早稲田大学審査学位論文

博士（スポーツ科学）概

要書

The impact of exercise intensity on appetite-related hormones and food reward in healthy young men

健常若年男性における運動強度が食欲関連 ホルモン及び食品報酬

に与える影響

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Chapter 1 Introduction

The regulation of appetite is controlled by a psychobiological process and this process involves episodic signals (Blundell *et al*. 1991; Blundell *et al*. 2015). The episodic signals can be excitatory (appetite-stimulating direction) or inhibitory (appetite-inhibiting direction) which coordinate the meal size and frequency. It has been reported that the suppression of appetite-stimulating peptide, acylated ghrelin is depends on the exercise intensity (Dorling *et al.* 2018; Anderson *et al.* 2021). However, the mechanistic aspects are unclear. Apart from homeostatic signals, appetite is also influenced by non-homeostatic signals. Recent research highlighted that exercise may indirectly bring a negative impact on energy intake via the non-homeostatic pathway which includes food reward (Beaulieu *et al*. 2018; Finlayson *et al.* 2009). However, the available findings regarding the impact of acute exercise on food reward are unclear. Therefore, this thesis focuses on using a laboratory-based study to investigate the potential mechanistic mediator involved the exercise intensity-induced acylated ghrelin suppression and the impact of exercise intensity on food reward.

Chapter 2 Review of literature

This chapter addresses the available literature that has examined ghrelin, food reward, and their responses to acute exercise. Although the mechanism by which high-intensity exercise suppresses acylated ghrelin, the only known orexigenic gut hormone, is still unclear, elevations in butyrylcholinesterase (BChE), a liver-derived enzyme that hydrolyses acylated ghrelin to des-acylated ghrelin, may be responsible (Darvesh *et al.* 1998). The previous studies regarding the mechanistic aspects have yielded inconsistent findings (Dorling *et al*. 2019; Li *et al.* 2022). On the other hand, food reward under the non-homeostatic signal is a hedonic conception of food and the sensory apperception of certain tastes of food that determine the food preference, leading to influence the size and the frequency of choice for certain foods (Dalton *et al.* 2013). However, the findings of the impact of acute exercise intensity on food reward were inconsistent.

Chapter 3 Study results

The purpose of Aspect 1 Result was to examine the acute effects of exercise intensity on BChE, acylated ghrelin and des-acylated ghrelin concentrations in young men. Fifteen young men (aged 22.7 ± 1.8 years, mean ± standard deviation) completed three, half-day laboratory-based trials (*i.e.,* high-intensity exercise, low-intensity exercise and control), in a random order. In the exercise trials, the participants ran for 60 min (from 09:30 to 10:30) at a speed eliciting 70 % (high-intensity) or 40 % (low-intensity) of their maximum oxygen uptake and then rested for 90 min. The present study used plasma samples to evaluate circulating concentrations of BChE, acylated ghrelin and des-acylated ghrelin. Regarding the Aspect 2 Result, The Japanese version of the Leeds Food Preference Questionnaire was used to measure the impact of exercise intensity on food reward by using the same dataset described in Aspect 1 Results. In Aspect 1 Result, BChE concentration was not altered over time among the three trials, while an acute bout of high-intensity exercise transiently suppressed acylated ghrelin and des-acylated ghrelin concentrations compared with other two trials. These findings may suggest that BChE is not the mediater of the high-intensity exercise induced-suppression of acylated ghrelin, and other factors might be involved. In Aspect 2 Result, high-intensity exercise increased the relative preference for sweet foods compared to low-inteisty exercise and rest, but did not influence the food reward for fatty foods bias. Additionally, implicit wanting for sweet foods was increased after the high-intensity exercise trial compared to the low-intensity exercise and control trials, but not explicit liking. These findings indicate that exercise intensity might alter the relative preference for the taste appeal bias (*i.e.*, sweet versus savoury foods) in healthy young men, suggesting taste preference shifts to more unconsciously to sweet-tasting foods after high-intensity exercise.

Chapter 4 General discussion

This chapter comprises two main results (Aspect 1 Result and Aspect 2 Result) from one randomised controlled study and the purpose is to advance the understanding of appetite-related hormones and food reward responses to different acute exercise intensities. This chapter addresses the following issues to interpret critically the findings derived from the study. Regarding the Aspect 1 Rusult, despite the transient suppression of both forms of ghrelin after a 60-minute high-intensity run, the circulating concentrations of BChE did not alter over time among the three trials. It indicates that the potential mechanisms underlying high-intensity exercise-induced suppression of acylated ghrelin, may not be explained by BChE. However, it should be interpreted with caution whether BChE is involved in modulating the exercise-induced acylated ghrelin suppression, as the energy expenditure created by exercise was different in the present study and the type of assays used for measuring BChE among the three studies are different (Li *et al.* 2022; Dorling *et al.* 2019). Thus, the impact of exercise intensity on the acylated ghrelin and BChE still requires further investigation. Also, the results of the present study suggested other factors might be involved in the exercise-induced suppression of acylated ghrelin such as the high-intensity exercise increased carbohydrate oxidation in the present study. A recent review suggested that lactate inhibits ghrelin production from gastric cells (McCarthy *et al.* 2020) and high-intensity exercise often increases the production of carbohydrate oxidation and lactic acid (Hargreaves *et al.* 1988; Iaia *et al.* 2011; Brouwer 1957). Regarding the Aspect 2 Result, an increase in the preference for sweet taste after high-intensity exercise was observed in the present study. The elevated carbohydrate oxidation by high-intensity exercise once again may contribute to the interpretation, as it could lead to perceiving more sweet-tasting foods (Westerterp-Plantenga *et al.* 1997). However, the findings derevied from the Aspect 2 Rusult should be interpreted with caution as total energy expenditure between high- and low-intensity exercise was not standardised which might be the confounding factor. Finally, this chapter addresses how exercise intensity influences both homeostatic appetite control and non-homeostatic appetite control aspects. This chapter also addresses the limitation of present study and ends with some suggestions for future research.