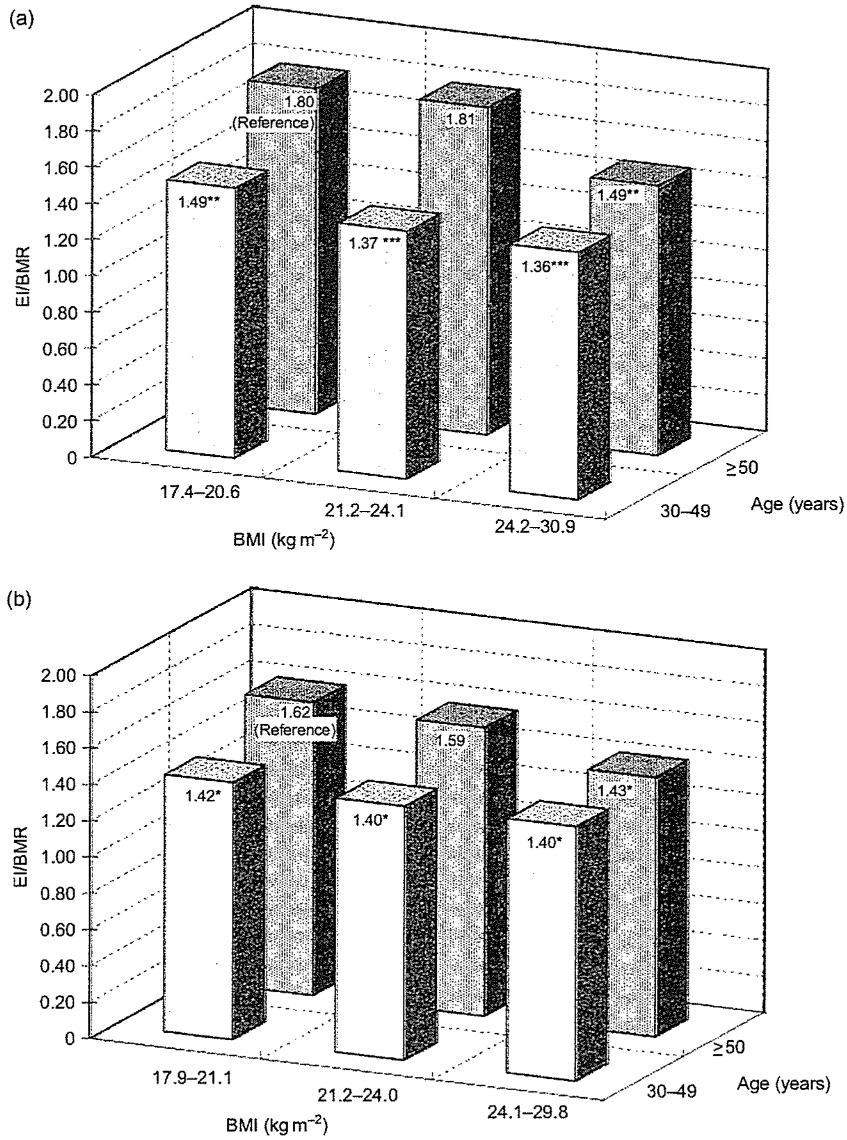

Fig. 1 The interaction of age and body mass index (BMI) in relationships with the ratio of reported energy intake to estimated basal metabolic rate (EI/BMR). Mean value of EI/BMR by tertile of BMI and age group (30–49, ≥50 years) in (a) Japanese men aged 32–76 years ($n = 92$) and (b) Japanese women aged 31–69 years ($n = 91$). EI/BMR values were adjusted for physical activity level and living area. Significance of difference compared with the oldest age and lowest BMI group (Dunnett's *t*-test of one-way analysis of variance): *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

BMI and youngest age group had EI/BMR that was 24% and 14% lower in men and women, respectively.

Discussion

To our knowledge, this is the first report to evaluate EI/BMR values over a wide age range of Japanese men and women. We conducted semi-weighed diet records for 4 days in four seasons, which is often considered to be the most accurate and precise method for determining energy intake. Furthermore, fax delivery was used so that we could check the diet records immediately on each survey day. Therefore, we believe that the data have higher precision than in any other such survey conducted in Japan. The EI/BMR in our study was 1.55 among men and 1.48 among women. Although we refrained from using a specific cut-off value to identify underreporters, 20% and 23% of men and women, respectively, showed EI/BMR below 1.27, the minimum survival level reported by FAO/WHO/UNU[19]. Moreover, the proportion of subjects with EI/BMR < 1.27 decreased with increasing age in both sexes, except in the 40–49 year age group in women. However, 10% and 4% of men and women, respectively, showed EI/BMR exceeding 2.0 as the maximum level. Even when physical activity level was considered, the proportion of subjects with EI/BMR > 2.0 increased with increasing age, and was especially more pronounced in the age group ≥60 years for both sexes. This indicates that older Japanese men and women tend to relatively overestimate energy intake rather than underreport.

The main finding of this study was that age and BMI independently affect EI/BMR as a positive and a negative factor, respectively. The statistical power of these findings became stronger after adjustment for potentially confounding factors such as physical activity level and living area (urban or rural) for both sexes (Figs 1a and 1b). According to previous studies, physiological and psychological factors are also related to reporting accuracy; for example, smoking habits, education level, socio-economic status and obesity-related behaviours[14,15,20–22]. However, we did not examine the effect of these factors on reporting accuracy because of a lack of information.

Most studies conducted in Western countries revealed that underreporting of energy intake was more prevalent among older subjects than among younger counterparts[7,23,24]. The tendency was completely opposite in this Japanese population. To our knowledge, no previous study has found underreporting to be more prevalent among younger compared with older subjects, either in Western or Asian countries. Possible factors affecting reporting accuracy may include dietary consciousness and knowledge of foods and diet. According to the National Nutrition Survey in Japan[25], the percentage of subjects who paid high attention to diet and nutrition was 12.1%, 17.5%, 24.4% and 27.2% among 30–39-, 40–49-, 50–59- and ≥60-year-old men, respectively, and 27.5%, 35.7% 42.9%, and 48.6%, respectively, among women. The capability to recognise foods and diet may be related to recording as correctly as possible. Some previous studies reported that cultural, behavioural and psychological factors affect reporting accuracy[14,15,20–22]. The results were, however, inconsistent and differed among the populations examined. Further research focusing on dietary consciousness and behaviours connected with food and the process of dietary assessment is needed.

Our study has several limitations. First, the subjects may not be representative because they were not randomly sampled from the general Japanese population. Moreover, the participants might be highly health-conscious because almost all of them completed the study despite the strict study design. Second, the sample size was relatively small. Therefore, the results may arise by chance. Third, we cannot exclude the possibility that the subjects changed their dietary behaviour or food choices during the recording periods. However, the relationships between EI/BMR and age and body weight did not change materially when the dietary record data of the first four days were used in the analysis (data not shown). Fourth, we used body height to take into consideration body size although body height is not an ideal marker of body size. Fifth, the reliability of the BMR prediction from the FAO/WHO/UNU formulas may be inappropriate when applied to the Japanese population[26]. The validity of the self-reported physical activity levels from the 6th Japanese recommended dietary allowance is questionable because of the lack of a validation study[18].

In summary, the results of the present study suggest that age and BMI may influence the relative accuracy of reported energy intake among Japanese adults. The positive correlation found between age and EI/BMR was especially interesting because almost all previous studies conducted in Western populations showed a negative correlation. This indicates that the factors related to reporting accuracy of energy intake may depend on population characteristics. Further studies are needed to examine whether or not this is a consistent tendency in Asian or Japanese populations.

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ORIGINAL ARTICLE

Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women

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Objective: Although under-reporting of dietary intake is more common in persons with a high body mass index (BMI), it is not well known whether or not misreporting is selective for different foods (and hence energy and nutrients), particularly in non-Western populations. We examined misreporting of dietary intake against biomarkers and its relation with BMI in young Japanese women.
Design: Cross-sectional study.
Subjects: A total of 353 female Japanese dietetic students aged 18–22 years (mean BMI: 21.4 kg/m^2, mean fat intake: 29.8% of energy).
Methods: Misreporting of dietary energy, protein, potassium and sodium (assessed by a self-administered diet history questionnaire) was examined against respective biomarkers (estimated energy expenditure and 24-h urinary excretion). Reporting accuracy was calculated as the ratio of reported intake to that estimated from corresponding biomarkers (complete accuracy: 1.00).
Results: Mean reporting accuracy of absolute intake (amount per day) varied considerably (0.86–1.14). Reporting accuracy of absolute intake decreased with increasing BMI (P for trend <0.001). However, no association was observed between reporting accuracy of energy-adjusted values and BMI (P for trend >0.15), indicating that BMI-dependent misreporting was canceled by energy adjustment. This was owing to positive correlation between the reporting accuracy of energy intake and that of absolute intake of the three nutrients (Pearson correlation coefficient: 0.49–0.67, $P<0.0001$).
Conclusions: Although differential misreporting of absolute intake was associated with BMI, differential misreporting of energy-adjusted value was not. These findings support the use of energy-adjusted values in the investigation of diet–disease relationships among lean populations with a low-fat intake.
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Keywords: energy; protein; potassium; sodium; misreporting; body mass index

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Introduction

Although accurate assessment of habitual dietary intake is a prerequisite in studies of diet and health, the difficulty of obtaining dietary data that accurately represents what people usually eat is now generally recognized (Livingstone and Black, 2003). In particular, obese people tend to under-report dietary intake to a greater extent than lean people (Livingstone and Black, 2003; Rosell *et al.*, 2003; Subar *et al.*, 2003; Tooze *et al.*, 2004; Mattisson *et al.*, 2005; Mahabir *et al.*, 2006). Whether this is a consequence of selective misreporting of certain foods, proportional misreporting of all foods, or both is not well established. This is an important issue: errors in dietary reporting do not necessarily invalidate dietary data if the misreporting is not selective, but may do so if the misreporting is selective.

Unfortunately, investigation of possible differential misreporting of dietary intake in free-living situations has been hampered, largely by a lack of suitable methods for quantifying absolute true intake for all dietary variables except energy (Black *et al.*, 1996), protein (Bingham and Cummings, 1985; Kipnis *et al.*, 2001), potassium (Holbrook *et al.*, 1984; Tasevska *et al.*, 2006) and sodium (Holbrook *et al.*, 1984; Willett, 1998). As a result, only a limited number of studies have examined this issue (Hulten *et al.*, 1990; Bingham *et al.*, 1995; Heitmann and Lissner, 1995, 2005; Black *et al.*, 1997, 2000; Heerstrass *et al.*, 1998; Heitmann *et al.*, 2000; Larsson and Johansson, 2002; Rosell *et al.*, 2003; Subar *et al.*, 2003; Freedman *et al.*, 2004), none of which were conducted in Asian countries, including Japan. A characteristic of Japanese people is their relatively low BMI and relatively low-fat consumption (Ministry of Health, Labour and Welfare, 2006), which differs somewhat from Western people. This difference hampers the extrapolation of findings in Western countries to Japanese.

Here, we examined misreporting of energy, protein, potassium and sodium intake assessed against estimated energy expenditure and 24-h urinary excretion of urea nitrogen, potassium and sodium, respectively, and its relation with BMI in a group of young Japanese women.

Methods

Subjects

The present study was based on a multi-centered nutritional survey conducted from February to March 2006 among female dietetic students from 10 institutions in Japan. All measurements at each institution were conducted according to the survey protocol. Staff at each institution briefly explained the survey to potential subjects. Subjects who responded positively were then provided detailed written and oral explanations of the general purpose and procedure of the survey. A total of 474 women took part in the survey. The protocol of the study was approved by the Ethics Committee of the National Institute of Health and Nutrition, and written informed consent was obtained from each subject, and also from a parent for subjects aged less than 20 years.

In total, 424 of 474 women undertook 24-h urine collection. For the present analysis, we selected 417 women aged 18–22 years without missing information on the variables used. We then excluded women whose 24-h urine collection was considered incomplete. Because the *p*-aminobenzoic acid (PABA) check method to verify the completeness of 24-h urine collection (Bingham and Cummings, 1983) was not available in the present study, we used the strict INTERMAP criteria for completeness of urine sampling (Stamler *et al.*, 2003) (a collection time outside the 22–26-h range ($n=10$), subject response that collection was not complete ($n=47$) and total volume <250 ml ($n=1$)) as well as a widely used criteria determined by creatinine excretion in relation to body weight (creatinine (mg) divided by body weight (kg) of <10.8 or >25.2 (WHO Regional Office for Europe, 1984), $n=13$). As some women were in more than one exclusion category, the final analysis sample comprised 353 women.

Diet history questionnaire

Dietary habits during the preceding month were assessed using a validated previously, self-administered diet history questionnaire (DHQ) (Sasaki *et al.*, 1998a, b 2000). All answered DHQs, as well as a lifestyle questionnaire, were checked at least twice for completeness. When necessary, forms were reviewed with the subject to ensure the clarity of answers. The DHQ is a 16-page structured questionnaire that consists of the following seven sections: general dietary behavior; major cooking methods; consumption frequency and amount of six alcoholic beverages; consumption frequency and semi-quantitative portion size of 122 selected food and nonalcoholic beverage items; dietary supplements; consumption frequency and semi-quantitative portion size of 19 cereals usually consumed as staple foods (rice, bread and noodles) and miso (fermented soybean paste) soup; and open-ended items for foods consumed regularly (⩾once/week) but not appearing in the DHQ. Items and portion sizes were derived primarily from data in the National Nutrition Survey of Japan and several recipe books for Japanese dishes (Sasaki *et al.*, 1998a).

Estimates of dietary intake for 148 food and beverage items, energy and nutrients were calculated using an *ad hoc* computer algorithm for the DHQ based on the standard tables of food composition in Japan (Science and Technology Agency, 2000). Discretionary salt (table salt and other seasonings with salty flavor) and seasonings used during cooking were taken into consideration for estimating sodium intake. Information on dietary supplements and data from the open-ended questionnaire items were not used in the calculation. Detailed descriptions of the methods used to calculate dietary intake and the validity of the DHQ have been published elsewhere (Sasaki *et al.*, 1998a, b 2000).

Pearson correlation coefficients between the DHQ and 3-day estimated dietary records were 0.48 for energy, 0.48 for protein, 0.68 for potassium and 0.32 for sodium among 47 women (Sasaki *et al.*, 1998a). In addition, Pearson correlation coefficients between the DHQ and 24-h urinary excretion were 0.40 for potassium and 0.23 for sodium among 69 women (Sasaki *et al.*, 1998b).

Estimated energy expenditure
Body height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, while wearing light clothes and no shoes. Basal metabolic rate (BMR) was estimated according to the FAO/WHO/UNU equation for women aged 18–30 years, as follows: BMR (kcal/day) = 14.7 × body weight (kg) + 496 (FAO/WHO/UNU, 1985). BMR calculated from the FAO/WHO/UNU equations was relatively comparable with measured BMR in Japanese people at the group level (arithmetic mean = 1182 and 1107 kcal/day, respectively) (Yamamura and Kashiwazaki, 2002). Energy expenditure can be estimated as BMR multiplied by an appropriate physical activity level value (Black *et al.*, 1996). In the present study, subjects self-reported in a lifestyle questionnaire the frequency and duration of high-intensity activities (e.g., carrying heavy loads; bicycling, moderate effort; jogging; singles tennis), moderate-intensity activities (e.g., carrying light loads; bicycling, light effort; doubles tennis) and walking during the preceding month. On average, less than half an hour per day was spent on these activities (arithmetic mean = 0.07, 0.30, and 0.50 h/day, respectively), indicating a predominantly sedentary lifestyle in our sample. We therefore estimated energy expenditure as BMR multiplied by physical activity level value for light activity (1.56) (FAO/WHO/UNU, 1985), and used this value as a biological marker for energy intake.

24-h urine
A single 24-h urine sample was collected for biological markers of intake of protein, potassium and sodium. Subjects were instructed both in writing and orally on the method of urine collection and the necessity of obtaining a complete 24-h urine collection. We requested the subjects to eat and drink normally during the collection and to follow their usual pattern of activity. Subjects were then provided with a bag, three or four 1-l plastic bottles (containing no additives) and 10 400-ml cups. A recording sheet was also provided. In the morning, subjects were asked to discard the first specimen and to record the time (usually 0600–0900 h) on the sheet (the start of the collection period). Subjects were asked to collect all specimens by the time of the start of the collection period in the next morning. When some specimens were missed, subjects were asked to record the estimated volume of missing urine and the time. In the next morning, subjects were asked to collect the last specimen at the time when the specimen was discarded last morning and to record the time on the sheet (the end of the collection period). The sheet was reviewed by staff when the collection bottles were handed in, and any missing information was obtained from subjects. The height of urine in each bottle was measured and later converted into volume with an empiric formula based on repeated measurements of volume in identical bottles (Stamler *et al.*, 2003). All urine from the 24-h collection period was then combined and mixed thoroughly by vigorous stirring, and several urinary aliquots were taken and sent by car or airplane to a laboratory in Tokyo. Urea nitrogen concentration was measured by urease ultraviolet spectorophotometry, potassium and sodium by electrode method and creatinine (for the assessment for completeness of urine collection) by enzymatic assay method. Total 24-h excretion was calculated by multiplying the measured concentration with the total volume of urine collected.

The urea nitrogen content in 24-h urine was multiplied by 9.08, assuming that urea nitrogen is in constant proportion (85%) to total urinary nitrogen (Bingham and Cummings, 1985), 81% of ingested nitrogen is excreted through the urine (Bingham and Cummings, 1985; Kipnis *et al.*, 2001) and nitrogen constitutes 16% of protein. The value obtained was used as a biological marker for protein intake. Potassium content in 24-h urine was divided by 0.77, assuming that 77% of ingested potassium is excreted through the urine (Holbrook *et al.*, 1984; Tasevska *et al.*, 2006), and used as a biological marker for potassium intake. Sodium content in 24-h urine was divided by 0.86, assuming that 86% of ingested sodium is excreted through the urine (Holbrook *et al.*, 1984; Willett, 1998), and used as a biological marker for sodium intake.

Reporting accuracy
Reporting accuracy was calculated as the ratio of reported dietary intake (energy, protein, potassium and sodium) obtained from DHQ to estimated dietary intake obtained from respective biological markers (estimated energy expenditure and 24-h urinary excretion) (Zhang *et al.*, 2000), in terms of both absolute (amount/day) and energy-adjusted (% energy for protein and mg/1000 kcal for potassium and sodium) values. At the group level, reporting accuracy of <1 was considered underestimation, >1 overestimation and 1 accurate estimation (Zhang *et al.*, 2000).

Other variables
BMI was calculated as body weight (kg) divided by the square of body height (m). Current smoking status was self-reported in the lifestyle questionnaire, whereas current dietary supplement use was assessed in the DHQ.

Statistical analysis
All statistical analyses were performed using SAS statistical software, version 8.2 (SAS Institute Inc., Cary, NC, USA).

Dietary intake (derived from both DHQ and biological markers) and reporting accuracy of energy, protein, potassium and sodium were natural-log transformed to meet the assumption of normal distribution. The formula $\log(X+1)$ was used for reporting accuracy. Geometric mean and 95% confidence intervals of these variables were calculated using back transformation. Differences between self-reported values and biological marker-based values were evaluated using the paired t-test. Reporting accuracy was compared with a value of 1 using the one-sample t-test. Mean values of dietary intake (derived from both DHQ and biological markers) and reporting accuracy were calculated by quintile categories of BMI. Linear trends with increasing levels of BMI were tested by assigning to each participant the median value for the category and modeling this value as a continuous variable. All reported P-values are two-tailed and were considered statistically significant at the <0.05 level.

Results

Subject backgrounds are shown in Table 1. Subjects were characterized by a relatively low BMI (arithmetic mean $=21.4\,\mathrm{kg/m^2}$), relatively low-fat intake (arithmetic mean $=29.8\%$ of energy) and low smoking rate (3%). Although 39% of subjects consumed alcoholic beverages, their contribution to dietary intake was negligible (arithmetic mean $=0.4\%$ of energy). Dietary supplements were used by 20% of subjects, but none consumed dietary supplements predominantly containing protein, potassium, or sodium. Table 2 shows the contribution of each food group to energy, protein, potassium and sodium intake, based on DHQ. Most food groups were important sources of at least one of them.

Table 1 Selected characteristics of subjects ($n=353$)[a]

Variable	*Value*
Age (years)	19.4±1.0
Body height (cm)	158.0±5.8
Body weight (kg)	53.4±7.7
Body mass index (kg/m^2)	21.4±2.7
Current smoker	10 (3)
Alcohol drinker[b]	139 (39)
Dietary supplement user[c]	69 (20)
Reported dietary intake[d]	
Energy (kcal/day)	1723±398
Protein (% of energy)	13.8±1.8
Fat (% of energy)	29.8±5.0
Carbohydrate (% of energy)	54.8±5.7
Alcohol (% of energy)	0.4±1.0

[a]Values are arithmetic mean ±s.d. or number of subjects (%).
[b]Subjects who consumed more than 0 g of any of alcohol beverage during the previous month.
[c]Subjects who used any dietary supplement at least once during the previous month.
[d]Assessed by a self-administered diet history questionnaire.

Dietary intake (estimated by DHQ and biological markers) and reporting accuracy for energy, protein, potassium and sodium are shown in Table 3. Misreporting of dietary intake was differential rather than proportional. In terms of absolute values, energy was significantly ($P<0.0001$) underestimated (geometric mean reporting accuracy $=0.86$) and sodium overestimated (geometric mean reporting accuracy $=1.14$), whereas estimation of protein and potassium was relatively accurate (geometric mean reporting accuracy is equal to 0.97 and 1.03, respectively). Mainly owing to underestimation of energy, energy-adjusted values of all three nutrients were significantly ($P<0.0001$) overestimated (geometric mean reporting accuracy is equal to 1.14 for protein, 1.20 for potassium and 1.32 for sodium).

The association of dietary intake (estimated by DHQ and biological markers) and reporting accuracy with BMI is also shown in Table 3. Reporting accuracy of absolute intake of energy and the three nutrients significantly decreased with increasing BMI (P for trend <0.001), as result of increasing intake derived from biological markers but no increase in dietary intake derived from DHQ with increasing BMI. However, no association between reporting accuracy and BMI was observed when energy-adjusted values were used, indicating that the BMI-dependent misreporting of dietary intake was canceled by energy adjustment. This was owing to a significant correlation between the reporting accuracy of energy and that of the absolute value of the three nutrients (Pearson correlation coefficient is equal to 0.67 for protein, 0.56 for potassium and 0.49 for sodium, $P<0.0001$).

Table 2 Contribution of each food group to dietary intake of energy, protein, potassium and sodium as assessed by a self-administered diet history questionnaire ($n=353$)[a]

	Energy	*Protein*	*Potassium*	*Sodium*
Cereals	38.8 (1)	23.9 (1)	8.4 (5)	9.6 (2)
Potatoes	2.4 (11)	1.0 (10)	7.6 (7)	0.2 (12)
Confectioneries[b]	14.7 (2)	7.0 (7)	5.0 (10)	3.5 (7)
Fat and oil	8.7 (3)	0.2 (13)	0.1 (14)	2.5 (8)
Pulses[c]	3.9 (7)	7.6 (5)	7.0 (8)	7.9 (3)
Fish and shellfish	4.3 (6)	15.9 (3)	7.8 (6)	4.9 (4)
Meats	7.5 (5)	17.2 (2)	8.8 (4)	2.3 (9)
Eggs	3.1 (8)	7.4 (6)	2.4 (11)	1.4 (10)
Dairy products	8.2 (4)	11.7 (4)	12.9 (2)	4.2 (6)
Vegetables[d]	2.9 (9)	4.4 (8)	22.3 (1)	4.7 (5)
Fruits	2.5 (10)	0.9 (12)	6.8 (9)	0.03 (14)
Seasonings[e]	0.6 (13)	0.9 (11)	1.8 (12)	58.2 (1)
Other foods[f]	0.2 (15)	0.1 (14)	0.1 (15)	0.1 (13)
Alcoholic beverages	0.5 (14)	0.04 (15)	0.2 (13)	0.01 (15)
Nonalcoholic beverages	1.6 (12)	1.7 (9)	8.9 (3)	0.5 (11)

[a]Values are the arithmetic mean percentage of total intake (ranking).
[b]Including sugar and sweeteners.
[c]Including nuts and miso (fermented soybean paste).
[d]Including mushrooms and sea vegatables.
[e]Including soups.
[f]Artificial sweeteners and nutrient supplement bars.

Table 3 Dietary intake (estimated by a self-administered diet history questionnaire (DHQ) and biological markers) and reporting accuracy of energy, protein, potassium and sodium and its relation with body mass index[a]

	Total (n = 353)[b,c]	Quintile category of body mass index					
		1 (n = 70)	*2 (n = 71)*	*3 (n = 71)*	*4 (n = 71)*	*5 (n = 70)*	*P for trend*[d]
Body mass index (kg/m^2)	21.1 (14.8–34.2)	18.4 (14.8–19.2)	19.9 (19.3–20.4)	21.1 (20.4–21.6)	22.2 (21.6–23.1)	24.7 (23.1–34.2)	
Absolute dietary intake							
Energy							
DHQ (kcal/day)	1678 (1638–1719)	1715 (1629–1805)	1637 (1546–1734)	1729 (1641–1821)	1644 (1561–1731)	1667 (1575–1764)	0.57
Biological marker (kcal/day)[e]	1992 (1975–2010)	1832 (1815–1850)	1918 (1898–1937)	1979 (1959–1999)	2029 (2009–2048)	2225 (2181–2271)	<0.0001
Reporting accuracy[f]	0.86 (0.83–0.88)	0.95 (0.9–0.99)	0.87 (0.82–0.92)	0.88 (0.84–0.93)	0.82 (0.78–0.86)	0.76 (0.72–0.81)	<0.0001
Protein							
DHQ (g/day)	57.6 (55.9–59.3)	59.0 (55.4–62.8)	58.1 (53.8–62.7)	60.1 (56.5–63.8)	55.3 (51.8–58.9)	55.5 (51.9–59.5)	0.12
Biological marker (g/day)[g]	60.9 (59.3–62.6)	54.6 (51.2–58.2)	61.1 (57.5–65.0)	61.9 (58.5–65.6)	60.6 (57.4–64.0)	66.9 (63.4–70.6)	<0.0001
Reporting accuracy[f]	0.97 (0.94–1.01)	1.11 (1.02–1.21)	0.98 (0.90–1.06)	1.00 (0.93–1.08)	0.93 (0.87–1.00)	0.85 (0.79–0.91)	<0.0001
Potassium							
DHQ (mg/day)	1902 (1833–1973)	2000 (1851–2162)	1957 (1796–2132)	2012 (1874–2159)	1747 (1613–1892)	1808 (1649–1982)	0.03
Biomarker (mg/day)[h]	1930 (1862–2001)	1793 (1677–1917)	1871 (1713–2044)	1993 (1843–2155)	1890 (1732–2061)	2121 (1969–2285)	0.005
Reporting accuracy[f]	1.03 (0.98–1.08)	1.15 (1.05–1.26)	1.10 (0.98–1.23)	1.06 (0.96–1.17)	0.96 (0.88–1.04)	0.89 (0.80–0.98)	<0.0001
Sodium							
DHQ (mg/day)	3442 (3321–3568)	3578 (3318–3859)	3477 (3182–3798)	3558 (3297–3839)	3275 (3030–3540)	3336 (3073–3620)	0.15
Biological marker (mg/day)[i]	3235 (3094–3384)	2830 (2535–3158)	3102 (2818–3415)	3495 (3228–3784)	3081 (2759–3440)	3753 (3426–4110)	0.0002
Reporting accuracy[f]	1.14 (1.07–1.21)	1.34 (1.17–1.52)	1.21 (1.05–1.38)	1.09 (0.96–1.21)	1.14 (0.98–1.30)	0.94 (0.84–1.05)	0.0002
Energy-adjusted dietary intake							
Protein							
DHQ (% energy)	13.7 (13.5–13.9)	13.8 (13.4–14.2)	14.2 (13.7–14.7)	13.9 (13.5–14.3)	13.4 (13.1–13.8)	13.3 (12.9–13.8)	0.02
Biological marker (% energy)[j]	12.2 (11.9–12.5)	11.9 (11.2–12.7)	12.8 (12.0–13.6)	12.5 (11.8–13.2)	11.9 (11.3–12.6)	12.0 (11.4–12.7)	0.61
Reporting accuracy[f]	1.14 (1.11–1.17)	1.17 (1.10–1.25)	1.13 (1.06–1.20)	1.13 (1.06–1.20)	1.14 (1.08–1.2)	1.12 (1.06–1.19)	0.42
Potassium							
DHQ (mg/1000 kcal)	1133 (1106–1161)	1167 (1106–1230)	1195 (1130–1264)	1164 (1104–1226)	1063 (1011–1117)	1085 (1027–1145)	0.005
Biological marker (mg/1000 kcal)[j]	969 (935–1003)	979 (915–1047)	976 (895–1064)	1007 (932–1088)	931 (855–1014)	953 (885–1026)	0.47
Reporting accuracy[f]	1.20 (1.16–1.25)	1.22 (1.13–1.31)	1.26 (1.15–1.38)	1.20 (1.09–1.31)	1.17 (1.08–1.27)	1.17 (1.08–1.27)	0.29
Sodium							
DHQ (mg/1000 kcal)	2052 (2000–2105)	2086 (1980–2199)	2124 (2013–2240)	2058 (1944–2178)	1992 (1874–2118)	2001 (1884–2126)	0.13
Biological marker (mg/1000 kcal)[j]	1624 (1555–1696)	1544 (1383–1724)	1617 (1470–1779)	1766 (1631–1913)	1518 (1363–1692)	1686 (1543–1842)	0.40
Reporting accuracy[f]	1.32 (1.26–1.39)	1.41 (1.26–1.57)	1.38 (1.22–1.54)	1.22 (1.10–1.34)	1.38 (1.20–1.58)	1.24 (1.11–1.37)	0.15

[a]Values are geometric mean (95% confidence intervals) except for body mass index (median (range)).
[b]Dietary intake values derived from DHQ were significantly different from the corresponding values derived from biological markers except for absolute potassium intakes ($P = 0.002$ for absolute protein intake, $P = 0.03$ for absolute sodium intake, and $P < 0.0001$ for other values; paired t-test).
[c]Reporting accuracy was significantly different from a value of 1 except for absolute protein and potassium intake ($P < 0.0001$; one sample t-test).
[d]Test for linear trend used the median value in each quintile as a continuous variable in linear regression.
[e]Calculated as estimated basal metabolic rate (14.7 × body weight (kg) + 496) (FAO/WHO/UNU, 1985) multiplied by 1.56 (physical activity level for light activity) (FAO/WHO/UNU, 1985) assuming that lifestyle of the subjects was predominantly sedentary.
[f]Calculated as the ratio of value derived from DHQ to that derived from biological marker.
[g]Calculated as 24-h urinary urea nitrogen multiplied by 9.08 assuming that urea nitrogen is a constant proportion (85%) of total urinary nitrogen (Bingham and Cummings, 1985), that 81% of the ingested nitrogen is excreted through the urine (Bingham and Cummings, 1985; Kipnis *et al.*, 2001), and that nitrogen constitutes 16% of protein.
[h]Calculated as 24-h urinary potassium divided by 0.77 assuming that 77% of the ingested potassium is excreted through the urine (Holbrook *et al.*, 1984; Tasevska *et al.*, 2006).
[i]Calculated as 24-h urinary sodium divided by 0.86 assuming that 86% of the ingested sodium is excreted through the urine (Holbrook *et al.*, 1984; Willett, 1998).
[j]Calculated using dietary intake values estimated by biological markers.

Discussion

To date, no information has appeared on possible differential misreporting of dietary intake and its relation with BMI in Japanese populations, who are relatively lean and whose proportion of energy intake derived from fat is relatively low. In this study of young Japanese women, misreporting of dietary intake of energy, protein, potassium and sodium was differential rather than proportional. Additionally, differential misreporting of absolute intake of energy, protein,