Comparison of the effects of acute exercise after overnight fasting and breakfast on energy substrate and hormone levels in obese men

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Abstract. [Purpose] We compared the effects of acute aerobic exercise following overnight fasting and breakfast on energy substrate and hormone levels in obese male college students. [Subjects and Methods] This crossover study recruited 10 obese male college students with a body mass index >25 kg/m² or >20% body fat. One week post-recruitment, the subjects exercised in the morning after an overnight fast. At 2 weeks, they exercised post-breakfast. Energy substrate (glucose, free fatty acid) and metabolic hormone (insulin, growth hormone, and cortisol) levels were measured immediately before and after exercise and at 60 min post-exercise. [Results] We observed interaction effects between the measurement time and exercise treatment for glucose; significant differences between measurement times and between exercise treatments for free fatty acids; interaction effects between the measurement time and exercise treatment for insulin and significant differences in the measurement time; significance differences between measurement times and between exercise treatments for growth hormone; and significant differences between measurement times and between exercise treatments for cortisol. [Conclusion] Morning exercise following an overnight fast can be more effective in reducing body fat than post-prandial exercise. However, increased cortisol levels following exercise after overnight fasting may negatively affect long-term weight loss in obese men. Key words: Exercise, Energy substrates, Metabolic hormone

INTRODUCTION

In many countries, increased consumption of a westernized diet and lack of physical activity have caused an energy intake imbalance and resulted in an increased prevalence of obesity and chronic diseases, including hypertension, cardiovascular disorders, diabetes, and arthritis. However, regular exercise and physical activity are reported to be effective methods for preventing obesity, its accompanying chronic lifestyle diseases, and premature death. When performed on a regular, long-term basis, aerobic exercise can prevent or cure obesity, increase muscle volume, elevate oxygen levels and oxidizing enzymes in myocytes, and increase blood volume and fat oxidation. In particular, aerobic exercise can improve the various metabolic risk factors involving blood pressure, fatty acids, and the cardiovascular system in obese and type 2 diabetic patients. One study suggested that exercise in the morning on an empty stomach promotes the utilization of lipids in adipose tissue because the exercise is performed under low blood sugar conditions. Because this exercise regime promotes increased utilization of lipids, it is thought to be more efficient for weight regulation. However, findings from other studies have suggested that performing aerobic exercise in the morning before eating can induce neurotic symptoms and fatigue because low blood sugar levels result in stimulation of the hypothalamic-pituitary-adrenal (HPA) axis. This stimulation can increase the secretion of the steroid hormone cortisol. Elevated cortisol level can decrease protein synthesis in the muscle, thereby affecting carbohydrate, fat, and protein metabolism, and can also promote gluconeogenesis in the liver. However, increased cortisol levels have also been observed to result from moderate- to high-intensity aerobic exercise, which complicates the interpretation of these previous studies. The ability of exercise to prevent obesity and reduce body weight depends on the retention of internal nutrition before exercise and the secretion of hormones that affect carbohydrate, fat, and protein metabolism. Many studies have evaluated energy substrate changes and hormone levels (e.g., cortisol, growth hormone, and insulin) in relation to different exercise parameters (e.g., intensity), but none have investigated the effects of exercise performed in the morning (when cortisol secretion is at its maximum) following an overnight fast or breakfast. Therefore, the present study aimed to compare the
Effects of exercise after overnight fasting and after breakfast on energy substrate changes and hormone levels in male university students with obesity.

SUBJECTS AND METHODS

The target group of the current investigation included 10 male students with obesity, a body mass index of >25 kg/m², and body fat of >20%. Subjects were included if they were physically healthy and had no specific diseases based on a questionnaire survey and medical examination and had not taken any specific drugs for at least 6 months prior to the experiment. Informed consent was obtained from the subjects prior to their participation in the study. Kyungwoon University approved this study, which complies with the ethical standards of the Declaration of Helsinki. The physical characteristics of the subjects are shown in Table 1.

The experiment had a crossover design (Fig. 1) and was conducted over a period of 4 weeks. The subjects performed the first experiment (exercising after an overnight fast) after 1 week of testing and then performed the second experiment (exercising 2 h after breakfast) subsequent to a 2-week washout period from the first experiment. For both experiments, the subjects maintained an empty stomach after 10 P.M. on the day before exercising and then performed the exercise at 9 A.M. on the next day. For the second experiment, the subjects consumed a specified ratio of calories and nutrients immediately before and after exercise and at 60 min following exercise for both exercise regimes. The collected venous blood was maintained for 10 min at room temperature and then centrifuged at 3,000 rpm for 10 min. The upper phase was transferred to a microtube and stored at −80 °C until the analysis. Glucose level was measured immediately after blood collection using One-Touch (LifeScan Company, Mountain View, CA, USA), and serum insulin level was analyzed using a commercial insulin reagent kit (Human insulin ELISA-kit, DSL, TX, USA). Serum free fatty acid (FFA), cortisol, and growth hormone levels were assessed by Green Cross Inc., Youngin, Korea. The parameters measured immediately before and after exercise and at 60 min after exercise between the 2 exercise regimes were compared and analyzed by two-way analysis of variance with repeated measurements. A significance level of p = 0.05 was used for the analyses. The statistics were performed with SPSS-PC version 20 (SPSS Inc., Chicago, IL, USA). The results are shown as the average ± standard deviation.

RESULTS

For minimizing the differences in the amount of exercise performed between the 2 experiments, energy consumption was set at 400 kcal. As a result, energy consumption did not differ between the exercise performed after an overnight fast and that performed after breakfast (426.05 ± 20.54 vs. 425.49 ± 19.00, t-value = 0.403, p = 0.692). Table 2 shows the energy substrate (glucose and FFA) and hormone levels (insulin, GH, and cortisol) immediately before and after exercise and at 60 min after exercise for both exercise treatments. Glucose showed significant interaction effects between the measurement time and the exercise treatment (p < 0.007), but no significant differences were observed between measurement times or between exercise treatments. A possible explanation for this interaction effect is that the glucose levels had not been restored to their post-breakfast exercise levels. Meanwhile, FFA showed no significant interaction between the measurement time and treatment. However, significant differences were observed between measurement times (p < 0.001) and between exercise treatments (p < 0.002). These results suggest that exercising in the morning before breakfast is more efficient than post-prandial exercise in terms of utilizing lipids as an energy source. Insulin

Table 1. Physical characteristics of the 10 study participants

| Parameter          | Mean ± standard deviation |
|--------------------|----------------------------|
| Age                | 20.2±1.9                  |
| Height (cm)        | 177.2±6.1                 |
| Weight (kg)        | 84.3±14.6                 |
| BMI (kg/m²)        | 26.7±4.1                  |
| Body fat (%)       | 23.8±4.9                  |
| VO₂max (ml/kg/min) | 45.2±8.5                  |

BMI: body mass index; VO₂max: maximal oxygen consumption.

Fig. 1. Schema of the study design and blood collection times.
observed after an overnight fast. According to these results, as compared to the levels after breakfast before exercise, higher at all evaluated time points after overnight fasting. Further, in the present study, growth hormone levels were significantly higher after fasting and morning exercise. In these previous studies, morning exercise was considered to be efficient for decreasing weight and body fat in those with obesity, particularly when performed on an empty stomach. However, in the current study, high cortisol concentrations were also observed at all the accessed time points for both treatment groups. During exercise, cortisol is secreted by the adrenal cortex in response to stress. Cortisol decreases protein synthesis in the muscles; increases catabolism, affecting the metabolism of carbohydrates, fats, and proteins; and stimulates gluconeogenesis in the liver. In the current study, the cortisol concentration was higher after overnight fasting than it was after dietary intake. These results indicate that glucose and insulin levels were high before exercise following dietary intake because the cortisol levels were too low for the hormone to play a strong antagonistic role. Moreover, these results suggest that a greater amount of muscle wasting for use as an energy source during exercise after a morning fast, as compared to exercise after breakfast, presumably resulted in a decreased improvement in the fat-free mass. However, because the current study only examined the effects of acute exercise, a long-term study will be needed for further validation. In addition, persistently high cortisol levels resulting from regular exercise after overnight fasting can negatively affect physical health. In particular, previous studies have indicated that these persistently high cortisol levels can promote fat accumulation in the abdomen, decrease insulin sensitivity, increase the risk of osteoporosis and hypertension, and decrease immune function and muscle mass, thereby negatively affecting the patient’s overall physical health. In the present study, we were unable to draw clear conclusions on the effect of performing exercise after overnight fasting on physical health. However, the fundamental results reported here provide the basis for a long-term study to more clearly address this issue.

**DISCUSSION**

In the current study, glucose and insulin showed a significant interaction effect between the measured time and treatment. One likely explanation is that their levels were high due to the dietary intake 2 hours prior to the exercise. In addition, there were significant differences in insulin level between the measurement time points, independent of treatment, indicating that the insulin levels decreased immediately after exercise due to the increased energy demand and then stabilized 60 min after the exercise. Increased physical exercise improves glucose homeostasis and increases sensitivity to insulin, and acute exercise can increase the sensitivity of tissues or organs such as the skeletal muscles, fat, liver, and hypothalamus to insulin. Further, acute exercise has been shown to result in improved glucose homeostasis in an animal model of obesity and activates fat disassembly in the adipocytes. In addition, cortisol levels are higher in the morning than at all the accessed time points for both treatment groups. During exercise, cortisol is secreted by the adrenal cortex in response to stress. Cortisol decreases protein synthesis in the muscles; increases catabolism, affecting the metabolism of carbohydrates, fats, and proteins; and stimulates gluconeogenesis in the liver. In the current study, the cortisol concentration was higher after overnight fasting than it was after dietary intake. These results indicate that glucose and insulin levels were high before exercise following dietary intake because the cortisol levels were too low for the hormone to play a strong antagonistic role. Moreover, these results suggest that a greater amount of muscle wasting for use as an energy source during exercise after a morning fast, as compared to exercise after breakfast, presumably resulted in a decreased improvement in the fat-free mass. However, because the current study only examined the effects of acute exercise, a long-term study will be needed for further validation. In addition, persistently high cortisol levels resulting from regular exercise after overnight fasting can negatively affect physical health. In particular, previous studies have indicated that these persistently high cortisol levels can promote fat accumulation in the abdomen, decrease insulin sensitivity, increase the risk of osteoporosis and hypertension, and decrease immune function and muscle mass, thereby negatively affecting the patient’s overall physical health. In the present study, we were unable to draw clear conclusions on the effect of performing exercise after overnight fasting on physical health. However, the fundamental results reported here provide the basis for a long-term study to more clearly address this issue.

**Table 2. Comparison of energy substrate and hormone changes according to exercise treatment**

| Variable       | Fasting exercise | Post-prandial exercise |
|----------------|------------------|------------------------|
| Glucose (mg/dl)| BE 98.7±9.7     | AE 102.8±8.8          |
|                | 60 min AE 105.4±9.4 | 100.1±10.3            |
| Cortisol (μg/dl)| 28.5±7.64      | 24.93±9.16            |
|                | 60 min AE 20.92±9.25 | 15.49±5.73        |

Values are shown as means ± standard deviation. *p < 0.05. significant main effect for time. †p < 0.05. significant main effect for group. ‡p < 0.05. significant interaction between time and group. BE; before exercise, AE; after exercise, 60 min AE; 60 min after exercise.
Recently, a number of studies have been carried out in the attempt to develop exercise methodologies for maintaining and improving physical health to reduce the prevalence of obesity. The effect of exercise timing and pre-exercise nutritional state has emerged as an important consideration. In the current study, it should be emphasized that energy substrate and metabolic hormone levels differed between the treatment groups. Compared to the post-prandial exercise, the exercise performed after overnight fasting showed low glucose and insulin levels but high cortisol, growth hormone, and FFA levels before exercise. Hence, the latter treatment could have a long-term positive effect on body fat reduction but negatively affect physical health because of the high concentration of cortisol.

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