Original Article

JER

https://doi.org/10.12965/jer.2448486.243

Journal of Exercise Rehabilitation 2024;20(5):183-188

Effects of circuit weight training by intensity on stress hormones and antioxidant capacity in high-school wrestlers

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We aimed to investigate the effects of 8-week circuit weight training by intensity on blood stress hormones and antioxidant capacity in high-school wrestlers. This study involved 27 male wrestlers with > 2 years of wrestling experience who were randomly assigned to either a low intensity (n = 13) or a high-intensity circuit weight training group (n = 14). The participants performed circuit weight training for 60 min per session, 3 times per week for 8 weeks. The low- and high-intensity circuit weight training exercises were performed at 50%–60% and 70%–80% of one-repetition maximum for 10 stations, respectively, and 8–15 repeated sessions per station were performed in order. No changes were observed in adrenocorticotropic hormone (ACTH), cortisol, epinephrine, and norepinephrine levels between the two training groups. When compared to levels before the training, ACTH and epinephrine levels decreased, whereas cortisol levels increased. However, no difference was observed in norepinephrine levels. Further, no differences were observed in malondialdehyde (MDA) and glutathione peroxidase (GPX) levels between the two groups. However, MDA and GPX levels were increased from those before training. Changes in superoxide dismutase levels were observed between the two groups, but the change was significant only in the high-intensity circuit weight training group. Long-term training did not increase lipid peroxidation, but increased the activity of antioxidant enzymes that defend against oxidative stress. The antioxidant defense system in tissues can be regulated by exercise intensity as well as physical training status.

Keywords: Circuit weight training, Stress hormone, Antioxidant activity, One-repetition maximum, Lipid peroxides, Antioxidant enzyme

INTRODUCTION

Repetitive stimulation due to exercise has significant effects on the functional regulation of internal organs involved in maintaining homeostasis in the human body. Moreover, repetitive exercise stimulation affects various hormones and neurotransmitters in the endocrine systems including the hypothalamus in the central nervous system (CNS), pituitary gland, adrenal medulla, pancreas, and thyroid gland. In addition, most metabolic and stress-related hormones in the body change organically depending on exercise intensity, body dehydration, or psychological state in relation to weight control through exercise. Among these hormones, catecholamine, a representative metabolic hormone of the sympathetic nervous system, and cortisol, a type of stress hormone, also receive signals from the CNS, and thus play an important role in psychological stimulation and energy metabolism during exercise (Gleeson et al., 2004).

Exercise-induced oxidative stress can be evaluated by measuring malondialdehyde (MDA), an indicator of lipid peroxidation. Antioxidant enzymes such as superoxide dismutase (SOD), glutathione peroxidase (GPX), and catalase are indicators of defense against oxidative stress. The activities of these enzymes are currently being studied with respect to exercise intensity, presence or absence of training, and stress. Typically, excessively increased oxygen up-

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Received: August 20, 2024 / Revised: September 5, 2024 / Accepted: September 11, 2024

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https://www.e-jer.org | pISSN 2288-176X eISSN 2288-1778

take during high-intensity intense exercise close to exhaustion can exceed the antioxidant system defenses and induce lipid peroxidation. The extent of such oxidation is determined by the type, intensity, and duration of the exercise (Richard et al., 2008). On the other hand, it has been reported that regular physical activity and exercise reduced stress responses (Du and Sim, 2021) and increased brain function by stimulating the CNS (Lattari et al., 2014). Recent studies have shown that in the event of continuous training (even with all-out exercise), reactive oxygen species (ROS) are generated, but antioxidant enzyme levels are also increased, indicating that the body's defense system is concurrently activated (Zhao and Sim, 2023).

Modern wrestling matches are a sport that is performed in two 3-min rounds, and requires both anaerobic and aerobic exercise abilities. In particular, due to the nature of this sport, wrestlers may undergo extreme anaerobic metabolism in situations where they are scoring points, and thus their anaerobic capacity is a crucial factor (Song et al., 2019). Therefore, wrestlers must train to improve not only aerobic capacity but also anaerobic exercise capacity. Although various types of training methods are common, circuit weight training is a form of exercise that adds aerobic elements to the conventional anaerobic resistance exercise. Circuit weight training is widely used by athletes and also by people who are not training as athletes. Wrestling is a representative weight class sport that involves fierce competition through physical contact with an opponent wrestler. If weight loss occurs repeatedly in athletes, it can cause physiological abnormalities as well as psychological disturbances due to imbalances in the CNS and sympathetic nervous systems. These changes can stimulate psychological arousal and induce secretion of various metabolic and stress hormones in the body (İrfan, 2015; Meguid et al., 2008).

Consequently, in this study, we aimed to examine changes in stress hormones and antioxidant capacity in wrestlers after performing circuit weight training by intensity. Changes in these factors may affect crucial aerobic and anaerobic exercise capacities in wrestlers.

MATERIALS AND METHODS

Subject

The participants were 27 high-school wrestlers at Luohe Sports School in Luohe city, China, randomized between the low-intensity circuit weight training group (n = 13) and the high-intensity circuit weight training group (n = 14). This study was approved by the Institutional Review Board of Kunsan National University (approval number: 1040117-202211-HR-034-03). The participants' characteristics are shown in Table 1.

Table 1. Physical characteristics of participants

Characteristic	Age (yr)	Height (cm)	Weight (kg)
LCWT (n = 13)	16.10 ± 1.04	176.90 ± 3.50	77.90 ± 18.07
HCWT (n = 14)	16.20 ± 0.74	174.50 ± 7.22	69.10 ± 27.31

Values are presented as mean ± standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Experimental procedure

The subjects' blood samples were collected before and after the 8-week program under the same conditions and time periods. The collected blood was centrifuged at 4°C at 3,000 rpm for 10 min at the Department of Diagnostic Testing. After centrifugation, the blood was stored in a freezer at -80°C. All variable analyses were performed at the clinical laboratory and medical verification center of hospital. Adrenocorticotropic hormone (ACTH), cortisol, epinephrine, and norepinephrine levels were analyzed as stress hormone indicators. Changes in MDA, SOD, and GPX levels were analyzed as antioxidant capacity. All items were measured using the enzyme-linked immunosorbent assay method.

Circuit weight training was performed for a total of 60 min daily, including the main exercise for 40 min with a warm-up for 10 min and a cool-down for 10 min. This routine was performed 3 times per week (Monday, Wednesday, and Friday) for 8 weeks, for a total of 24 times. The low- and high-intensity circuit weight training exercises were performed at 50%–60% and 70%–80% of one-repetition maximum (1RM), respectively, and 8–15 bouts were repeated per station at a total of 10 stations in order. The intensity of the circuit weight training program was adjusted by re-measuring 1RM using the direct measurement method every 2 weeks. The rest time between stations was 20 sec for the low-intensity training, 10 sec for the high-intensity training, and 5 sets were repeated. The rest time between sets was 3 min for the low-intensity training and 2 min for the high-intensity training (Table 2).

Statistical analyses

All data analyses in this study were conducted using IBM SPSS Statistics ver. 26.0 (IBM Co., Armonk, NY, USA). The measurements are presented as means and standard errors, and repeated measures analysis of variance was performed to identify statistical significance ($P < 0.05$).

 https://doi.org/10.12965/jer.2448486.243

Table 2. High and low-intensity circuit weight training program

Exercise	Exercise program	Intensity (1RM)	Frequency	Time (min)	Set (repetition)
Warm-up	Stretching			10	
Main exercise	Bench press Barbell curl Dumbbell lateral raise Cable press down Barbell rowing Seated row Abdominal machine Leg extension Barbell squat Barbell deadlift	LCWT: 50%–60% HCWT: 70%–80%	3/wk (Monday, Wednesday, Friday)	40	5 (8–15)
Cool-down	Stretching			10	

1RM, one-repetition maximum; LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Table 3. Adrenocorticotropic hormone (ng/L) before and after training

Group	Before training	After training
LCWT	70.26±9.15	64.28±6.99
HCWT	69.99±11.11	57.57±8.88
$F_{group*time}$ = 3.118 (P= 0.094), F_{group} = 0.907 (P= 0.354), F_{time} = 25.452 (P= 0.001)		

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Table 4. Cortisol level (μg/L) before and after training

Group	Before training	After training
LCWT	270.28±32.08	310.68±43.19
HCWT	272.84±44.47	316.95±50.22
$F_{group*time}$ = 0.101 (P= 0.754), F_{group} = 0.019 (P= 0.891), F_{time} = 9.245 (P= 0.007)		

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

RESULTS

Changes in ACTH level

Changes in ACTH are presented in Table 3. There was no interaction between group and time of measurement. Although no main effect in groups observed, significant difference in times was observed (F = 25.452, P = 0.001).

Changes in cortisol level

Changes in cortisol are presented in Table 4. There was no interaction between group and time of measurement. Although no main effect in groups observed, significant difference in times was observed (F = 9.245, P = 0.007).

Table 5. Epinephrine (ng/L) before and after training

Group	Before training	After training
LCWT	228.72±28.91	201.55±43.73
HCWT	243.14±46.05	197.42±37.41
$F_{group*time}$ = 0.143 (P= 0.710), F_{group} = 0.670 (P= 0.424), F_{time} = 7.172 (P= 0.015)		

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Table 6. Norepinephrine (ng/L) before and after training

Group	Before training	After training
LCWT	260.13±52.06	249.76±34.39
HCWT	252.73±69.78	240.88±33.33
$F_{group*time}$ = 0.269 (P= 0.611), F_{group} = 0.002 (P= 0.963), F_{time} = 0.501 (P= 0.488)		

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Changes in epinephrine level

Changes in epinephrine level are presented in Table 5. There was no interaction between group and time of measurement. Although no main effect in groups observed, significant difference in times was observed (F = 7.172, P = 0.015).

Changes in norepinephrine level

Changes in norepinephrine level are presented in Table 6. There was no interaction between group and time of measurement. No main effects in groups and times were observed.

Changes in MDA level

Changes in MDA level are presented in Table 7. There was no

Table 7. Malondialdehyde (ng/L) before and after training

Group	Before training	After training
LCWT	2.99±1.11	4.59±0.74
HCWT	2.93±0.98	4.94±1.22
$F_{group*time}$=0.197 (P=0.662), F_{group}=0.391 (P=0.539), F_{time}=30.647 (P=0.001)		

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Table 8. Superoxidedismutase (U/mL) before and after training

Group	Before training	After training	F(P-value)
LCWT	94.36±10.44	88.73±9.04	1.61 (0.236)
HCWT	90.12±9.09	114.90±26.55	8.38 (0.018)
$F_{group*time}$=18.00 (P=0.005)			

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

interaction between group and time of measurement. Although no main effect in groups observed, significant difference in times was observed (F=30.647, P=0.001).

Changes in SOD level

Changes in SOD level are presented in Table 8. A significant interaction was observed between group and time (F=18.00, P=0.005). Significant difference was observed in SOD of high-intensity circuit weight training group (F=8.38, P=0.018) but not of low-intensity circuit weight training group.

Changes in GPX level

Changes in GPX level are presented in Table 9. There was no interaction between group and time of measurement. Although no main effect in groups observed, significant difference in times was observed (F=112.80, P=0.001).

DISCUSSION

High-intensity exercise or psychological anxiety stimulates the sympathetic nervous system to induce the secretion of stress hormones such as catecholamines and cortisol from the adrenal gland (Simpson et al., 2015; Wheatley et al., 2015). The secretion rate of these stress hormones changes organically depending on physical changes such as the degree of sweating or changes in plasma volume induced by exercise stimulation, and is determined by the complex mechanism of the sympathetic nervous system and interaction with the external environment and psychological state.

Table 9. Gluatathione peroxidase (ng/mL) before and after training

Group	Before training	After training
LCWT	40.64±5.95	99.43±24.78
HCWT	35.57±9.71	103.44±21.60
$F_{group*time}$=0.579 (P=0.456), F_{group}=0.011 (P=0.917), F_{time}=112.80 (P=0.001)		

Values are presented as mean±standard error.
LCWT, low-intensity circuit weight training; HCWT, high-intensity circuit weight training.

Therefore, stress hormone secretion rate is used as an indicator for inferring stress and psychological changes in response to external stimuli (Lanzi et al., 2014). Cortisol levels are regulated by ACTH, and increase in stressful situations. In particular, exercise imposes stress on the human body, and the degree of stress imposed varies depending on exercise time, intensity, and individual training status (Tianlong and Sim, 2019). Although previous studies regarding changes in stress hormones such as ACTH and cortisol have reported conflicting results, stress hormones generally showed a significant increase during moderate- or higher-intensity exercise for a long period of time, or high-intensity exercise for a short period of time (Duclos and Tabarin, 2016). Tremblay et al. (2004) reported that exercise intensity is the greatest factor for changing cortisol levels, and Williams et al. (2002) also reported that a higher amount of exercise in a given amount of time was associated with a greater increase in cortisol secretion.

In this study, we found no significant difference in the blood ACTH levels before and after 8-week high-intensity or low-intensity circuit weight training sessions, but a decrease in ACTH levels was detected at rest after completion of the circuit weight training in both groups. Furthermore, cortisol levels in both groups were increased after the training when compared to those before the training, but no differences in cortisol levels were found between the two groups. The results of a recent study by Du and Sim (2021) showed that blood ACTH levels at rest decreased in high-school sprinters after moderate- and high-intensity interval training, whereas cortisol levels tended to increase in the two groups. These results are consistent with those in this study. Viru et al. (2001) stated that elevated cortisol levels induced by exercise might result from the activation of the sensitivity to negative feedback regulation of ACTH. In addition, the secretion of ACTH is known to be decreased in athletes when compared to that in the general population (Duclos and Tabarin, 2016). Although ACTH secretion is accelerated when subjects are exposed to physical and mental stress, it is thought that the repeated process of continuous training can result in an improvement in the capability to respond

https://doi.org/10.12965/jer.2448486.243

to stress. This adaptation can result in a decrease in antidiuretic hormone and lactate levels, which thereby leads to a decrease in ACTH secretion.

Although no change is observed in the secretion rate of catecholamine at low intensities of exercise, blood catecholamine levels increase at exercise intensities exceeding 60% of maximal oxygen uptake, and show a proportional relationship as exercise intensities increase (Wheatley et al., 2015). In particular, when summarizing the results of previous studies regarding catecholamine levels stimulated by weight loss-related psychological stress and high-intensity exercise, it was observed that the levels of secreted catecholamines in exercise groups were lower than those in nonexercise groups. In other words, changes in secreted catecholamines can be very diverse depending on the intensity or type of training applied, exercise duration, etc. (Kraemer and Ratamess, 2005), and continuous training can be considered another effective variable that can increase adaptation of stress hormones for stress relief. In this study, no differences in secreted blood epinephrine and norepinephrine levels were observed at rest between the two groups according to training intensity. We found no differences in norepinephrine levels in both groups after training; however, epinephrine levels decreased in both groups after training. These results may be due to the stimulation caused by the repeated process of circuit weight training, leading to a positive effect on changes in stress hormones activated by the sympathetic nervous system.

One-time high-intensity exercise increases the production of ROS, which oxidizes body tissues, resulting in tissue damage and an increase in MDA (Viña et al., 2000). Previous studies on athletes or men in their 20s in which one-time high-intensity exercise was performed showed that no decrease or significant changes occurred in SOD activity (Gül et al., 2011; Zembron-Lacny et al., 2007). However, regular training improved the body's defense against ROS, thereby resulting in a decrease or no significant increase of MDA levels stimulated by exercise (Oztasan et al., 2004; Schneider et al., 2005; Zhao and Sim, 2023). Antioxidant defense is promoted after training, which is reflected in increased levels of SOD after exercise (Miyazaki et al., 2001; Laufs et al., 2005).

This study found that after 8-week high- and low-intensity circuit weight training, at rest MDA levels increased in both groups, but no difference was detected between the groups. On the other hand, SOD levels (an antioxidant defense against oxidative stress) significantly increased in the high-intensity circuit weight training group. In a study by Schneider et al. (2005), MDA levels showed a decreasing trend in trained subjects after high-intensity exercise, but no change in MDA levels was observed after medium-intensity or low-intensity exercise. A study by Zhao and Sim (2023) reported no significant change in MDA levels in middle-distance runners after interval training. However, in contrast, this study showed that MDA levels increased in the low- and high-intensity circuit weight training groups after the training. Thus, it is possible that changes and inconsistencies in lipid peroxidation according to training might be attributed to individual characteristics related to oxidative stress adaptation or antioxidant defense. Different characteristics in subjects from the general public and those with athletic careers might affect the results, and suggest that interpreting lipid peroxidation in conjunction with changes in antioxidant capacity is necessary.

In this study, GPX also did not differ between the groups, but was increased in both the low- and high-intensity circuit weight-training groups. Karanth et al. (2004) reported that exercise increased GPX activity by 20%–177% in skeletal muscles with high muscle mass, and Leichtweis and Ji (2001) reported that the levels of antioxidant enzymes and defenses against free ROS generation in athletes were higher than those of the general population. Thus, these findings suggest that although oxidative stress was induced by training for a long period of time, the activities of antioxidant enzymes such as SOD and GPX were also increased to protect the body against increased oxidative damage. With respect to exercise intensity, the results of a recent study by Zhao and Sim (2023) on interval training in track and field athletes showed that no change in SOD was observed in the moderate-intensity training group, whereas a significant increase in SOD was observed in the high-intensity training group after training.

These results indicate that the activity of antioxidant enzymes to protect the body against training-induced oxidative damage in athletes can be triggered above a certain level of stimulation, and suggest that high-intensity training may be more effective in antioxidant defense than low-intensity training.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

The authors received no financial support for this article.

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