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Matching energy intake to expenditure of isocaloric exercise at high- and moderate-intensities

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HIGHLIGHTS

- Participants acutely matched energy intake with the energy expenditure of exercise.
- Energy cost of exercise was undervalued, especially moderate-intensity exercise.
- There was a small undervaluation of the energy content of food (20–25%).
- The high-intensity exercise bout was perceived as more energetic.

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ABSTRACT

Background: Those seeking to manage their bodyweight use a variety of strategies, but the most common approaches involve attempting to exercise more and/or consume fewer calories. A poor comprehension of the energy cost of exercise and the energy content of food may contribute to weight-gain and the poor success rate of exercise weight-loss interventions.
Purpose: The purpose of this study is to investigate individuals' ability to consciously match energy intake with energy expenditure after isocaloric exercise at moderate and high intensities.
Method: In a counterbalanced cross-over study design, 14 low- to moderately-active, lean individuals (7 male, 7 female; mean age 23 ± 3 years; mean BMI 22.0 ± 3.2 $kg \cdot m^{-2}$) completed both a moderate-intensity (60% VO_{2max}, MOD) and a high-intensity (90% VO_{2max}, HIGH) exercise bout on a treadmill, matched for energy expenditure, EE (450 kcal). Participants were blinded to the intensity and duration of each bout. Thirty minutes post-exercise, participants were presented with a buffet, where they were asked to consume food in an attempt to match energy intake with the energy expended during the exercise bout. This was termed the "matching task," providing a matching task energy intake value (EI_{MATCH}). Upon finishing the matching task, a verbal estimate of energy expenditure (EST) was obtained before the participant was allowed to return to the buffet to consume any more food, if desired. This intake was covertly measured and added to EI_{MATCH} to obtain an *ad libitum* intake value ($EI_{AD\ LIB}$).
Results: A significant condition × task interaction showed that, in MOD, EST was significantly lower than EE (298 ± 156 kcal vs. 443 ± 22 kcal, $p = 0.01$). In the HIGH condition, EE, EI_{MATCH} and EST were similar. In both conditions, participants tended to over-eat to a similar degree, relative to EST, with EI_{MATCH} 20% and 22% greater than EST in MOD and HIGH respectively. Between-condition comparisons demonstrated that EI_{MATCH} and EST were significantly lower in MOD, compared with HIGH (374 ± 220 kcal vs. 530 ± 248 kcal, $p = 0.002$ and 298 ± 156 kcal vs. 431 ± 129 kcal, $p = 0.002$ respectively). For both conditions, $EI_{AD\ LIB}$ was approximately 2-fold greater than EE.
Discussion: Participants exhibited a strong ability to estimate exercise energy expenditure after high-intensity exercise. Participants appeared to perceive moderate-intensity exercise to be less energetic than an isocaloric bout of high-intensity exercise. This may have implications for exercise recommendations for weight-loss strategies, especially when casual approaches to exercise and attempting to eat less are being implemented.

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1. Introduction

With obesity statistics now demonstrating that 63% of adults and 30% of children in England are overweight or obese [1], many individuals are seeking effective weight-management strategies. Those seeking to manage their bodyweight, whether it be attempting to lose weight or avoid weight-gain, use a variety of strategies to do so. The most common strategies involve attempting to exercise more and/or consume fewer calories [2]. For effectively implementing rather crude weight-loss strategies, such as undertaking more regular exercise, eating less food and eating less fat, a sound appreciation of energy expenditure and energy intake is desirable. It has been extensively demonstrated that individuals are prone to underreporting energy intake when using techniques such as food diaries [3–6], with obese individuals likely to underreport to a greater extent [7–9]. A contributing factor to this underreporting may be individuals' poor understanding of the energy content of food [10–13] which, incidentally, has been suggested to be particularly awry in relation to the energy cost of exercise [14,15]. Further, this may partly explain why exercise alone can prove to be an unsuccessful weight-loss strategy [14,16], with large individual variability in response to increased exercise energy expenditure, when individuals eat *ad libitum* [17].

To the best knowledge of the authors, only two studies have acutely and directly assessed individuals' ability to estimate acute energy expenditure and intake. Harris and George [18] asked participants to estimate their energy expenditure after a 60 minute bout of treadmill exercise, at 65% of predicted maximum heart rate. Fifteen minutes post-exercise, an *ad libitum* buffet meal was provided. The participants were then asked to estimate their energy intake at an *ad libitum* meal. Estimated energy expenditure was significantly greater than the actual energy expenditure of the exercise bout. Conversely, estimated energy intake was significantly lower than actual intake, with participants eating almost twice as many calories as estimated. Willbond et al. [19] conducted a similar study, but after exercise (a 200 kcal and a 300 kcal bout of treadmill running at 50% VO_{2peak}), participants were asked to estimate the energy expenditure of the exercise bout and then consume the caloric equivalent from a buffet meal. The energy expenditure of exercise was significantly and substantially overestimated, with estimates 3–4-fold greater than actual expenditure. Intake significantly exceeded expenditure, by 2–3-fold. However, it may be argued that with such low total energy cost of exercise, overcompensation is likely. In addition, it is likely that the perception of energy cost of exercise is dependent on the intensity, as well as the duration of exercise.

Therefore, the aim of this study was to assess individuals' ability to match energy intake with energy expenditure after isoenergetic bouts of moderate-intensity and high-intensity treadmill exercise. In light of the recent proposed health benefits of low volume, high-intensity interval training [20–22], it was deemed of interest to investigate how the intensity and duration of exercise may influence the perceived energy cost. It is hypothesised that participants will overestimate the expenditure of both exercise bouts, while underestimating the energy content of food, resulting in a greater intake than expenditure. It is also postulated that the overestimate of the energy cost of exercise will be greater after high-intensity exercise, with a greater perceived exertion leading to a higher perceived energy cost. A secondary aim was to assess *ad libitum* intake after high-intensity and moderate-intensity isoenergetic treadmill exercise.

2. Materials and methods

2.1. Participants

Fourteen healthy-weight, low- to moderately active individuals were recruited primarily from The School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham. The characteristics of the participants are shown in Table 1. The criterion for low to moderately active was a score of <3000 METS on the International Physical Activity Questionnaire (IPAQ). Those suffering from illness such as cold or flu, those taking medication that was likely to affect appetite or that needed to be taken with food more frequently than once a day, those with food allergies and those suffering from diabetes were excluded from taking part. Ethical approval was obtained from the Ethics Committee of the University of Birmingham.

Table 1
Participant characteristics. Values are mean ± SD.

Age (years)	23 ± 3
BMI ($kg \cdot m^{-2}$)	22.0 ± 3.2
VO_{2max} ($l \cdot min^{-1}$)	3.36 ± 0.67*
IPAQ score (METS)	2207 ± 697

* VO_{2max} value for nine participants, VO_{2peak} value for five participants.

2.2. Study design

A within-subject, randomised cross-over study design was utilised, with participants randomly allocated to each of two exercise intensity conditions, termed moderate intensity (MOD — 60% VO_{2max}) and high intensity (HIGH — 90% VO_{2max}).

2.3. Preliminary testing

A single session of pre-testing preceded the study protocol in order to calculate specific exercise intensities to be used for each participant. Participants reported to the Exercise Metabolism Laboratory, in the School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham after an overnight fast. The participant information pack was administered and explained and the participant was given the opportunity to ask any questions regarding the study, prior to providing written consent for their participation. A health questionnaire was completed as a means of a health screening procedure and The International Physical Activity Questionnaire (IPAQ) was completed as a measure of habitual physical activity. Height and weight were then recorded. An incremental exercise test to volitional exhaustion was then completed on a motorised treadmill (H/P/Cosmos. Nu dorf, Germany) in order to obtain VO_{2max}, and HR_{max} values and to establish the relationship between running speed and rate of oxygen uptake. To achieve this, the test comprised of two components: a constant gradient, steady-state component during which the relationship between running speed and rate of oxygen uptake was calculated; followed by a rapid speed and gradient increase component, from which maximum oxygen uptake (VO_{2max}) was calculated. The test began at a speed of 6 $km \cdot h^{-1}$ and a gradient of 1%. Each stage in the initial section of the test lasted 3 min. The speed was increased to 8 $km \cdot h^{-1}$ at stage 2 and 10 $km \cdot h^{-1}$ at stage 3. From there on, the speed increased by 1 $km \cdot h^{-1}$ at each stage with the gradient remaining constant at 1%. This protocol was followed until an RER of 1.00 was reached. At this point, component two of the test commenced. Stages were shortened to 1 min in duration and with each stage, speed or gradient increased in alternating fashion, by 1 km h^{-1} and 1% respectively. Participants were adjudged to have reached the end of the test when they voluntarily stopped running, if VO_2 ceased to increase with increasing workload or if it was felt that the participant was struggling to maintain the speed of the treadmill belt. Breath-by-breath measures of exhaled gas, averaged every eight breaths, were recorded using Oxycon Pro (Jaeger, Wuerzburg, Germany) apparatus. Prior to incremental exercise test, the gas analysers were calibrated using a calibration gas (BOC Gases, Guildford, Surry, UK) of mixed, known concentrations of O_2 (14.99%) and CO_2 (5.04%) and volume was calibrated using a 3 litre calibration syringe (Jaeger, Wuerzburg, Germany). Exhaled gas was collected throughout the entire test, but submaximal VO_2 values were obtained for each stage during