Calorie Estimation in Adults Differing in Body Weight Class and Weight Loss Status

RUTH E. BROWN, KARISSA L. CANNING, MICHAEL FUNG, DISHAY JIANDANI, MICHAEL C. RIDDELL, ALISON K. MACPHERSON, and JENNIFER L. KUK

School of Kinesiology and Health Science, York University, Toronto, Ontario, CANADA

ABSTRACT

BROWN, R. E., K. L. CANNING, M. FUNG, D. JIANDANI, M. C. RIDDELL, A. K. MACPHERSON, and J. L. KUK. Calorie Estimation in Adults Differing in Body Weight Class and Weight Loss Status. *Med. Sci. Sports Exerc.*, Vol. 48, No. 3, pp. 521–526, 2016. **Purpose**: Ability to accurately estimate calories is important for weight management, yet few studies have investigated whether individuals can accurately estimate calories during exercise or in a meal. The objective of this study was to determine if accuracy of estimation of moderate or vigorous exercise energy expenditure and calories in food is associated with body weight class or weight loss status. **Methods**: Fifty-eight adults who were either normal weight (NW) or overweight (OW), and either attempting (WL) or not attempting weight loss (noWL), exercised on a treadmill at a moderate (60% HR_{max}) and a vigorous intensity (75% HR_{max}) for 25 min. Subsequently, participants estimated the number of calories they expended through exercise and created a meal that they believed to be calorically equivalent to the exercise energy expenditure. **Results**: The mean difference between estimated and measured calories in exercise and food did not differ within or between groups after moderate exercise. After vigorous exercise, OW–noWL overestimated energy expenditure by 72% and overestimated the calories in their food by 37% ($P < 0.05$). OW–noWL also significantly overestimated exercise energy expenditure compared with all other groups ($P < 0.05$) and significantly overestimated calories in food compared with both WL groups ($P < 0.05$). However, among all groups, there was a considerable range of overestimation and underestimation (−280 to +702 kcal), as reflected by the large and statistically significant absolute error in calorie estimation of exercise and food. **Conclusions**: There was a wide range of underestimation and overestimation of calories during exercise and in a meal. Error in calorie estimation may be greater in overweight adults who are not attempting weight loss. **Key Words:** BODY MASS INDEX, WEIGHT LOSS, ENERGY EXPENDITURE, ENERGY INTAKE, EXERCISE INTENSITY

Approximately 50% of adults in the United States are attempting to control their weight, with the most common methods including exercise and caloric restriction (22). Weight loss occurs when energy intake is less than energy expenditure (6). Therefore, to successfully manage body weight, it would be beneficial for an individual to be able to accurately estimate the number of calories expended through exercise and consumed in a meal (3). Previous research has demonstrated that adults generally underestimate calories in meals (2,9,17,23), and the few studies that have investigated how accurately adults estimate exercise energy expenditure have reported mixed findings (9,12,23). Furthermore, whether calorie estimation differs by weight class and weight loss status is not clear. For example, although both dieters and nondieters underestimated calories in a postexercise meal (20), dieters have been reported to be more accurate at calorie estimation compared with nondieters (5). Additionally, some studies have demonstrated that obesity is associated with poorer calorie estimation (4,14). However, no study has simultaneously examined the effect of body weight class and weight loss status on calorie estimation accuracy. Furthermore, although knowledge of calories is reported to be important for weight management (10), whether calorie estimation ability is associated with better weight management has not been tested.

To date, only two studies have attempted to simultaneously determine how accurately adults estimate exercise energy expenditure and calories in food (12,23). Willbond et al. (2010) demonstrated that adults overestimated exercise energy expenditure by 300% to 400% and underestimated energy intake by 200% to 300% (23). On the other hand, a recent study reported that adults underestimated moderate exercise energy expenditure but accurately estimated high-intensity energy expenditure and energy intake (12). However, neither study examined participants with overweight or obesity or the effects of weight loss status on caloric estimates. Furthermore, only one study has examined the impact of exercise intensity on the accuracy of calorie estimation

Address for correspondence: Jennifer Kuk, Ph.D., School of Kinesiology and Health Science, York University, 4300 Keele St., Toronto, Ontario, Canada; E-mail: jennkuk@yorku.ca.
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(12). Given the importance of calorie estimation for weight management, the present study aimed to determine if accuracy of estimation of moderate or vigorous exercise energy expenditure and calories in food is influenced by body weight class and intention to lose weight.

METHODS

Participants

Adults between the ages of 18 and 65 yr were recruited via poster advertisement from a large urban university setting. Participants were screened for eligibility as assessed by a Physical Activity Readiness Questionnaire form. Participants were assessed over three visits that were at the same time of day approximately 1 wk apart. Participants were instructed to refrain from exercising at least 24 h before and to avoid eating, smoking, or drinking caffeinated beverages for a minimum of 2 h before each experimental session. Informed written consent was obtained before participation. The procedures for this study have been approved by the local university ethics board and conform to the Declaration of Helsinki.

Procedures and Protocol

Participants were categorized into one of four groups based on weight and weight loss status: normal weight (NW) (BMI $\geq$18 and <25 $kg \cdot m^{-2}$) or overweight/obese (OW) (BMI $\geq$ 25 $kg \cdot m^{-2}$), and either attempting (WL) or not attempting weight loss (noWL). During the first session, participants completed a variety of demographic-, health-, and lifestyle-related questionnaires, including a question that inquired whether participants were currently attempting weight loss. To determine BMI, height was measured using a stadiometer (Seca Telescopic Height Rod, Model 220, Hamburg, Germany), and weight was measured with a mechanical scale (SECA 700, Hamburg, Germany). Cardiorespiratory fitness was assessed using a modified Balke protocol (1), which is an incremental exercise test to volitional exhaustion on a treadmill, using indirect calorimetry (Cardio Coach CO2, Model 9002-CO2; KORR Medical Technologies, Salt Lake City, UT).

For the second and third visits, participants were instructed to indicate their level of hunger immediately before exercise using a 150 mm visual analog scale that ranged between "I am not hungry at all" and "I have never been more hungry" (23). Participants wore an electronic heart rate monitor (Polar FT1; Polar Electro Oy, FI-90440 Kempele, Finland) and exercised at either a moderate intensity (50%–70% age-predicted maximum heart rate − HR_{max}) or vigorous intensity (70%–85% HR_{max}) (CDC, 2011) for 20 min on a treadmill, with an additional 2.5-min warm-up and 2.5-min cooldown. The trials were conducted in a random order. $\dot{V}O_2$ measures were averaged over 15-s intervals for the entire 25-min exercise protocol using indirect calorimetry (CardioCoach CO2, Model 9002-CO2) to calculate energy expenditure (21). Approximately 10 to 20 min after exercise, participants again indicated their level of hunger using the same 150 mm visual analog scale and were asked to estimate how many calories they expended during the entire 25-min protocol. Subsequently, participants were presented with a variety of preweighed foods, including whole wheat sliced bread, sliced turkey, cheese, mayonnaise and mustard, pasta with pasta sauce, chicken breast, salad, Italian salad dressing, ranch salad dressing, and chocolate candy. They were verbally instructed to create a meal, using any combination of the foods provided, that was equivalent to the number of calories that they estimated to have expended during the exercise bout. The participants were informed that they did not have to consume the meal they created but that they had the option of eating any of the food once the task was complete. The foods chosen were then weighed with an electronic scale (Ohaus, Model V11P15; Ohaus Corporation, Pine Brook, NJ) to the nearest gram, and the caloric content of the food was calculated using the nutrition information provided on the food packaging. Any food that the participants did consume was covertly recorded, and their ad libitum energy intake was calculated.

Statistical Analyses

Participant characteristics are presented as mean ± SD or prevalences with group differences assessed using ANOVA for continuous variables and chi-square tests for categorical variables. The main outcome variables were measured energy expenditure, estimated energy expenditure, measured food energy, and food energy consumed in the ad libitum meal. The error in calorie estimation was determined as both the mean difference and the absolute difference between the main outcome variables. Differences in the main outcome variables and for the error in calorie estimation were assessed with a 4 × 2 (group × intensity) mixed models repeated measures ANOVA with post hoc tests. Because of either time constraints or dietary preferences, only 41 of the 58 participants chose to eat a postexercise meal. Therefore, differences between calories consumed and energy expended were analyzed only in this subsample. Alpha was considered statistically significant at $P < 0.05$. All analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

Characteristics of the 58 participants are shown in Table 1. There were six participants (10%) who were obese in the OW groups. The NW–noWL group had a significantly lower BMI and higher cardiorespiratory fitness compared with the OW groups ($P < 0.05$). All groups exercised at a similar percentage of HR_{max} during the moderate condition (62.6% ± 4.5% HR_{max}) and vigorous condition (75.3% ± 5.4% HR_{max}). As expected, all groups expended significantly more calories during the vigorous condition (207.2 ± 79.5 kcal) than the moderate condition (152.6 ± 57.0 kcal), over the 25 min of

TABLE 1. Subject characteristics according to BMI class and weight loss status.

	NW–noWL	NW-WL	OW–noWL	OW-WL
N	18	12	13	15
Age (yr)	21.6 ± 2.5	27.6 ± 11.8	27.3 ± 13.9	35.3 ± 15.7*
Sex (% male)	38.9	33.3	38.5	26.7
Ethnicity (% white)	50.0	66.7	38.5	73.3
BMI ($kg \cdot m^{-2}$)	21.4 ± 2.3	23.1 ± 1.6	27.8 ± 2.8*,**	28.4 ± 2.6*,**
$\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	49.8 ± 10.2	42.0 ± 11.5	33.7 ± 10.7*,**	35.3 ± 11.8*

Data presented are means ± SD unless otherwise indicated.
*Significantly different compared with the NW–noWL group ($P < 0.017$).
**Significantly different from the NW-WL group ($P < 0.017$).
NW indicates normal weight; WL, attempted weight loss; BMI, body mass index; $\dot{V}O_2$, volume of oxygen.

exercise ($P < 0.001$). There were also no differences in hunger pre-exercise to postexercise within or between any of the groups (data not shown).

There were no within-group differences in the moderate exercise intensity condition between estimated and measured energy expenditure or calories in food (Fig. 1A) ($P > 0.05$). In the vigorous exercise intensity condition, OW–noWL overestimated energy expenditure by 72% and overestimated the calories in their food by 37% relative to the measured energy expenditure (Fig. 1B) ($P < 0.05$). In both exercise conditions, all groups, except for OW–WL, consumed nearly double the calories in the ad libitum meal compared with the calories they expended during exercise (Fig. 1A + B) ($P < 0.05$). Only 14% (moderate exercise) and 24% (vigorous exercise) of participants were able to estimate calories in food with less than 15% error.

Differences in the mean error are presented in Table 2. After moderate-intensity exercise, there were no differences between groups in the mean error of calorie estimation of exercise or food ($P > 0.05$). Although the mean error in selecting food calories to match moderate intensity energy expenditure did not differ between groups ($P > 0.05$), the number of calories in the food ranged from 88% under to 273% over what was actually expended (Table 2). After vigorous-intensity exercise, OW–noWL overestimated energy expenditure to a greater degree compared with all other groups ($P < 0.05$) (Table 2) and also significantly overestimated calories in food compared with both WL groups ($P < 0.05$) (Table 2). Although the mean error in selecting food calories to match vigorous-intensity energy expenditure did not differ between groups ($P > 0.05$), the number of calories in food ranged from 106% under to 339% over what was expended (Table 2). As well, the absolute error in calorie estimation was significant for all groups for all comparisons ($P < 0.05$), with OW–noWL having a higher absolute error in estimating energy expenditure compared with the NW groups ($P < 0.05$).

DISCUSSION

The present study is the first to show that adults who are overweight and not attempting weight loss may be more prone to errors in estimating energy expenditure and energy in food following vigorous exercise, but not moderate exercise. Although on average participants were able to match energy intake from food to energy expended during exercise, there was a considerable range of over and underestimation within all groups, as reflected by the large absolute error in calorie estimation of exercise and food. Overall,

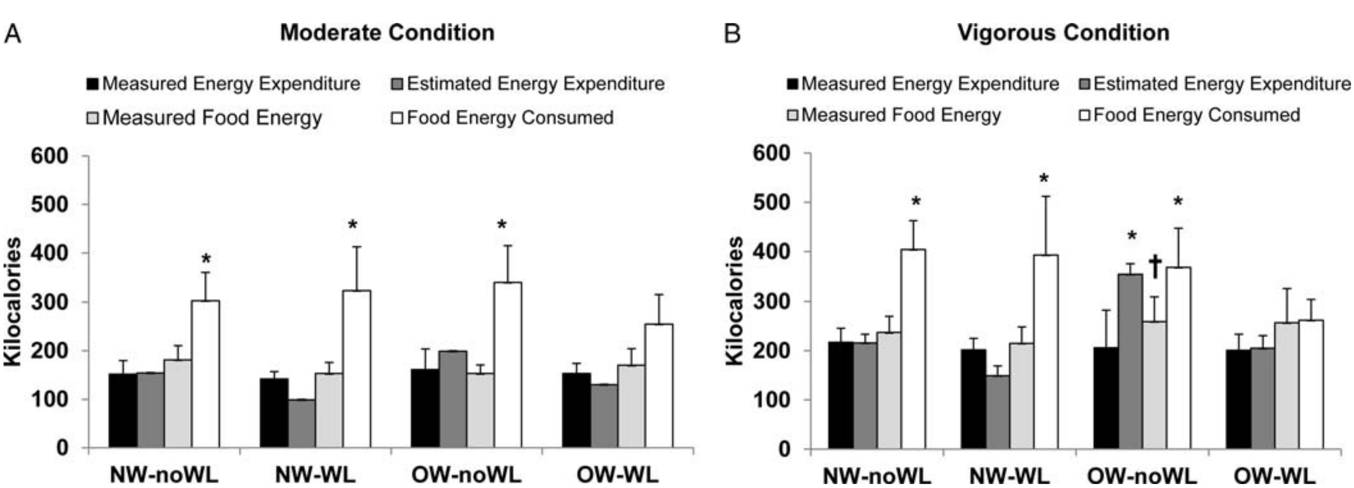

FIGURE 1—Measured exercise energy expenditure (black bars), estimated exercise energy expenditure (dark gray bars), measured food energy (light gray bars), and ad libitum energy intake (white bars) after moderate-intensity exercise (A) and vigorous-intensity exercise (B), according to BMI and weight loss status. Data presented are mean ± standard error. NW indicates normal weight; OW, overweight/obese; WL, weight loss; *Significantly different from measured energy expenditure within a group ($P < 0.05$). †Significantly different from estimated energy expenditure within a group ($P < 0.05$).

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TABLE 2. Mean error in estimating exercise energy expenditure and calories in food by BMI and weight loss status.

	NW–noWL		NW-WL		OW–noWL		OW-WL	
	Moderate Exercise Condition							
Kilocalories	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
EEE - MEE	2 ± 125	−97 to 444	−43 ± 48	−123 to 50	37 ± 149	−109 to 321	−24 ± 104	−177 to 198
EFE – MFE	−28 ± 91	−195 to 188	−54 ± 89	−280 to 32	40 ± 145	−135 to 404	−40 ± 111	−218 to 123
MFE – MEE	29 ± 123	−135 to 319	11 ± 90	−105 to 213	−3 ± 66	−83 to 142	17 ± 146	−133 to 417
MEI - MEE	157 ± 179	−85 to 478	187 ± 242	−52 to 678	171 ± 215	−69 to 554	109 ± 230	−133 to 467
	Vigorous Exercise Condition							
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
EEE - MEE	−2 ± 117	−167 to 361	−53 ± 72	−187 to 102	150 ± 271*	−87 to 754	4 ± 145	−279 to 274
EFE – MFE	−21 ± 139	−306 to 243	−66 ± 97	−302 to 50	96 ± 194*	−215 to 468	−51 ± 224	−760 to 176
MFE – MEE	20 ± 147	−220 to 416	13 ± 116	−104 to 284	54 ± 174	−112 to 543	55 ± 206	−172 to 702
MEI - MEE	180 ± 169	−45 to 431	203 ± 290	−87 to 787	147 ± 210	−70 to 531	59 ± 147	−69 to 410

*Significantly different from all other groups ($P < 0.05$).
BMI indicates body mass index; NW, normal weight; OW, overweight/obese; WL, weight loss; EEE, estimated energy expenditure; MEE, measured energy expenditure; EFE, estimated food energy; MFE, measured food energy; MEI, measured energy intake.

these findings demonstrate an overall poor ability to estimate energy expended through exercise and calories in food, which may have important implications for weight management.

Given the popular theory that excess energy intake is the primary driver of the obesity epidemic (16), it is important to investigate if individuals have an understanding of the caloric content of food. In the present study, we extend the work of Carels et al. (2006) and illustrate that high BMI is only associated with greater error in calorie estimation in those not attempting to lose weight. We demonstrate that only OW–noWL overestimated food calories (~68%), whereas all other groups underestimated food calories (~25%) after vigorous exercise. In contrast to previous research that has observed that adults generally underestimate calories in food (2,9,24), we demonstrate that the mean error between estimated and actual calories in food was less than 55 kcal in all groups but that there is a large interindividual range in the errors ranging from 760 kcal underestimation to 468 kcal overestimation of food calories. Indeed, less than a quarter of participants were able to estimate calories in food with an error of less than 15%. This suggests that a large proportion of individuals have a poor understanding of calories, and this may lead to problems with weight management.

Studies that have investigated whether BMI or dieting status influences accuracy of exercise energy expenditure estimation have shown mixed results. For example, among NW adults, there have been reports of both overestimation (23) and underestimation (12) of moderate energy expenditure. As well, Visona and George (2002) reported that OW adults who were dieting underestimated moderate energy expenditure, whereas nondieters overestimated moderate energy expenditure (20). Conversely, our results demonstrate that, on average, both NW and OW adults accurately estimated moderate-intensity expenditure, regardless of whether they were attempting weight loss. However, because of the wide range of underestimation and overestimation, all groups had a significantly large absolute error in estimation of moderate energy expenditure that ranged between 57 and 104 kcal. On the other hand, the only other study to investigate how exercise intensity influences calorie estimation reported that NW adults underestimate moderate-intensity expenditure but accurately estimate high-intensity expenditure (12). This is in contrast to the present study, in which the mean difference between estimated and measured energy expenditure was not different for NW adults for either moderate or vigorous exercise. However, OW–noWL overestimated vigorous energy expenditure and to a significantly greater degree compared with all other groups. Yet, OW–noWL also overestimated the energy content of their meals and, despite their larger errors, were able to match energy in food with energy expended through exercise. Thus, the complex association between calorie estimation and weight management may require further investigation.

It is recommended that to maintain a healthy body weight, individuals must be able to correctly match energy intake with energy expenditure (11). In one study by Willbond et al. (2010), it was reported that NW adults chose postexercise meals that contained two to three times the number of calories than what was expended during moderate intensity exercise (23). Conversely, Holliday and Blannin (2014) demonstrated that NW participants were able to accurately match calories in a postexercise meal to the energy expended during moderate- and high-intensity exercise (12). The present study extends these previous findings by including both NW and OW adults who were and were not attempting weight loss. Regardless of BMI or weight loss status, these findings are in accordance with those of Holliday and Blannin (2014) in that, on average, participants were able to match calories in a postexercise meal to the energy expended during moderate and vigorous-intensity exercise. However, again, there was a large variability in the individual accuracy, as some individuals constructed meals that contained 220 kcal less to 543 kcal more than the number of calories they expended during exercise. Given that the higher rates of overweight and obesity today compared with 30 yr ago is estimated to be due to an energy surplus of 370 $kcal \cdot d^{-1}$ (13), the observed error in calorie estimation in the present study may help explain why many adults struggle with weight management.

Although participants accurately matched calories in food to calories expended during exercise, most individuals consumed significantly more calories in a postexercise ad libitum meal compared with the energy they expended. This finding is consistent with other studies (9,12), although there were fewer food options in the present study compared with the large buffet type meals that others have provided. Interestingly, OW-WL was the only group that did not consume more calories than they expended. This may have been due to the fact that this group was trying to lose weight and therefore may have a better understanding of calories and were consciously restricting their caloric intake. In contrast, NW-WL consumed nearly double what they expended, with some of these individuals consuming up to five times the number of calories that they burned during exercise. However, because diet was not tracked over time, we cannot infer that the amount of food that was eaten represents a typical meal or daily intake for these individuals.

Although it has been reported that knowledge of calories is important for weight management, it is possible that even if individuals do have an understanding of calories, this may not influence their food choices. For example, recent legislation in the United States requiring restaurants to post calorie information for regular food and drink items (15) has not resulted in consumers purchasing lower calorie meals (7,19), even when they notice the available calorie information (18). Further research is needed to investigate the association between calorie estimation and weight management.

Strengths and limitations of this study warrant mention. Unlike other studies that used predictive equations to determine exercise energy expenditure (9,20), the current study used indirect calorimetry, which accounts for individual variability in economy (8). This is also the first study to examine the joint effects of BMI class, weight loss status, and exercise intensity on calorie estimation. Although the groups were not balanced, the repeated measures ANOVA were conducted with the PROC MIXED procedure, which has the capacity to handle unbalanced data. Furthermore, the current sample is significantly larger than past studies (12,23). Although there were several nonsignificant differences between groups, these differences are likely not clinically relevant (i.e., measured food energy – measured energy expenditure: 7 to 25 kcal), given the proposed caloric surplus hypothesized to be responsible for the rise in obesity prevalence (13). A retrospective sample size analysis determined that this study would have needed a minimum of 252 participants per group to see statistically significant group differences. Although information for $\%HR_{peak}$ was available, we chose to calculate exercise intensity based on predicted $\%HR_{max}$, as the majority of individuals would not have access to incremental exercise testing and would have to rely on age-predicted formulas to calculate exercise intensity. However, the $\%HR_{max}$ was 4.9% higher than the $\%HR_{peak}$, and thus, the magnitude of difference has minimal clinical relevance. The present study was also unable to statistically compare participants who were overweight versus those with obesity because of a small sample of participants with obesity. As well, although there was a range of common foods, it is possible that the food provided was not representative of what all of the participants typically eat. Although there were group differences in age, ethnicity, and cardiorespiratory fitness, there is currently no evidence from the present study or from the literature to suggest that either of these variables would influence ability to estimate calories. Finally, because participants engaged in aerobic exercise only, these results may not be generalizable to other forms of exercise.

CONCLUSIONS

In conclusion, BMI, weight loss status, and exercise intensity may all be important factors to consider when investigating calorie estimation. There was a large degree of variability in error of calorie estimation for both exercise and food, indicating that many individuals have a poor understanding of calories. Nevertheless, the large observed errors in calorie estimation even in individuals who are attempting to lose weight is concerning and may be a potential contributor to the generally poor weight loss success observed when attempted through diet and exercise.

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The authors' contributions are as follows: R. E. B. and J. L. K. conceived and designed the study. R. E. B., K. L. C., M. F., and D. J. collected all of the study data. R. E. B conducted the statistical analyses and drafted the manuscript. M. C. R., A. K. M., and J. L. K. provided guidance and critical revisions to the manuscript. All authors read and approved the final version of the manuscript.

The authors have no conflicts of interest to declare.

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