Circulating Adiponectin Concentration and Body Composition Are Altered in Response to High-Intensity Interval Training

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ABSTRACT

Shing, CM, Webb, JJ, Driller, MW, Williams, AD, and Fell, JW. Circulating adiponectin concentration and body composition are altered in response to high-intensity interval training. J Strength Cond Res 27(8): 2213–2218, 2013—Adiponectin influences metabolic adaptations that would prove beneficial to endurance athletes, and yet to date there is little known about the response of adiponectin concentrations to exercise, and, in particular, the response of this hormone to training in an athlete population. This study aimed to determine the response of plasma adiponectin concentrations to acute exercise after 2 different training programs and to determine the influence of the training on body composition. Seven state-level representative rowers (age: 19 ± 1.2 years [mean ± SD], height: 1.77 ± 0.10 m, body mass: 74.0 ± 10.7 kg, VO2peak 62.1 ± 7.0 ml kg−1 · min−1) participated in the double-blind, randomized crossover investigation. Rowers performed an incremental graded exercise test before and after completing 4 weeks of high-intensity interval ergometer training and 4 weeks of traditional ergometer rowing training. Rowers’ body composition was assessed at baseline and after each training program. Significant increases in plasma adiponectin concentration occurred in response to maximal exercise after completion of the high-intensity interval training (p = 0.016) but not after traditional ergometer rowing training (p = 0.69). The high-intensity interval training also resulted in significant increases in mean 4-minute power output (p = 0.002) and VO2peak (p = 0.05), and a decrease in body fat percentage (p = 0.022). Mean 4-minute power output, VO2peak, and body fat percentage were not significantly different after 4 weeks of traditional ergometer rowing training (p > 0.05). Four weeks of high-intensity interval training is associated with an increase in adiponectin concentration in response to maximal exercise and a reduction in body fat percentage. The potential for changes in adiponectin concentration to reflect positive training adaptations and athlete performance level should be further explored.

KEY WORDS rowing, body fat, metabolism, endurance, hormone

INTRODUCTION

Human adipose tissue is recognized as having an endocrine function in combination with its role in energy metabolism and storage (6). Adiponectin is a protein secreted primarily by adipose tissue, and its targets include the liver and skeletal muscle where, among other functions, it regulates energy metabolism and insulin sensitivity (24,32). Adiponectin has been shown to activate adenosine monophosphate-activated protein kinase (AMPK) in skeletal muscle (8), and evidence suggests that enhanced activity of AMPK can stimulate increased number and oxidative capacity of mitochondria in the muscle (29). Upregulation of AMPK also promotes fatty acid oxidation through improved oxidative phosphorylation (2,6,24), which has the potential to benefit endurance exercise performance by sparing muscle glycogen and blood glucose.

Adiponectin influences metabolic adaptations that would prove beneficial to endurance athletes, and yet to date there is little known about the response of circulating adiponectin concentrations to exercise, and, in particular, the response of this hormone to training in an athlete population. Immediately post-exercise, adiponectin concentrations of trained rowers have been reported to increase or decrease depending on performance level of the athlete (19). Rowers selected for representing their national team at the Olympic games experienced an increase in adiponectin after a maximal 2000-m row, whereas nonselected rowers, who did not perform as fast, showed a reduction in circulating adiponectin (19). In healthy and active males, cycling at 50% and 60% VO2max for durations of 60–120 minutes did not influence post-exercise concentrations of adiponectin (9,23,30), whereas running at approximately 80% VO2max for 30 minutes was associated with an increase (23). Consequently, exercise intensity and training status may influence plasma adiponectin response to
exercise. In an athlete population with already well-developed mitochondrial biogenesis, it remains unknown if acute exercise intensity is an important influencer of adiponectin concentration or if a period of high-intensity training influences the response to an acute bout of exercise.

In combination with the effects on substrate metabolism, adiponectin concentration has been inversely related to body mass and body mass index (9,10,17,21), waist to hip ratio (26), and intra-abdominal fat (3). In a rat model, 6 months of treadmill exercise leading to a reduction in visceral fat was accompanied by significant elevations in circulating adiponectin concentration (5). Resting levels of adiponectin have been shown to increase in healthy females after 10 weeks of exercise training at 70% \( V_{\text{O2max}} \), which increased maximal exercise capacity and reduced obesity indices (25). In trained athletes, adiponectin concentration at rest is reported to remain unchanged over 6 months of high volume low-intensity rowing training (19), although these athletes did not experience a significant change in fat mass across the training period either. Whether exercise training at a higher intensity can lead to changes in adiponectin concentration in trained athletes, and if these are related to changes in body composition is yet to be investigated.

Training that induces higher concentrations of adiponectin may be associated with adaptations also associated with successful endurance performance. Given that adiponectin influences metabolic adaptations that would prove beneficial to endurance athletes, we investigated the response of adiponectin to 4 weeks of aerobic training and 4 weeks of interval training in trained rowers.

**METHODS**

**Experimental Approach to the Problem**

The study was a randomized crossover design. Rowers completed a baseline maximal graded exercise test and were then randomly allocated into 1 of 2 groups to complete 2 prescribed ergometer training sessions per week over a 4-week period before retesting. After retesting, the crossover occurred, and each rower completed the alternative ergometer training program. Each rower completed 4 weeks of high-intensity interval training and 4 weeks of traditional endurance training. The investigators were blinded to the training program (either high-intensity interval or traditional rowing ergometer training program) each rower was completing. The rowers were informed that there was no reported advantage of one training program over the other and that the study was investigating 2 types of ergometer training protocols. At weeks 0, 5, and 10, rowers completed the graded exercise test. Venous blood was collected pre- and post-graded exercise test, and body composition was assessed pre- and post-training intervention. Rowers used the same ergometer during each test session, and testing was conducted at the same time of day.

**Subjects**

Participants were junior state- and national-level rowers from the Tasmanian Rowing Team (male \( n = 5 \), female \( n = 2 \); age: 19.0 \( \pm \) 1.2 years [mean \( \pm \) SD], height: 1.77 \( \pm \) 0.10 m, body mass: 74.0 \( \pm \) 10.7 kg, \( V_{\text{O2peak}} \): 62.1 \( \pm \) 70 ml-kg\(^{-1}\)-min\(^{-1}\), body fat: 17.1 \( \pm \) 6.3%) and were recruited to take part in the study during the preparation phase of their season. On entry to the study, each rower completed a physical activity readiness questionnaire, a coronary artery disease risk factors questionnaire, and provided their informed consent. The study was approved by the Institutional Human Research Ethics Committee.

**Procedures**

**Graded Exercise Test.** The maximal exercise test was conducted to determine each rower’s peak power, lactate threshold, and relative peak oxygen consumption (\( V_{\text{O2peak}} \)) according to the methods of Hahn et al. (13). Rowers arrived at the exercise laboratory for the test having fasted for 2 hours. Each rower was also instructed not to exercise in the 12 hours leading up to their test. All rowers were familiar with the equipment (Concept II rowing ergometer; Concept 2, Inc., Morrisville, VT, USA) and protocols that were used. The protocol involved completing six 4-minute workloads relative to their most recent 2 km ergometer trial result before an all-out effort for the final 4 minutes (coefficient of variation of 2.8%) (31). Each stage was separated by a 1-minute recovery period, during which blood lactate concentration was measured using a LactatePro (Ark-ray, Kyoto, Japan), and rating of perceived exertion was recorded using the 6-20 Borg Scale (1). Heart rate was measured during each stage of the test (Polar Electro Oy, Kempele, Finland). Expired gases (\( O_2 \) and \( CO_2 \)) were collected for analysis during all stages of the exercise test to enable determination of each rower’s peak. Mean power in the final 4-minute maximal stage of the graded exercise test was used to determine the intensity at which each participant would row during the interval training sessions, and blood lactate concentration was used to determine the traditional rowing training intensity.

**Training Protocols.** After baseline, testing rowers were randomly assigned to 1 of 2 groups, each of which completed either high-intensity ergometer interval training or traditional ergometer training for 4 weeks before retesting and a crossover of training intervention occurred. The experimental period involved the incorporation of 2 ergometer sessions per week. All training sessions supplementary to the ergometer sessions were similar between rowers because they were all part of the same squad preparing for the same race schedule. The only major difference in training between the groups was the ergometer protocol they completed twice a week. The interval training sessions consisted of eight 2.5-minute intervals at 90% of mean 4-minute maximal power achieved during the incremental exercise test. Recovery between each interval was at an intensity of 40% of mean 4-minute maximal power, and the recovery duration was until heart rate returned to 70% of maximum heart rate, up to a maximum of 5 minutes. The traditional training program involved rowers completing
2 ergometer sessions per week; one with a duration of 35 minutes and the other of 40 minutes. The traditional training protocols were used because they were the current practice implemented by the coaches in the preparation phase of the season for the rowers involved. The intensity of each session was relatively low and more aerobic in nature when compared with the interval training protocol. The intensity of the traditional ergometer sessions was set to power outputs that corresponded to blood lactate concentrations of 2 and 3 mmol·L$^{-1}$ determined from the incremental exercise test, as previously described (7). The traditional endurance training program matched the interval training program for energy expenditure during the sessions. The training program was completed for 4 weeks at which time retesting occurred. A 4-week period was chosen because this has been shown to result in physiological adaptations that benefit performance (4).

**Body Composition.** Body composition was assessed before each incremental exercise test via dual-energy x-ray absorptiometry (Lunar DPX-L; Lunar Radiation Corporation, Madison, WI, USA) to determine body fat percentage, lean mass, and fat mass. The coefficient of variation for body fat percentage, lean mass, and fat mass on the Lunar DPX-L are 1.89, 2.0, and 1.11%, respectively (20).

**Activity and Diet Monitoring.** During each 4-week training period, rowers kept a log book in which they recorded their mean training wattages, heart rate and recovery times, and team rowing training. Training diaries were completed to enable the determination of training volume for each training program. Rowers also kept a diary of dietary intake in the 24 hours preceding the incremental exercise test. On the following testing occasions, this dietary intake was replicated.

**Blood Collection and Adiponectin Determination.** A 5 ml blood sample was obtained from the forearm antecubital space of each rower pre-exercise and immediately post-exercise on the day of the incremental exercise test. Hematocrit was determined via capillary tube centrifugation in duplicate, and hemoglobin was determined with a HemoCue (HemoCue AB, Ängelholm, Sweden). Lithium Heparin collection tubes were centrifuged at 4°C for 15 minutes at 2,500 rpm. Plasma was then transferred to new tubes for storage at −80°C until analysis. Plasma was analyzed for adiponectin concentration using a sandwich enzyme-linked immunosorbent assay (DRP300; R&D Systems, Inc., Minneapolis, MN, USA) according to the manufacturer’s instructions. Absorbance was measured at 450 nm using a microplate reader (Tecan Trading AG, Männedorf, Switzerland). The intra-assay coefficient of variation was 2.92%. Post-exercise values were adjusted for changes in plasma volume.

**Statistical Analyses**

All statistical analyses were performed using SPSS version 14.0 for Windows (SPSS, Chicago, IL, USA). An analysis of variance was used to determine changes across maximal exercise testing trials. When a significant main effect was found, post hoc t-tests were used to determine where the differences existed. Cohen’s $d$ was calculated to determine effect size ($d$) and interpreted as 0.2, 0.6, 1.2, 2.0, and 4.0 for small, moderate, large, very large, and extremely large effects, respectively (16). Training data were analyzed using a t-test. Statistical significance was set at $p \leq 0.05$. Data are presented as mean ± SD.

**RESULTS**

There was no significant order effect of training ($p > 0.05$); therefore, all data collected were analyzed as one group. Analysis of total work completed during the high-intensity interval ergometer training program was not significantly different from that of the traditional ergometer training program ($p = 0.25$). Subjects reported 100% adherence to both ergometer training protocols.

**Adiponectin**

Adiponectin concentration was significantly different across maximal exercise trials ($p = 0.02$). After completion of the high-intensity interval ergometer training program, there was a significant increase in adiponectin concentration from pre- to post-exercise ($p = 0.016$, $d = 0.47$) (Figure 1).
was a moderate to large increase in resting adiponectin concentration after high-intensity interval ergometer training, although this was not statistically significant (24 \( \pm \) 29\%, \( p = 0.09, d = 0.91 \)). After traditional rowing ergometer training, there was no significant change in the response of adiponectin concentration to maximal exercise (\( p = 0.69, d = 0.14 \)), and there was no significant change in resting adiponectin concentration across the 4-week period (0.3 \( \pm \) 10\%, \( p = 0.91, d = 0.05 \)).

**Peak Oxygen Consumption**
Relative \( \dot{V}O_2 \)peak was significantly different across maximal exercise trials (\( p = 0.031 \)). Improvements in relative \( \dot{V}O_2 \)peak were evident after completion of high-intensity interval training (7.3 \( \pm \) 7.1\%, \( p = 0.05, d = 0.64 \)) but not after traditional rowing training (0.7 \( \pm \) 5.2\%, \( p = 0.7, d = 0.22 \)).

**Four-Minute Power**
Mean power on the final stage of the graded exercise test was significantly different across the testing sessions (\( p = 0.044 \)). Four-minute power was significantly increased after completion of high-intensity interval training (6.1 \( \pm \) 3.9\%, \( p = 0.002, d = 0.23 \)) but not after traditional rowing training (4.5 \( \pm \) 4.9\%, \( p = 0.09, d = 0.18 \)).

**Body Composition**
Fat percentage was significantly different across testing times (\( p = 0.032 \)). Fat percentage significantly decreased after high-intensity interval training (\( p = 0.022, d = 0.17 \)); however, there was no significant change across 4 weeks of traditional rowing training (\( p = 0.64, d = 0.03 \)) (Figure 2). The effect size of the difference in change between training protocols was moderate (\( d = 0.84 \)). Lean mass was not significantly different after high-intensity interval training (\( p = 0.12, d = 0.01 \)) or traditional training (\( p = 0.68, d = 0.01 \)). Fat mass was significantly reduced after high-intensity interval training (\( p = 0.03, d = 0.13 \)) but not traditional training (\( p = 0.62, d = 0.03 \)). The effect size of the difference in change between training protocols was moderate (\( d = 0.72 \)).

**Discussion**
To our knowledge, this is the first investigation to determine adiponectin response to a maximal exercise test after a period of high-intensity ergometer interval training and a period of traditional ergometer training in trained rowers. The major novel finding of this study is that although resting adiponectin concentration did not significantly change in response to either training period, there was a small-to-moderate, significant post-exercise increase in adiponectin concentration after the 4 weeks of high-intensity interval training. Interval training was also associated with a small but significant improvement in maximal 4-minute mean power output, a significant moderate increase in \( \dot{V}O_2 \)peak, and a trivial yet significant decrease in body fat percentage. In comparison, there were smaller effect sizes and no statistically significant change in any of these variables after traditional training. An increase in post-exercise adiponectin concentration may reflect positive training adaptations associated with improvements in physiological indicators of rowing performance.

Resting adiponectin concentrations were not significantly changed across the training period; however, there was an increase in concentrations after a maximal incremental exercise test after a period of high-intensity interval training. Traditional ergometer training was not associated with significant changes suggesting that the increase in post-exercise adiponectin may reflect differences in adaptation to a particular training program, i.e., interval training was associated with greater improvements in variables associated with successful rowing performance. Jürimäe et al. (19) has shown that post-exercise adiponectin concentrations after a 2000-m rowing time trial were significantly increased in rowers of a higher performance level, those rowers who were selected for representing their national team for Olympics, when compared with nonselected rowers. In combination with the findings of this study, this suggests that training...
status and exercise intensity may influence the acute exercise response of adiponectin. The intensity of the high-intensity interval program in this study was higher than that which was completed in the traditional ergometer rowing training program, and this may have mediated the changes in adiponectin concentration post-exercise.

A number of studies in untrained and obese individuals have shown an increase in resting adiponectin concentration after a period of low-to-moderate intensity aerobic exercise (22,25,27). In contrast, a majority of investigations have reported no change in resting concentration, particularly in healthy trained populations (14,19). In this study, resting adiponectin concentrations after a 4-week period of high-intensity intervals were increased, although not significantly. Although the lack of statistical significance may be attributed to the small number of highly trained rowers available for this study, the effect size was large (d = 0.91) suggesting a trend toward increased resting adiponectin concentration after a short-term period of interval training. Recently, Moghadasi et al. (27) have shown an increase in adiponectin gene expression in adipose tissue and plasma adiponectin concentrations after a 12-week period of high-intensity endurance training. However, these subjects were untrained and had lower concentrations of circulating adiponectin than the athletes in this study both before and after training. Consequently, it may be that trained subjects have less capacity to elevate resting adiponectin concentrations because of previous adaptations.

The increases in plasma adiponectin concentration may be associated with improved performance and enhanced recovery of an athlete (19) because of its influence on skeletal muscle bioenergetics. Adiponectin has been shown to upregulate AMPK activity, increasing peroxisome proliferator-activated receptor gamma coactivator 1 alpha signaling and, in turn, mitochondrial biogenesis (2,6,11,12). In this study, there was a small improvement measured in 4-minute peak power output and a moderate increase in V̇O₂peak in response to the high-intensity interval training, but not the traditional ergometer rowing training. It is possible that the improvement in the maximal 4-minute power output and V̇O₂peak evident after the high-intensity training, but not after traditional ergometer training, may have been partly mediated by adiponectin, although this remains speculative.

Improvements in rowing performance have been shown in previous research to be correlated with increased body weight and lean body mass, and decreases in fat mass. The traditional ergometer rowing training did not produce any significant changes in body composition over the 4 weeks of training. However, the high-intensity interval training was associated with significant decrease in fat mass and body fat percentage over the 4 weeks. While the effect size of this change was trivial (d = 0.17), high-intensity interval training provided a moderate benefit (d = 0.84) to body fat loss when compared with the traditional ergometer training. Of interest, the change in body fat percentage after interval training was greater than half the coefficient of variation for the measure suggesting a worthwhile change (15) and one that may be of considerable interest to weight class–restricted athletes. Previous research involving type 2 diabetics and obese individuals have reported a link between body composition and adiponectin concentration, with reductions in body weight and fat mass mediating increases in adiponectin concentration (9,10,17,28,33). In this study, body fat percentage of rowers was decreased after 4 weeks of high-intensity interval training, and there was a moderate to large effect of the training on resting adiponectin concentration. Previous research by Jürimäe et al. (19) found no significant correlation between changes in body composition and adiponectin concentration, despite a significant decrease in body fat percentage over a 6-month training period in trained rowers. Body fat percentage was reduced in these athletes; however, fat mass remained unchanged (19). Interestingly, when the groups of rowers were separated into those selected for representing in the Olympics and those not selected, the selected rowers experienced a significant decrease in fat mass and a trend for an increase in resting adiponectin concentration over the training period (19), supporting the present findings. The relationship between body composition and plasma adiponectin concentration appears to be influenced by fat mass and possibly related to training adaptations. While an individual’s body composition before the initiation of the training may play a role in the change in adiponectin concentration (18,19,33), a decrease in fat mass and increase in resting adiponectin concentration has been shown in this study, and this has occurred in parallel with performance improvements.

In conclusion, 4 weeks of high-intensity interval training elicits a significant increase in adiponectin concentration in response to maximal exercise and a large increase in resting adiponectin concentration. High-intensity interval training also resulted in improvements in V̇O₂peak and maximal 4-minute power output, and a reduction in body fat. The potential for adiponectin to mediate these beneficial training adaptations requires further investigation.

**Practical Applications**

Previous research has found that rowers selected for national team representation at the Olympic Games (19) showed an increase in post-exercise adiponectin concentration when compared with nonselected rowers that did not perform as well. In combination with this study, these findings suggest that an increase in post-exercise adiponectin concentration may reflect positive training adaptations and athlete performance level. The incorporation of interval training into competition preparation for trained athletes has the potential to increase circulating adiponectin concentration, which may stimulate mitochondrial biogenesis and decrease body fat leading to more rapid improvements in aerobic performance. Any decreases in body fat are likely to be of particular relevance to weight class–restricted athletes. Given that adiponectin concentrations have been shown to increase with

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positive training adaptations and reductions in body fat, regular monitoring of concentrations may prove a useful tool to monitor training load and adaptation, thereby informing training prescription and reducing the risk of nonfunctional overreaching.

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