The BASES Expert Statement on the Effects of Aerobic Exercise on Appetite Control and Energy Intake

Produced on behalf of the British Association of Sport and Exercise Sciences by Dr David Broom, Dr Mark Hopkins, Dr David Stensel, Prof Neil King and Prof John Blundell.

Introduction

Aerobic exercise is a commonly prescribed method of weight management, with sustained increases in daily energy expenditure intended to promote energy deficit and weight loss. However, the regulation of energy balance is a dynamic process in which individual components of energy balance interact in a coordinated fashion. Consequently, adjustments in exercise-induced energy expenditure (ExEE) may elicit compensatory changes in other components of energy balance that attenuate the prescribed energy deficit and subsequent weight loss (see Table 1). Indeed, compensatory changes in hunger and energy intake (EI) are commonly cited as reasons why exercise often produces modest weight loss (1.5 to 3.0 kg over 3 to 12 months) that is less than expected theoretically (Thomas *et al.*, 2012). This has led to debate concerning the effectiveness of exercise in weight management. Notwithstanding the independent health benefits of exercise, a sound understanding of how exercise affects hunger and EI is therefore needed if effective weight loss strategies are to be designed. Consequently, the aim of this statement is to summarise the scientific literature examining the effect of aerobic exercise on appetite control and EI.

Table 1. Potential compensatory responses to increased exercise-induced weight loss. See King *et al.* (2007) or Hopkins *et al.* (2010) for a detailed discussion of these.

Physiological Compensatory Responses	Behavioural Compensatory Responses
↓ Resting metabolic rate	↓ Non-exercise physical activity
↓ Energy expenditure of non-exercise physical activity	↑ Hunger, ↓ Fullness
↓ Energy expenditure of exercise	↑ Energy intake
↓ Fat mass and ↑ Fat-free mass (or maintenance)	Changes in macronutrient content, inter-meal satiety control or food preference
Changes in appetite-related hormones	

The effect of acute exercise on appetite control and energy intake

Studies have consistently shown that a single bout of aerobic exercise does not lead to an automatic increase in hunger or EI to restore energy balance (see Donnelly *et al.*, 2014). Indeed, acute bouts of high-intensity exercise (~70% $\dot{V}O_{2max}$) may actually induce transient declines in subsequent hunger (Broom *et al.*, 2007), termed exercise-induced anorexia (King *et al.*, 1994). Consequently, acute exercise appears to be effective in eliciting an immediate energy deficit, as individuals fail to compensate for the increased ExEE through increased EI. However, these findings are at odds with the modest weight loss typically seen with medium- to long-term exercise interventions (3 to 12 months). It is important to recognise that mean changes for a group mask the individual variability in exercise-induced compensatory eating behaviour. While, on average, there is no change in post-exercise EI, post-exercise compensatory eating behaviour is highly heterogeneous; some individuals partially compensate for acute increases in ExEE via increased EI (approximately 50%- although research on this issue is sparse), while others show no evidence of compensation (Hopkins *et al.*, 2013). Although typically insufficient to fully off-set the additional ExEE, compensatory eating can therefore moderate the capacity of exercise to create an immediate energy deficit in some individuals (particularly in the presence of highly palatable, energy dense foods).

The effect of short-term exercise (2-14 days) on appetite control and energy intake

A single bout of exercise does not reflect the cumulative effects of regular exercise on energy balance. Consequently, inferences made about the relationship between exercise and appetite control based on acute exercise studies should be made cautiously. Unfortunately, there are few well controlled studies that measure appetite and EI accurately during regular exercise training. When EI has been measured objectively following 7-14 days of daily exercise (using laboratory-based test meals), there is evidence of partial compensation in EI that equates to approximately 30% of the additional ExEE (Whybrow *et al.*, 2008). While the degree of compensation is modest, such findings suggest that EI begins to track energy expenditure during sustained periods of energy deficit. This raises the possibility that if exercise is continued for longer, EI compensation may more closely match the elevated energy expenditure.

The effect of medium (2 to 12 weeks) and long-term (>12 weeks) exercise on appetite control and energy intake

When exercise has been performed over longer periods (>2 weeks), studies often report no change in hunger or EI (Donnelly *et al.*, 2014). However, exercise is typically unsupervised and the total ExEE is low (making it unlikely that the energy deficit is sufficient to elicit physiological and behavioural compensation). Furthermore, EI is commonly measured using self-report, but this approach lacks the sensitivity required to detect small (but meaningful) changes in EI. When EI has been measured objectively following medium-term exercise, evidence suggests that compensatory changes in EI may play an important role in mediating exercise-induced weight loss. For example, King *et al.* (2008) reported highly variable body weight responses (-14.7 kg to +1.7 kg) to 12 weeks of supervised aerobic exercise (2,500 kcal. wk^{-1}) in overweight and obese individuals. Based on the relationship between actual and predicted

Left: Feeding booth and visual analogue scale commonly used in food and appetite-related research
Courtesy of Sheffield Hallam University

weight loss, participants were retrospectively classified as responders or non-responders. Mean (standard deviation) weight loss in the non-responders was only 1.5 (2.5) kg, while the responders lost 6.3 (3.2) kg. Importantly, EI increased by 268 (455) kcal.day^{-1} in the non-responders, while daily hunger increased by approximately 7%. In contrast, EI decreased by 130 (485) kcal.day^{-1} in the responders and hunger remained constant. However, given the limited research in this area, these findings need to be replicated. Furthermore, the effect of sex and adiposity (i.e., lean *vs* obese) on compensatory eating behaviour needs to be further examined.

When EI has been assessed during long-term exercise training (12 weeks to 18 months), studies typically report no change in EI (see Donnelly *et al.,* 2014). However, again, EI is typically measured using self-report. The modest reductions in body weight seen with long-term exercise are suggestive of some form of compensation in response to prolonged energy deficit (via changes in EI or other pathways such as resting metabolic rate or non-exercise physical activity; see Table 1 or King *et al.,* 2007). However, at present there are few well-controlled studies to support or refute this.

Areas for future research

While marked individual variability exists in exercise-induced compensatory eating behaviour, this heterogeneity is rarely acknowledged. While beyond the scope of this statement, changes in appetite-related hormones (Stensel, 2010) and non-homeostatic factors such as food preference or reward (Hopkins *et al*., 2010) may play important roles in mediating exercise-induced weight loss. However, future research should attempt to better understand the physiological and behavioural mechanisms that underlie this variability in compensatory eating behaviour (and the intra-individual consistency of these compensatory responses). Given the adaptive nature of energy balance, it is unlikely that EI compensation acts in isolation to mediate exercise-induced weight loss. Therefore, the inter-relationships between physiological and behavioural components of energy balance should be examined in order to achieve a greater understanding of how exercise influences appetite control and body weight regulation.

Conclusions

- Acute exercise does not lead to an automatic increase in hunger or EI to restore energy balance in most individuals.
- There is evidence of partial compensation in EI after short (2-14 days) and medium-term (2 to 12 weeks) exercise, but exercise-induced compensatory eating behaviour is characterised by a high degree of individual variability.
- Future research should focus on characterising 'responders' and 'non-responders' after exercise-induced weight loss, and examine the physiological and behavioural mechanisms that mediate compensatory changes in EI after long-term exercise. ■

Dr David Broom

David is a Senior Lecturer at the Academy of Sport and Physical Activity, Sheffield Hallam University.

Dr Mark Hopkins

Mark is a Senior Lecturer at the Academy of Sport and Physical Activity, Sheffield Hallam University.

Dr David Stensel

David is a Reader in Exercise Metabolism at the School of Sport, Exercise and Health Sciences, Loughborough University.

Prof Neil King

Neil is Professor of Eating Behaviour and Obesity at the Institute of Health and Biomedical Innovation, Queensland University of Technology.

Prof John Blundell

John is a Professor of Psychobiology at the Institute of Psychological Sciences, University of Leeds.

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