Reliability of a food menu to measure energy and macronutrient intake in adolescents

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Abstract:

Background/Objectives: The aim of this study was to evaluate the reliability of a food menu to measure energy and macronutrient intake within the laboratory and under real-life conditions in adolescents. **Subjects/Methods:** A total of 12 boys and 8 girls (age 14.3 (s.d. 2.4) years, body mass index (BMI) 20.8 (s.d. 4.0) kg/m^2) completed two identical in-laboratory sessions (ILS) and two out-of-laboratory sessions (OLS). During the ILS, participants had *ad libitum* access to a variety of foods (74 items in total), which they chose from a menu every hour, for 5 h (0800–1300 h). For the OLS (1300 h until bedtime), the foods were chosen from the same menu at 1300 h and packed into containers to bring home with them. **Results:** Test–retest analysis of energy and macronutrient intake revealed no significant differences (ILS and OLS). Intra-class correlations ranged between 0.69 and 0.83 (ILS) and between 0.48 and 0.73 (OLS) for energy and macronutrient intake (all $P<0.01$). Within-subject coefficients of variation ranged between 12.9% and 23.5% for the ILS and between 24.0% and 37.7% for the OLS. Bland–Altman plots showed acceptable agreement. Finally, the food menu was well appreciated by the participants with a 75% appreciation rate on a visual analog scale. **Conclusions:** This food menu provides a reasonably reliable measure of energy and macronutrient intake in adolescents, irrespective of sex and BMI, especially inside the laboratory setting. Despite the difficulties in capturing a stable measure of energy intake in research, this tool could be a useful addition to the methods currently used to assess *ad libitum* food intake in youth.

Keywords: adolescent | energy intake | macronutrient | food

Article:

Introduction

Food intake is one of the most difficult variables to measure and its assessment in research has been a highly debated topic in recent years.[1, 2] However, despite the inherent limitations associated with dietary measurements, the assessment of food intake is of great importance in energy balance-related research. In an experimental context, the use of an *ad libitum* test meal is generally used to measure spontaneous food intake and/or macronutrient preference. Variations of a cold buffet-style meal[3] and a standardized energy-fixed meal[4] have been widely used to measure *ad libitum* energy intake under controlled laboratory conditions. Although both methods are reliable,[3, 4] they have only been used over a short period of time (that is, one meal) inside the laboratory and they do not offer many food options compared with what may be found and sought after by participants under free-living conditions.

In order to address this problem, a food menu comprising a large variety of food items to measure energy and macronutrient intake was recently developed and tested for reliability within the laboratory and under free-living conditions in 16 adults. Overall, this food menu provided a relatively reliable measure of energy intake inside and outside the laboratory.[5] Furthermore, the food items on the menu were well appreciated by the participants, as they rated them high on a visual analog scale (124 mm/150 mm on average). However, this method has yet to be tested in youth. Given that food intake is especially difficult to measure in youth,[6] it may be relevant to investigate the potential utility of such a food menu in this population, in particular in the current context of increased scientific interest for pediatric research on obesity and energy balance.

Therefore, the objective of this study was to evaluate the reliability of a food menu for 5 h (0800–1300 h) within a laboratory setting as well as for the rest of the day (1300 until bedtime) under free-living conditions in adolescents. We hypothesized that energy and macronutrient intake measured with the food menu over several meals and snacks would be reliable and could be used as a new tool for future studies in the field.

Subjects and methods

Participants

A total of 12 boys and 8 girls between the ages of 10 and 17 years were recruited to participate in this study based on previous power analysis.[5] Participants were recruited through postings in the community, using social media and through word of mouth. In addition to age, participants had to meet the following inclusion criteria: stable body weight (±2 kg) within the past 3 months, non-smoker, no medication and no drug or alcohol abuse. Female participants were tested during the follicular phase of the menstrual cycle. At least 7 days separated each testing session. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the University of Ottawa Ethics Committee and the Children's Hospital of Eastern Ontario Research Ethics Board. Written informed parental consent and child assent were obtained for all participants.

Study design and procedure

Participants were asked to take part in two identical experimental sessions in our facilities. During the in-laboratory sessions (ILS), participants were in a quiet room, alone and without distractions (for example, no TV/computer). During the out-of-laboratory sessions (OLS), no restrictions were given with regards to the amount and types of activities that the participants could perform (that is, free-living conditions). However, they were instructed to only eat and drink the items that were selected from the menu while outside of the laboratory setting (*ad libitum*). The participants arrived at the laboratory following a 12-h overnight fast and were not tested if they presented signs of illnesses. They were also instructed not to consume alcohol or engage in any type of structured physical activity (for example, playing sports or training) for at least 24 h before the start of testing. A good night's sleep also had to be respected the previous night (as assessed by a screening questionnaire).

Total energy and macronutrient intake were measured with an *ad libitum* food menu (Supplementary Appendix 1), as previously described.[5] A total of 74 items were provided on the menu to ensure that a sufficient amount of breakfast items, hot-meal items, snacks, fruits/vegetables and beverages were available to the participants. The foods presented on this food menu had varying amounts of carbohydrates, lipids and proteins. During the ILS, the food menu was presented to the participants every hour, for 5 h (0800–1300 h). Every hour, the participants had the possibility to select the foods and beverages from the menu that they wanted to consume at that time. During the OLS, the participants were given the same food menu at 1300 h and were asked to choose the foods and beverages that they wanted to consume for the rest of the day (until bedtime). The food items were then packed into plastic containers and the beverages were poured into plastic bottles. These containers and bottles were then placed into a portable cooler for the participants to bring with them. They were also asked to bring back all leftovers, wrappings and peels, and to put them into their original containers when applicable. In both cases (ILS and OLS), two portions of each of the food and beverage items selected were prepared and served (or packed into the portable cooler). The specific quantity (portions) of each food and beverage item provided/served to the participants was reported previously.[5] The participants were then given the instructions to eat *ad libitum* (that is, as little or as much as they wanted). The participants were also not required to eat or choose items from the menu if they did not want to. The food items were weighed to the nearest 0.1 g before serving (ILS) or before being put into coolers (OLS) using an electronic scale (Scout Pro SP2001; Ohaus Corporation, Parsippany, NJ, USA) and after the allocated 30-min time period for eating (ILS) or after the coolers were brought back to the laboratory the following day (OLS). The macronutrient composition of foods and beverages consumed was determined with the Food Processor SQL software (version 9.6.2; ESHA Research, Salem, OR, USA).

Standing height (wall stadiometer) and body weight (digital scale) were measured according to standardized procedures in the morning of the first testing visit, in an effort to better characterize the participants. Furthermore, the appreciation of the food menu was assessed using a 100-mm visual analog scale immediately after the foods were eaten. An average score was calculated for both ILS and OLS. The appreciation rating was assessed in order to determine whether the participants liked the foods and beverages consumed.

Statistical analysis

As there was no statistically significant sex interaction with the outcome variables (that is, energy and macronutrient intake), data for both male and female participants were combined to improve clarity and to maximize power. Homogeneity of variance and normality were checked and revealed that parametric tests could be used. A repeated-measures analysis of variance was conducted on energy and macronutrient intake data, to test for possible test–retest differences. Intra-class correlation coefficients (ICCs) and within-subject coefficients of variation (CV_{ws}) were calculated for energy and macronutrient intake. Published criteria for the strength of ICC values are as follows: 0.4 (moderate), 0.6 (substantial) and 0.8 (excellent).[7] Finally, Bland–

Altman plots were used to visually assess the repeatability of the food menu.[8] A two-tailed *P*-value of <0.05 was the threshold to indicate statistical significance. All statistical analyses were performed using JMP version 10 (SAS Institute, Cary, NC, USA) and SPSS version 21 (IBM, Armonk, NY, USA).

Results

Participants involved in the present study (12 boys and 8 girls) had a mean age of 14.3 (s.d. 2.4) years and had a wide range of body size (body mass index (BMI) ranging between 14.8 and 29.6 kg/m^2). Test–retest analysis of energy and macronutrient intake revealed no significant differences (Table 1). Likewise, test–retest analysis of energy and macronutrient intake did not show differences by BMI, that is, above versus under the median of 20.1 kg/m^2 (data not shown). Participants consumed 15 833 kJ (3784 kcal) on average over the 24-h protocol, an indication of overeating and a phenomenon expected in an experimental context where unrestricted access to many novel food items takes place. Overall, participants ordered a large diversity of food items on the menu (48 food items ordered at least once per participant, hence 26 not at all). The five most favorite food items on the menu were: three cheese pizza, meat lasagna, marinara grilled chicken, Lays BBQ chips and chocolate milk. The five least favorite food items on the menu were: raisin bran, Lays nature chips, lettuce, Breton original crackers and mustard. The participants took a full cooler of food items to bring home and brought back all leftovers; more than 80% of food items have been eaten on average.

Table 1. Energy and macronutrient intake in the two sessions of self-selection from a food menu

	In-lab session			***Out-lab session***			***Whole day***		
	Session 1	*Session 2*	P	*Session 1*	*Session 2*	P	*Session 1*	*Session 2*	P
Total energy intake (kJ)	7594±2834	7112±3281	0.24	8157±2938	8804±5080	0.48	15751±4712	15916±6406	0.87
Carbohydrate (kJ)	4586±1849	4472±2359	0.7	4646±1869	4924±2609	0.56	9232±3133	9396±3733	0.76
Lipid (kJ)	2160±973	1860±954	0.09	2652±1120	2863±2142	0.6	4812±1717	4723±2432	0.84
Protein (kJ)	848±462	780±469	0.32	859±468	1017±704	0.12	1707±789	1797±990	0.49

Abbreviations: In-lab, in-laboratory; out-lab, out-of-laboratory. Values are mean ± s.d. Test–retest differences were analyzed using a repeated-measures analysis of variance. *n* = 20.

As shown in Table 2, ICCs ranged between 0.69 and 0.83 (ILS) and between 0.48 and 0.73 (OLS) for energy and macronutrient intake. Although all ICCs were significant (*P*<0.01), they were in the substantial-to-excellent range for the ILS and in the moderate-to-substantial range for the OLS. Likewise, CV_{ws} ranged between 12.9% and 23.5% for the ILS and between 24.0% and 37.7% for the OLS.

Table 2. Reproducibility of energy and macronutrient intake in the two sessions

	ICC*			***CV_{ws}* (%)**		
	In-lab	***Out-lab***	***Whole day***	***In-lab***	***Out-lab***	***Whole day***
Total energy intake (kJ)	0.83	0.54	0.71	12.9	25.5	13.9
Carbohydrate (kJ)	0.81	0.58	0.78	13.2	25.8	14.3
Lipid (kJ)	0.69	0.48	0.56	23.5	37.7	19.4
Protein (kJ)	0.80	0.73	0.79	19.0	24.0	16.7

Abbreviations: CV_{ws}, within-subject coefficient of variation; ICC, intra-class correlation coefficient; In-lab, in-laboratory; out-lab, out-of-laboratory. **P*<0.01 for all ICCs. Established criteria for the strength of ICC values are as follows: 0.4 (moderate), 0.6 (substantial) and 0.8 (excellent). *n* = 20.

Repeatability of the food menu was also illustrated using Bland–Altman plots (Figure 1). This graphical method shows the individual differences between energy intake on sessions 1 and 2 against their mean. According to the three diagrams, test–retest agreement was relatively good (as shown by the average discrepancy or bias between sessions). Removing the outliers from our analyses did not materially change the analysis of variance and ICC results (the strength of the associations were the same with or without the outliers). Similar variability was observed for the individual macronutrient intake differences (Bland–Altman plots not shown).

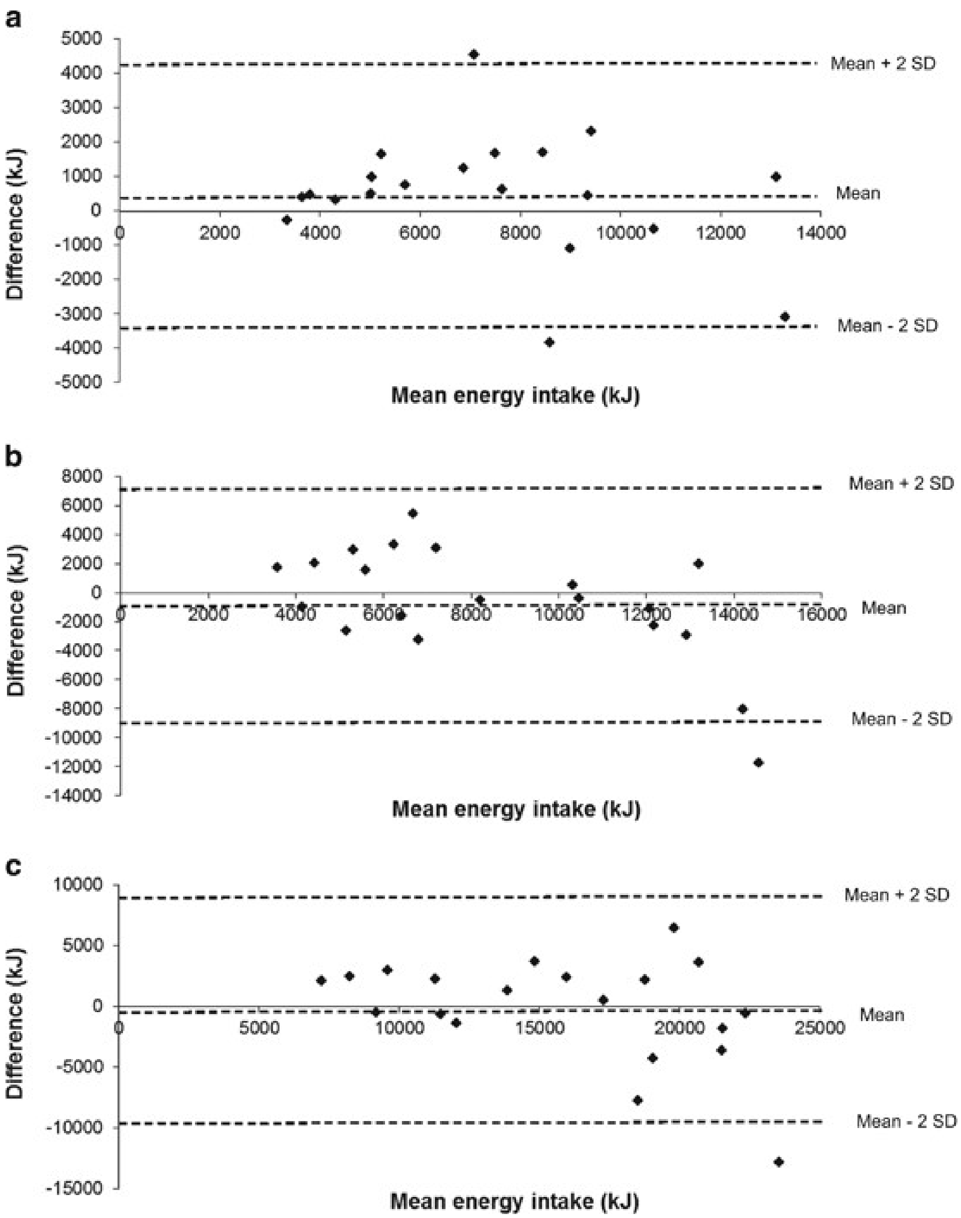

Figure 1. (**a**) Bland–Altman diagram of total energy intake (kJ) for the ILS. Individual differences between energy intake on sessions 1 and 2 are plotted against individual mean energy intake values. *n*=20. (**b**) Bland–Altman diagram of total energy intake (kJ) for the out-of-laboratory session. Individual differences between energy intake on sessions 1 and 2 are plotted against individual mean energy intake values. *n*=20. (**c**) Bland–Altman diagram of total energy intake (kJ) for the whole day. Individual differences between energy intake on sessions 1 and 2 are plotted against individual mean energy intake values. *n*=20.

Finally, the overall appreciation of the food items offered to the participants was calculated to be on average 75 (s.d. 20) mm for the ILS and of 75 (s.d. 18) mm for the OLS on a scale of 100 mm.

Discussion

Collectively, we observed that our food menu provides a reasonably reliable measure of energy and macronutrient intake in adolescents. Using a large variety of meal-type foods, beverages and snacks (74 items in total), we observed no test–retest significant differences for energy and macronutrient intake, moderate-to-excellent ICC and an acceptable discrepancy or bias according to Bland–Altman plots. The food menu was overall well appreciated by the participants, with a 75% appreciation rate on a visual analog scale. Despite the limitations associated with the measurement of food intake (especially in the pediatric population), we believe that this tool provides a scientifically acceptable approach to measure *ad libitum* food intake in this population.

Intra-individual day-to-day variation in energy and macronutrient intake can potentially have an impact on the validity of studies using an *ad libitum* paradigm. However, the present study shows that our food menu is reliable, especially inside the laboratory setting (ICCs of 0.83 and CV_{ws} of 12.9% for total energy intake). This level of reliability is similar to the results observed by McNeil *et al.*[5] using the same food menu but in adults (ICCs of 0.77 and CV_{ws} of 18.3% for energy intake during the ILS). Although test–retest reliability of this food menu has already been reported previously in adults,[5] this method needed to be tested in youth given the increased use of this tool in pediatric research. The use of a cold *ad libitum* buffet-type meal[3] has been shown to have a very high reliability (ICCs of 0.97 and CV_{ws} of 8.2%) for total energy intake between two experimental sessions in men. However, the buffet was only served for one single meal and did not offer many food options (for example, hot food items), thereby reducing variability. In contrast, *ad libitum* access to a standardized energy-fixed meal (a mixed hot-pot meal containing pasta, vegetables, minced meat and cream) during lunch on two separate occasions in a laboratory setting provided similar results with an ICC of 0.86 and a CV_{ws} of 18.3% in men.[4] To our knowledge, our food menu aimed at measuring energy and macronutrient intake is the first to be evaluated in youth and our findings suggest that this approach is reliable.

Several studies have measured food intake responses after different manipulations[9, 10, 11, 12] with the use of single-meal designs; however, compensatory adjustments in food intake can be delayed,[13, 14] suggesting that a follow-up assessment outside of the laboratory setting may be needed. However, results of the present study suggest that our food menu is more reliable inside than outside the laboratory (ICCs of 0.83 versus 0.54 for total energy intake during the ILS and OLS, respectively). It is therefore important to keep in mind that the reduced reliability of using this food menu outside the laboratory setting as well as the additional factors, which may need to be controlled for under free-living conditions (for example, physical activity participation and parental involvement in food choices) may, to some degree, compromise the accuracy of food intake measurements under such conditions.

The overfeeding commonly observed in the laboratory setting when participants have *ad libitum* access to a variety of food items is generally the result of a spontaneous overdrive to eat more when food is offered *ad libitum.*[15] Our participants ingested 15 833 kJ (3784 kcal) on average over the 24-h protocol, which is well above the daily energy needs of adolescents, indicating that overconsumption of food occurred with the use of this testing paradigm. The double portion sizes and the demand characteristics of asking participants every hour what they wanted to eat can explain the overeating observed. However, we need to keep in mind that the use of an *ad libitum* food menu is not a valid tool to measure representative daily energy intake but is rather aimed at measuring food intake responses after different experimental manipulations. With this in mind, comparisons of food consumed between experimental conditions with the use of this food menu still provide important and relevant information, and may serve to assess spontaneous energy intake following various interventions.

Our food menu comprised a large variety of food items (74 in total), to allow for the determination of macronutrient preferences. Among all macronutrients, lipid intake appeared to be the least reliable, and this especially outside the laboratory setting (ICCs of 0.69 and of 0.48 for the ILS and OLS, respectively). This finding agrees with the study of McNeil *et al.*[5] conducted in adults (ICCs of 0.54 and of 0.72 for the ILS and OLS, respectively). In addition, it is interesting to note that this food menu was more reliable during the ILS in adolescents and during the OLS in adults.[5] The reason behind these observations is unclear and warrants more attention. Previous studies have however reported higher variability for fat intake than for carbohydrate and protein intake when measured over time,[16, 17, 18] which may in part explain the greater variability in lipid intake observed in McNeil *et al.*[5] and the present study.

Although moderate-to-substantial ICC values were observed for OLS in the present study, our food menu is accompanied by limitations when used outside of the laboratory setting, including the possibility of sharing foods with others and/or that other food items may be consumed. Compliance to these recommendations can always be an issue despite strict advice given to the participants. Furthermore, the activities performed by the participants during the OLS (for example, screen time and physical activity) were not assessed or restricted and can also have an impact on food intake. The present findings also need to be interpreted in light of the small sample size (n=20) of boys and girls, and of the characteristics of the participants who took part in the study. Food intake can be influenced by multiple factors and it is unknown whether the same level of reliability would be observed in a different context and with a different population. It is nevertheless reassuring to observe that this food menu can be reproduced in youth and adults with similar reliability. Finally, the time, cost and labor intensity of this method might reduce the number of studies to apply it.

In summary, the present results provide evidence that our food menu produces a relatively reliable measure of energy and macronutrient intake in adolescents, irrespective of sex and BMI, especially inside the laboratory. The food menu was also generally well appreciated by the participants. Despite the difficulties in accurately measuring energy intake inside and outside of laboratory conditions, we believe that this tool can be a useful addition to the tests currently used to assess *ad libitum* food intake in youth.

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The authors declare no conflicts of interest.

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