The Acute Effects of Aerobic and Resistance Exercise on Plasma Acylated Ghrelin and Hunger in Overweight Men

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Abstract: This study investigated the acute effects of aerobic and resistance exercise on plasma acylated ghrelin and hunger in overweight men. Ten healthy overweight male students (age, 23.9±2.5 yrs; BMI, 27.6±2.2 kg/m²; VO₂ max, 29.0±6.3 ml.kg⁻¹.min⁻¹) undertook two trials, 1) aerobic exercise: 60 min running with 70% of VO₂ max in a 400 meter track, 2) resistance exercise: 3 circuits of 15-20 repetitions of 6 exercises, with a workload corresponding to 70% of 1RM, in a randomized crossover design. Hunger ratings and plasma concentrations of acylated ghrelin measured before and immediately after exercise. In order to analyze of data, the dependent and independent t-tests were used respectively to examine within groups and between groups differences and relation between the variables was assessed using Pearson’s method. The level of significance was set at p=0.05. Hunger (p=0.015, p=0.002) and plasma acylated ghrelin (p=0.001, p=0.001) suppressed after aerobic and resistance exercise without significant correlation and observed no significant differences in the magnitude of changes in hunger scores and plasma acylated ghrelin after two trials. In conclusion, acute aerobic and resistance exercise, similarly decreased hunger sensations which is not related to reduced acylated ghrelin responses immediately after exercise.

Key words: Aerobic exercise · Resistance exercise · Hunger · Acylated ghrelin

INTRODUCTION

The prevalence of overweight and obesity has increased worldwide to epidemic proportions [1-3]. Obesity is associated with several comorbidities such as diabetes and cardiovascular and neurodegenerative diseases as well as some types of cancer [2]. Genetic, environmental, socioeconomic, cultural and behavioral factors all may play a major role in the development of obesity [4, 5]. Among cultural and behavioral factors, eating has become an important aspect [4]. Body weight is regulated by a balance between food intake and energy expenditure [6]. Exercise is an effective method of increasing energy expenditure [7] and it may, paradoxically, lead to short-term hunger suppression [8-12]. The mechanisms by which exercise influences appetite have recently begun to receive significant interest with specific attention being given to peptides implicated in the neuroendocrine regulation of feeding [13,14]. Ghrelin is a 28 amino acid peptide hormone [15, 16] that has a potent effect on eating behavior, causing an increase in hunger [17] and plays a key role in the central regulation of feeding [18]. It has been suggested that stomach is a major source of circulating ghrelin in human [16]. Plasma ghrelin concentrations rise before meals and decrease following meals [15], suggesting that ghrelin is orexigenic (appetite stimulating) [9]. The effect of acute exercise bouts on total plasma ghrelin concentrations is controversial. Investigators shown increase [19-21], decrease [22-24] or no change [11,25,26] in plasma ghrelin concentrations either during or post-exercise. The majority of studies have focused on aerobic exercise [27], but few studies examining the effects of resistance exercise and these have reported contradictory effects [22,24,26]. Resistance exercise is a key component of exercise recommendations for weight control [7] and

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public health [28]; thus, it is important to clarify the effects of resistance exercise on appetite and gut hormones. A limitation of research concerning exercise and ghrelin is that all of the studies performed so far have measured total ghrelin [11,19-26]. Ghrelin exists in nonacylated and acylated forms with the majority (80-90%) being nonacylated [16, 28]. It seems that acylation of ghrelin is essential for appetite regulation because only the acylated form of the hormone can cross the blood-brain barrier [29]. Thus, measurements of total ghrelin may mask important changes in acylated ghrelin [10]. Concomitant suppressions in hunger have been reported by Broom and colleagues [9] raising the possibility that acylated ghrelin may be important in determining changes in appetite resulting from exercise. The data about the influence of exercise, particularly resistance exercise, on acylated ghrelin is still scarce and there are few studies in the literature regarding to comparison of the acute effects of aerobic and resistance exercise on hunger and plasma acylated ghrelin. Thus, we conducted a study to examine the effects of a single bout of aerobic and resistance exercise on hunger and plasma acylated ghrelin in overweight males.

**MATERIAL AND METHODS**

**Subjects:** Ten overweight (25<BMI<30) males college student volunteered to participate in this study. Subjects were nonsmokers, not taking any medication, weight-stable for 3 months prior to the study and had no food allergies according to their statement. Complete advice about possible risks and discomfort was given to the participants and all of them give their written informed consent to participate. Their characteristics are shown in Table 1.

**Procedures:** All procedures were in accordance with the Declaration of Helsinki and the study was approved by the research committee of Gilan-E-Gharb branch of Azad University. Before initiating the tests, the participants underwent an anamnesis, a clinical evaluation and weight, height, body mass index and body fat mass measurements. Then all of them underwent familiarization sessions and participated in VO_{max} and 1-repetition maximum (1RM) assessment test. Afterwards, participants carried out experimental sessions in counterbalance manner. Pre- and post-exercise hunger and plasma acylated ghrelin of participants were assessed and analyzed.

**Table 1:** Formal measurements of the participants

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.9 ± 2.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>86.7 ± 13.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.6 ± 7.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.6 ± 2.2</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>19.5 ± 3.6</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>69.5 ± 9.0</td>
</tr>
<tr>
<td>VO_{max} (ml.kg⁻¹.min⁻¹)</td>
<td>29.0 ± 6.3</td>
</tr>
</tbody>
</table>

In familiarization sessions, participants were familiarized with endurance running, standard techniques of weight lifting and how to complete the VAS (Visual Analogue Scale) questionnaire. All participants received same food regimen based on the university food program during study. Participants were also asked to refrain from vigorous exercise and ingesting caffeine or alcohol 24 h prior to the main trials. On trial days, participants arrived at the laboratory at 08:00 having fasted for 12 h. Main trials performed in the same time of day.

**Anthropometric Measurements:** Height and weight were measured and body mass index (BMI; kg/m²) was calculated from height and weight of each subject. Fat mass and lean body mass were assessed by bioelectrical impedance analysis using a Body Composition Analyzer (Biospace, Inbody 3.0, Jawn, Korea).

**Assessment of VO_{Max}:** Cooper VO_{max} test was used to estimate VO_{max} of participants. In this test participants run/walked in a 400 meter track for 12 minutes. The total distance traveled by the participants was recorded and VO_{max} was calculated using the following formula [30]:

\[
VO_{max} (\text{ml.kg}^{-1}.\text{min}^{-1}) = (d-505) / 45
\]

Where \(d\) is distance (in meter) covered in 12 minutes.

**Assessment of IRM:** A 1RM test was completed for each of the 6 resistance exercises employed in the study. The order in which each exercise was performed was bench press, leg press, lat pull-down, knee extension, biceps curl and knee flexion.

In this regard, a weight that can be lifted maximally to fatigue after 2-10 repetitions has been used to calculate 1RM, according to the formula proposed by Brzycki [31].
Exercise Protocol: One week after completing the preliminary exercise test, subjects undertook a counterbalanced randomized two-way crossover study with an interval of 7 days between trials. The two trials were aerobic and resistance exercise.

Resistance exercise protocol consisted of 3 circuits of 15-20 repetitions of 6 exercises (bench press, leg press, lat pull-down, knee extension, biceps curl and knee flexion); with a workload corresponding to 70% of 1RM. 90s rest interval was set between the circuits and 45s between exercises.

The aerobic exercise protocol consisted a 60 min running with 70-80% of HRmax in a 400 meter track. Exercise session began and ended with a 5-min warm up/cool down. Age-predicted maximal heart rate was calculated for each subject. Heart rate was monitored during exercise with a heart rate monitor (Polar Electro, Kempele, Finland)

Measurements of Variables: After 12h overnight fasting in pre- and post-exercise blood sampling for hormonal analyses were drawn from a forearm vein. Blood samples were immediately transferred to chilled polypropylene tubes containing EDTA-2Na (1 mg/ml) and aprotinin (Ohkura Pharmaceutical, Kyoto, Japan: 500 kallikrein activating unit/ml), were centrifuged at 4°C. Plasma levels of acylated ghrelin were measured with a commercially available ELISA kits, the Active Ghrelin ELISA, according to the manufacturer’s protocol. Hunger score were assessed using 100mm visual analogue scales [32].

Statistical Analysis: All data were expressed as mean ± SD and were aalyzed using SPSS software (v. 16.0). The dependent andindependent t-tests were used respectively to examine within groups and between groups differences of variables. The relation between variables was assessed using Pearson’s method. The level of significance was set at p<0.05.

RESULTS

Hunger Scores: Fasting hunger did not differ significantly between trials. Hunger scores were reduced by aerobic (p=0.015) and resistance exercise (p=0.002) and these reductions were significant in compared with the pre-exercise values. The data showed that there were no significant differences in the magnitude of changes in hunger scores after aerobic and resistance exercise (Table 2).

Table 2: Pre- and post-exercise values of plasma acylated ghrelin and hunger scores and their rate of change (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Acylated ghrelin (pmol/l)</th>
<th>Hunger scores</th>
<th>Rate of change (pmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RE</td>
<td>AE</td>
<td>RE</td>
</tr>
<tr>
<td>Pre-exercise</td>
<td>17.39 ± 1.38</td>
<td>16.48 ± 1.26</td>
<td>5.1 ± 0.99</td>
</tr>
<tr>
<td>Post-exercise</td>
<td>7.48 ± 1.54*</td>
<td>6.32 ± 1.29*</td>
<td>3.8 ± 0.78*</td>
</tr>
<tr>
<td>Delta</td>
<td>9.91 ± 0.78</td>
<td>10.16 ± 1.90</td>
<td>1.3 ± 0.95</td>
</tr>
</tbody>
</table>

RE= resistance exercise; AE= aerobic exercise; delta =post - pre.
*Significant difference in compare to pre values (p<0.05)

Plasma Acylatedghrelin: Fasting acylated ghrelin concentrations did not differ significantly between trials. Significant decreases were observed in plasma acylated ghrelin level after both aerobic (p=0.001) and resistance exercise (p=0.001). The data showed that there were no significant differences in the magnitude of changes in plasma acylated ghrelin level after aerobic and resistance exercise (Table 2).

Correlations Between Acylated Ghrelin and Hunger:
Baseline acylated ghrelin concentration wasn't significantly correlated with fasting hunger in aerobic (r = -0.044, p = 0.904) and resistance trials (r = 0.057, p = 0.875). Also there were no significant correlations between acylated ghrelin concentration and hunger immediately after aerobic (r = 0.486, p=0.172) and resistance exercise (r = 0.389, p = 0.266).

DISCUSSION

The present study investigated the acute effects of aerobic and resistance exercise on hunger and Plasma acylated ghrelin in overweight males.

The main findings arising from this investigation are 1) hunger and plasma acylated ghrelin suppressed after aerobic and resistance exercise without significant correlation and 2) there were no significant differences in the magnitude of changes in hunger scores and plasma acylated ghrelin after aerobic and resistance exercise.

Our finding about hunger suppression immediately after aerobic exercise is consistent with previous studies indicating that strenuous (around 60% of maximum oxygen uptake and above) aerobic exercise transiently suppresses appetite [8-12]. In previous studies, transient suppression of appetite lasts from several hours to two or more days.

The data about hunger response after an acute bout of resistance exercise is still scarce. To our knowledge, only Broom and colleagues [10] investigated hunger response after an acute bout of resistance exercise and
compared with post-aerobic responses of it. Similarly with
the present study, these authors reported significant
reduction in hunger immediately after resistance
exercise and spite of the lower energy expenditure during
resistance exercise, the intermittent nature of resistance
exercise and the lower gut disturbance compared with
running that can affect hunger [10], observed no
significant differences in hunger after aerobic and
resistance exercise.

At present, the mechanism for transient suppression
of appetite after aerobic exercise is unknown and the
effects of resistance exercise on appetite are uncertain
[10].

Regarding plasma acylated ghrelin, the results of our
study confirm previous findings that aerobic exercise
suppresses acylated ghrelin [9,10,12,33]. Nevertheless
there are conflicting results [34, 35]. To our knowledge,
Although there are few studies examining the effects of
resistance exercise on ghrelin and these have reported
contradictory results [22,24,26], Broom and colleagues
study [10] is the only study that has been done on plasma
acylated ghrelin after aerobic and resistance exercise.
Similarly with the present study, these authors verified
that a single bout of resistance exercise (3 sets of 12
repetitions of 10 exercises at 80% of 12 1-RM) produces a
significant decrease in plasma acylated ghrelin
immediately after the exercise and observed no significant
differences in post-aerobic and resistance responses of
acylated ghrelin.

It is inconclusive how ghrelin concentration alone
changes in response to an acute bout of exercise [36].
While some studies suggested that energy deficiency
induced by acute exercise increases acylated ghrelin [34],
others expressed that post-exercise ghrelin responses may
be independent of energy balance [37] and acute exercise
does not increase energy intake in the short term, i.e. 1 to
2 days after exercise [38, 39]. The results from studies on
acylated ghrelin are contradictory and further study is
certainly warranted in this area. The possible causes of the
conflicting results are further related to methodological
differences such as the selection of participants and the
intensity, duration, frequency and type of exercise [34].

Ghrelin appears in two major forms: acylated and
nonacylated ghrelin. Aciylated ghrelin is the active form
of ghrelin whereas nonacylated ghrelin, which is present
in greater quantities than acylated ghrelin, appears to be
biologically inactive [16, 28]. Only the acylated form of the
hormone can cross the blood-brain barrier, therefore it
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In conclusion, this study demonstrates that plasma
acylated ghrelin concentration and hunger are reduced
immediately after an acute bout of aerobic and resistance
exercise without significant correlation and these
results don’t support the role of acylated ghrelin in
appetite suppression immediately after exercise. A better
understanding of the role of exercise in appetite regulation
may lead to a more effective prescription of exercise for
weight control. Further research is required to determine the influence of other modes, durations and intensities of exercise on plasma acylated ghrelin concentration and to document plasma acylated ghrelin responses to exercise in different subject groups (e.g. older subjects, trained subjects, normal or obese subjects). Such research could have important implications regarding the role of exercise in weight management.

**ACKNOWLEDGMENTS**

This study is supported by the research committee of Gilan-E-Gharb Branch, Islamic Azad University.

**REFERENCES**


