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Short Communication

Reproducibility of 24-h post-exercise changes in energy intake in overweight and obese women using current methodology

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Abstract

Direct observation(s) of energy intake (EI) via buffet meals served in the laboratory are often carried out within short-term exercise intervention studies. The reproducibility of values obtained has not been assessed either under resting control conditions or post-exercise, in overweight and obese females. A total of fourteen sedentary, pre-menopausal females (BMI 30·0 (SD 5·1) kg/m^2) completed four trials; two exercise and two control. Each trial lasted 24 h spanning over 2 d; conducted from afternoon on day 1 and morning on day 2. An exercise session to expend 1·65 MJ was completed on day 1 of exercise trials, and three buffet meals were served during each trial. Reproducibility of post-exercise changes in energy and macronutrient intakes was assessed at each individual buffet meal by intraclass correlation coefficient (r_i). Only the r_i values for post-exercise changes in energy (r_i 0·44 (95 % CI −0·03, 0·77), P=0·03) and fat intake (r_i 0·51 (95 % CI 0·04, 0·81), P=0·02) at the lunch buffet meal achieved statistical significance; however, these r_i values were weak and had large associated 95 % CI, which indicates a large degree of variability associated with these measurements. Energy and macronutrient intakes at the breakfast and evening buffet meals were not reproducible. This study concludes that the frequently used laboratory-based buffet meal method of assessing EI does not produce reliable, reproducible post-exercise changes in EI in overweight and obese women.

Key words: Energy intake: Exercise: Obesity

Obtaining accurate estimates of energy intake (EI) in the free-living population is a difficult proposition[1,2] as there are extensive limitations associated with all available methods. As a result, direct, laboratory-based observation of EI has become increasingly common, particularly in short-term exercise intervention studies which include buffet meals to assess EI[3–5]. Conclusions in these studies are thus often drawn from a single measurement obtained in an atypical setting. Reproducibility of EI measurements made using this method has been shown to be high for sedentary and moderately active lean males at rest[6–8]; reproducibility coefficients range from 0·86 to 0·97. The only existing study assessing reproducibility of post-exercise EI reported a coefficient of 0·89 obtained from male and female recreational athletes[9]. All of these existing studies assess EI at a single meal only; none has examined the reproducibility of 24-h EI in overweight, sedentary females either under sedentary or under exercise conditions. Thus, it is not known whether findings in these short-term exercise studies are exercise-induced or simply attributable to day-to-day variation in food intake. Women, particularly overweight and obese, are known to frequently underreport their dietary intake[1]; hence EI assessment is perhaps most difficult in this group. Reproducibility of this method in lean males cannot be assumed to be similar for overweight and obese women due to differences in adiposity, and greater hormonal influences in women[10]. The present study aimed to examine the reproducibility of acute post-exercise EI responses, measured via *ad libitum* buffet style meals over a 24-h period, in overweight, pre-menopausal, sedentary females.

Subjects and methods

Subjects

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures

Abbreviation: EI, energy intake.

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involving human subjects were approved by the University of Glasgow Medical Faculty ethics committee. Written informed consent was obtained from all subjects. Subjects were recruited by poster and e-mail advertisements around the University. A total of fourteen healthy women gave written, informed consent to participate and all completed the study. Subjects were pre-menopausal, healthy, non-smokers, currently sedentary (participation in < 2 h planned exercise/week), not currently attempting weight loss, and were classed as either overweight or obese (BMI ≥ 25 kg/m^2).

Screening

All subjects completed standard questionnaires to assess their current physical activity levels (International Physical Activity Questionnaire), health status and food preferences before beginning the study. Height was measured to the nearest cm using a stadiometer (Seca 213; Seca, Birmingham, UK). Body mass (to the nearest 0·1 kg) and composition were measured using foot-to-foot bio-impedance scales (Tanita B.V., Hoofddorp, The Netherlands).

Sub-maximal fitness test

Before the beginning of the trial, subjects completed a graded, sub-maximal treadmill fitness test. Tests were conducted according to exercise testing guidelines[11] and began at a moderate walking speed which was tailored to an individual subject's fitness level, and the speed was gradually increased until the heart rate reached 85 % of the age-predicted maximum. Each stage lasted 5 min and the heart rate and expired air samples were taken in the last minute of each stage to enable the prediction of maximal oxygen (VO_{2max}) consumption.

Study design and measures

Each subject completed two sets of trials; hence participation involved a total of four trials – two exercise and two control. Subjects were asked to avoid alcohol and standardise their food intake before each trial. All trials were timed to control for effects of the menstrual cycle for each subject; the trials were carried out at least 3 weeks apart in practice. The first set of trials, one exercise and one control, was completed in a randomised, counter-balanced fashion. The second set of trials was completed in reverse order so as to minimise potential bias effects of order.

Each trial lasted 24 h, spanning over 2 d; observation was carried out in the afternoon of day 1, and in the morning of day 2. Subjects attended the laboratory on day 1 at 14.00 hours and remained for 4 h, during which time the intervention (exercise or control) period was completed. Subjects fasted overnight at home and returned to the laboratory the next morning at 09.00 hours, remaining for a further 5 h. Body composition was measured via bio-impedance in the fasted state at the beginning of day 2 of all trials. During each trial, three *ad libitum* buffet meals were served; evening meal on day 1, and breakfast and lunch on day 2.

Intervention

During the exercise trials, a moderate (65 % VO_{2max}) intensity treadmill walking session was carried out in the afternoon of day 1 to expend 1·65 MJ; an energy expenditure similar to recommendations for individual sessions of exercise aimed at weight control[12]. At all other times, the subjects were sedentary. The control trials were identical, except that the subjects remained sedentary during the intervention period.

Ad libitum *buffet meals*

Buffet meals included a selection of commercially prepared foods which were identical between trials; all meals included a selection of fresh, chopped fruit, orange juice and yoghurt, while lunch and evening meals both included salad with dressing served separately and a selection of cupcakes. Foods served specifically at certain meals included cereal, milk, croissants and jam at breakfast, soup and a selection of sandwiches at lunch, and a pasta ready meal at the evening meal. Exact individual menus were tailored to each subject's personal tastes to ensure that all foods presented were palatable. The amount of food presented at each meal was significantly more than the subject was expected to consume to ensure that it was possible to eat to satiety without requiring additional food to be presented mid-meal. Subjects were left alone for 30 min to consume each meal. All foods were weighed before and after consumption to enable the calculation of EI using nutrient analysis software (Windiets 2005; Robert Gordon University, Aberdeen, UK). Subjects were not informed that EI was being monitored, in an attempt to minimise potential adverse effects on consumption[13].

Statistical analyses

Before analysis, all data were found to be normally distributed using the Anderson–Darling normality test. Paired *t* tests were used to compare characteristics of the exercise sessions. Repeated-measures ANOVA with *post hoc* Tukey test was used to assess differences in energy and macronutrients between trials.

Reproducibility of appetite scores and EI measurements made in identical trials were assessed using two-way mixed-effects intraclass correlation coefficients (r_i). Statistical significance was set at 5 %. Data were analysed using Minitab 14 (Minitab Limited, Coventry, UK) and IBM SPSS Statistics 19 (IBM Corporation, Somers, NY, USA).

Results

Subjects' characteristics

A total of fourteen subjects completed the study with no attrition. Subjects had mean age of 35·7 (SEM 2·3) years, height 162 (SEM 1·5) cm, body mass 78·6 (SEM 3·8) kg, BMI 30·0 (SEM 1·4) kg/m^2, body fat 38·7 (1·5) % and VO_{2max} 30·9 (SEM 1·9) ml/kg per min. There were no significant differences in body composition between trials.

Exercise responses

Mean energy expenditure of the exercise sessions was 1·65 (SEM 0·01) MJ. There were no significant differences in intensity (Δ 3·9 (SEM 4·2) % VO_{2max}), duration (Δ 0·1 (SEM 1·9) min or energy expenditure (Δ 0·01 (SEM 0·05) MJ) of the two exercise sessions conducted during the exercise trials.

Energy and macronutrient intake

Repeated-measures ANOVA comparison of EI in all trials showed no significant main effect of trial ($P=0·21$), or interaction effect of meal × trial ($P=0·73$); however, there was a significant main effect of meal; EI was significantly lower at the breakfast meal compared to the evening meal in all trials ($P=0·0003$).

There was no significant main effect of trial or interaction effect of meal × trial on carbohydrate, fat or protein intake (all $P<0·01$), though a significant effect of meal was observed for all macronutrients (all $P<0·0001$). EI and macronutrient intake at all buffet meals are summarised in Table 1.

The r_i values representing the reproducibility of exercise-induced changes in energy and macronutrient intake measured at each of the three buffet meals are presented in Table 2.

Discussion

A substantial field of literature has built up using a potentially flawed study protocol to investigate factors which may mediate in the regulation of appetite post-exercise; the reliability of this method has not been demonstrated. The present study was designed to evaluate the reproducibility of EI values obtained from laboratory-based buffet meals, in overweight and obese women under control and exercise conditions. No acute exercise-induced compensatory increase in EI was observed in these women; however, despite the apparent agreement in measurements, the associated r_i values indicate low reproducibility of these values and a large degree of individual variation associated with the EI estimates obtained via this method. The r_i for exercise trial EI was not significant, which indicates very low reproducibility of this method. This finding disagrees with a previous study assessing post-exercise EI[9]; this study observed EI following a short exercise session (35 min) in male and female lean recreational athletes at a single non-buffet type meal, hence subjects and methodology differ significantly from the present work. r_i for the difference in EI between sets of exercise and control trials was calculated to assess the reproducibility of the direction of change in EI; this was non-significant, indicating that this change was not uniform or consistent. These differences may reflect normal daily variation in EI[14], or indicate that the effects of exercise on EI are highly inconsistent.

The r_i for EI in control trials was significant but low; the value of 0·50 represents a low level of agreement and rather weak reproducibility. The CI associated with this value must also be taken into account[15]. Spanning from 0·03 to 0·80, this CI reflects great individual variability in the extent of agreement and thus EI assessed in control conditions by this method will not be reliable for all subjects. This finding disagrees with similar studies involving lean males[6–8]; all of which report high reproducibility of EI values obtained from lean males at a single meal, often consisting of a single foodstuff. These studies do not report CI of reproducibility coefficients and thus the extent of variability associated with these estimates is unclear. No other study assessing the reproducibility of 24-h EI assessed via buffet meals could be identified; the EI of lean males at multiple meals could prove to be more variable than the reported values suggest. Differences in study populations, mainly in sex, adiposity and activity

Table 1. Total energy and macronutrient intake assessed by buffet meals during exercise and control trials
(Mean values with their standard errors)

	Energy intake (kJ)		Carbohydrate intake (g)		Protein intake (g)		Fat intake (g)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Control trial 1								
Breakfast	2902[a]	131	119·5[a]	5·9	20·9[a]	1·6	18·2[a]	1·3
Lunch	3665	294	102·6[b]	8·1	32·5[b]	3·5	40·2[b]	5·3
Evening meal	3802[b]	284	112·0[c]	8·9	36·8[c]	4·4	38·0	4·4
Exercise trial 1								
Breakfast	3137[a]	102	128·7[a]	4·1	22·2[a]	1·0	20·0[a]	1·8
Lunch	3410	290	100·9[b]	8·0	29·0[b]	2·6	35·7[b]	5·1
Evening meal	4203[b]	370	120·4[c]	9·2	37·9[c]	5·1	44·6	5·7
Control trial 2								
Breakfast	3012[a]	215	130·1[a]	8·9	21·8[a]	8·9	16·2[a]	1·8
Lunch	3029	361	83·7[b]	7·3	26·3[b]	3·1	33·9[b]	7·8
Evening meal	3381[b]	250	107·2[c]	8·0	31·1[c]	2·2	31·3	3·9
Exercise trial 2								
Breakfast	3119[a]	289	135·6[a]	12·5	22·0[a]	12·4	16·7[a]	1·9
Lunch	3542	189	103·7[b]	6·7	31·2[b]	2·4	37·1[b]	4·6
Evening meal	3868[b]	344	117·8[c]	10·7	33·1[c]	2·5	38·9	4·8

[a,b,c] Mean values with unlike superscript letters were significantly different (effect of meal; $P<0·05$; repeated-measures ANOVA).

Table 2. Intraclass correlation coefficients (r_i) representing reproducibility of differences in energy intake (EI) and macronutrient intake between control and exercise trials at three separate buffet meals

(Mean values and 95 % confidence intervals)

	r_i	95 % CI	*P*
Breakfast			
EI (MJ)	−0·40	−0·83, 0·19	0·91
CHO (g)	−0·36	−0·81, 0·24	0·88
Protein (g)	−0·42	−0·82, 0·16	0·93
Fat (g)	0·05	−0·52, 0·56	0·44
Lunch			
EI (MJ)	0·44	−0·03, 0·77	0·03
CHO (g)	0·10	−0·34, 0·56	0·34
Protein (g)	0·29	−0·17, 0·60	0·11
Fat (g)	0·51	0·04, 0·81	0·02
Evening meal			
EI (MJ)	−0·37	−0·82, 0·22	0·89
CHO (g)	−0·45	−0·87, 0·15	0·93
Protein (g)	−0·12	−0·66, 0·44	0·66
Fat (g)	−0·13	−0·67, 0·44	0·66

CHO, carbohydrates.

levels of subjects, may also contribute to the discrepancies in results between previous literature and the present study.

To our knowledge, there is no evidence regarding the reproducibility of this method in overweight and obese females with which to compare these results. This study is novel in examining this reproducibility of 24-h EI measures using this laboratory-based buffet meal method. It does not give reproducible and reliable results in overweight and obese women. It may be that short-term exercise studies may be attempting to measure a phenomenon that simply does not exist in these subjects. Further investigation is needed to clarify if this method is reliable for use in other population groups.

Like other available methods, the laboratory-based buffet meal method also has inherent limitations which may also have contributed to poor reproducibility. Food is served in an unnatural environment and this may affect eating behaviour[13]. Although subjects are not informed that EI is being measured, the presence of a researcher serving food may introduce perceived social pressure which can affect EI[13,16]. Additionally, restrained eating status was not measured in this group of subjects, which may serve as a limitation in the present study.

Due to the exploratory nature of this study, a prospective power calculation was not carried out. However, we consider fourteen subjects to be a relevant sample size, as this number is typical of many short-term exercise studies[3,5] and previous reliability studies with lean males[6,8].

This study has shown that the laboratory-based *ad libitum* buffet meal method does not provide a reliable, reproducible estimate of EI in all pre-menopausal, overweight and obese women under control or acute exercise conditions. The reproducibility of this method varies greatly between individuals under control and in particular post-exercise conditions; as a result, this method does not seem appropriate to assess the effects of exercise on EI in overweight women.

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