Original Article

JER

https://doi.org/10.12965/jer.2346212.106

Journal of Exercise Rehabilitation 2023;19(3):181-186

Effects of muscle damage indicators and antioxidant capacity after interval training on the 800-m records of adolescent middle-distance runners

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To examine the effect of 10-week interval training (IT) at varying intensities on serum muscle damage indicators and antioxidant capacity and determine its effect on the 800-m records of adolescent middle-distance runners. Twenty male high-school middle-distance runners were randomized between the high-intensity IT (HIIT; n=10) and the medium-intensity IT (MIIT; n=10) groups. Three sessions/week for 10 weeks (total of 30 sessions) were performed; one session of IT was for 60 min. The high and medium exercise intensities were set at 90%–95% and 60%–70% heart rate reserve (HRR), respectively. Intensity at rest was 40% HRR for both groups. Weight training was performed at 60%–70% of one repetition maximum for two sessions/week. The changes in serum muscle damage indicators and antioxidant capacity in the two groups were measured, and their effects on the 800-m records were analyzed. The 10-week training reduced serum muscle damage indicators in middle-distance runners, but only the HIIT group displayed a decrease in creatine kinase. For the change in antioxidant capacity, the two groups demonstrated no significant change in malondialdehyde (MDA), whereas the HIIT group exhibited a significant increase in superoxide dismutase (SOD). IT also reduced the 800-m records in middle-distance running, and the effect was stronger in the HIIT group. In conclusion, 10-week HIIT can have a positive effect on muscle damage indicators, showed a significant increase in SOD as a key indicator of antioxidant capacity, and improved the 800-m records in middle-distance runners.

Keywords: High-intensity, Medium intensity, Interval training, Heart rate reserve, Muscle damage indicators, Antioxidant activity

INTRODUCTION

Interval training (IT) has gained much attention as a method for enhancing cardiopulmonary fitness and aerobic exercise performance of middle- and long-distance runners and marathoners. While IT can be applied in various sports, the specific IT exercises can be selected according to the sport type, with the speed and rest intervals adjusted accordingly. Notably, high-intensity IT (HIIT) is commonly used nowadays for enhancing the athletic performance of middle- and long-distance runners. Compared to conventional training with aerobic exercise, HIIT allows higher energy consumption levels and exercise effects in a given amount of time (Du and Sim, 2021). According to a previous study, given the same level of energy consumption in high-intensity and medium-intensity exercises, participating in high-intensity exercise is more effective in reducing the risk factors for cardiovascular disease and inducing positive physical changes (Swain and Franklin, 2006). However, high-intensity exercise could cause muscle damage or fatigue, and the postexercise muscle damage could increase the serum concentrations of enzymes in both the general population and athletes, which are the potential adverse effects (Hasenoehrl et al., 2017; Lippi et al., 2008). Such changes in serum enzyme concentrations are closely associated with the exercise intensity, time, or level of training, and the observed patterns vary according to physical condition (Lippi et al., 2008). Regular long-term training has been shown to reduce muscle damage indicators

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Received: April 23, 2023 / Accepted: May 20, 2023

and exert anti-inflammatory effects compared to acute exercise training (Du and Sim, 2021; Timmerman et al., 2008), ultimately leading to enhanced athletic performance.

Meanwhile, reactive oxygen species (ROS) and oxidative stress, which increase during exercise, promote the generation of lipid peroxides through a change in polyunsaturated fatty acids, the main components of biological membranes, and the scope of oxidation is dependent on the exercise type, intensity, and duration (Richard et al., 2008). In general, malondialdehyde (MDA) is used as an indicator for lipid peroxides, and acute high-intensity exercises are known to affect MDA and the antioxidant enzyme superoxide dismutase (SOD) (Bloomer, 2008). Based on these findings, IT is presumed to have varying effects on metabolic variables according to the athlete and the exercise intensity. Thus, this study aimed to examine the changes in muscle damage indicators and antioxidant capacity at different intensities of IT for 10 weeks and determine the effect on 800-m records of adolescent middle-distance runners.

MATERIALS AND METHODS

Subject

The participants were 20 male high-school middle-distance runners in Handan City, China, randomized between the high-intensity (n=10) and the medium-intensity IT (MIIT) groups (n=10). This study was approved by the Institutional Review Board of Handan University (HDU-202109-l01). The participants' characteristics are shown in Table 1.

Experimental procedure

The subjects' blood samples were collected before and after the 10-week program under the same conditions and time periods. The collected blood was centrifuged at 4°C at 3,000 rpm for 30 min at the Department of Diagnostic Testing. After centrifugation, the blood was stored in a freezer at 70°C. All variable analyses were performed at the clinical laboratory and medical verification center of J Company. Lactate dehydrogenase (LDH) and creatine kinase (CK) levels were analyzed as muscle damage indicators. Changes in MDA and SOD levels were analyzed as antioxidant capacity.

IT was performed 3 times a week (Mondays, Wednesdays, and Fridays) in the morning for 10 weeks for a total of 30 times. Two groups performed a 20-min warm-up exercise, including jogging and joint stretching, and performed IT for 35 min. This was followed by a 5-min cool-down exercise. The exercise intensity was defined by the target heart rate using the formula by Karvonen as follows: target heart rate = exercise intensity × (maximum heart rate − resting heart rate) + resting heart rate. The exercise intensity for high- and medium-intensity IT were 90%–95% and 60%–70% of the heart rate reserve (HRR), respectively, while the exercise intensity during the resting period for both groups was 40% of the HRR. Heart rate was measured using a smart band, and the exercise was repeated 4 times in each exercise group (Table 2). To maximize the exercise effect, weight training was performed at 60%–70% of 1 repetition maximum by 60 min a day and two sessions a week (Tuesday and Saturday). The exercise intensity was identical between the two groups. For the 800-m records, the runners set off on a 400-m straight course by standing start, and the time the runner's trunk touched the finish line was recorded in 1/100 sec. All measurements were taken twice, and higher records were selected.

Statistical analyses

All data analyses in this study were conducted using IBM SPSS Statistics ver. 26.0 (IBM Co., Armonk, NY, USA). A general linear model was used to calculate the mean and standard error for each variable, and examine changes in serum muscle damage indicators, and antioxidant capacity between the training groups and

Table 1. Physical characteristics of subjects

Subject	HIIT (n=10)	MIIT (n=10)
Age (yr)	17.5±0.71	17.1±0.57
Height (cm)	175.3±4.47	172.9±4.46
Weight (kg)	71.25±6.14	68.29±4.29

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

Table 2. Interval training program

Exercise	Exercise program	Time (min)	Intensity (HRR)	Set	Frequency
Warm-up	Jogging, stretching	20	30%–40%	1	All components were performed 3/week (Mon, Wed, Fri).
Main					
HIIT	A 40-sec break after 200-m run	35	90%–95%	4	
	A 60-sec break after 400-m run		At rest: 40%		
MIIT	A 60-sec break after 200-m run	35	60%–70%	4	
	A 90-sec break after 400-m run		At rest: 40%		
Cool-down	Stretching	5	30%–40%	1	

HIIT, high-intensity interval training; MIIT, medium-intensity interval training; HRR, heart rate reserve.

https://doi.org/10.12965/jer.2346212.106

their effects on the 800-m records. The significance level was set at 0.05.

RESULTS

Changes in LDH level

Changes in the LDH are presented in Table 3. The probability of significant group and time interactions was slightly higher than 0.05, the set level of significance, but the interaction was determined to be significant ($F=3.828$, $P=0.066$). Both HIIT ($F=10.028$, $P=0.011$) and MIIT ($F=17.264$, $P=0.002$) groups demonstrated a significant decrease in LDH after training.

Changes in CK level

Changes in the CK level are presented in Table 4. The probability of significant group and time interactions was slightly higher than 0.05, the set level of significance, but the interaction was determined to be significant ($F=3.786$, $P=0.067$). The HIIT group demonstrated a significant decrease in CK after training ($F=16.530$, $P=0.003$), whereas the MIIT group displayed no significant difference.

Table 3. Lactate dehydrogenase (U/L) before and after training

Group	Before training	After training	*F* (*P*-value)
HIIT	291.36±53.72	227.23±36.11	10.028 (0.011)
MIIT	243.46±27.34	220.84±22.88	17.264 (0.002)
$F_{group*time}$=3.828 (0.066)			

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium intensity interval training.

Table 4. Creatine kinase level (U/L) before and after training

Group	Before training	After training	*F* (*P*-value)
HIIT	381.17±84.45	258.63±48.28	16.530 (0.003)
MIIT	330.72±118.76	293.26±94.64	1.398 (0.267)
$F_{group*time}$=3.786 (0.067)			

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

Table 5. Malondialdehyde (nmol/mL) before and after training

Group	Before training	After training
HIIT	117.56±22.39	121.19±16.12
MIIT	116.84±20.17	117.96±24.12
$F_{group*time}$=0.176 (P=0.679), F_{group}=0.176 (P=0.826), F_{time}=0.176 (P=0.440)		

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

Changes in MDA level

Changes in the MDA level are presented in Table 5. No significant group and time interaction were found. For the main effect, no difference by either group or time was observed.

Changes in SOD level

Changes in the SOD level are presented in Table 6. Significant group and time interactions were found ($F=4.864$, $P=0.041$). Compared to before training, the HIIT group after training exhibited a significant change in SOD ($F=12.237$, $P=0.007$), but the MIIT group displayed no significant difference.

Changes in the 800-m records

Changes in the 800-m records are presented in Table 7. Significant group and time interactions were found ($F=7.063$, $P=0.016$). Compared to before training, both HIIT ($F=89.014$, $P=0.000$) and MIIT ($F=10.347$, $P=0.011$) groups after training exhibited a significant improvement in the 800-m records.

Longitudinal effect of each variable on the 800-m records

Table 8 shows the results of the analysis of covariance using each variable as a covariate to determine how the change of each variable had an effect on the change in 800-m records and whether this effect was different for each group. No significant between-group variation in the 800-m records was observed across all variables except MDA ($F=6.284$, $P=0.023$). The level of SOD had an effect on the change in 800-m records. The level of MDA had no impact on the change in 800-m records in the HIIT group, but the records in the MIIT group showed a change ($t=3.310$, $P=0.011$).

Table 6. Superoxide dismutase (nmol/mL) before and after training

Group	Before training	After training	*F* (*P*-value)
HIIT	162.87±7.85	172.21±7.94	12.237 (0.007)
MIIT	156.70±11.55	159.12±8.11	2.170 (0.175)
$F_{group*time}$=4.864 (0.041)			

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

Table 7. Changes in 800-m record times (min) before and after training

Group	Before training	After training	*F* (*P*-value)
HIIT	2.24±0.07	2.16±0.06	89.014 (0.000)
MIIT	2.27±0.06	2.24±0.05	10.347 (0.011)
$F_{group*time}$=7.063 (0.016)			

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

Table 8. Analysis of covariance on the variables

Variable	β	SE	t	P-value
CK (U/L)	4.906E-5	0.000	0.599	0.556
LDH (U/L)	-1.607E-5	0.000	-0.093	0.927
SOD (nmol/mL)	0.003	0.001	-2.631	0.017
MDA (nmol/mL)				
HIIT	0.000	0.001	0.213	0.836
MIIT	0.003	0.001	3.310	0.011
MDA*group $F=6.284$, $P=0.023$				

SE, standard error; CK, creatine kinase; LDH, lactate dehydrogenase; SOD, superoxide dismutase; MDA, malondialdehyde; HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

DISCUSSION

In general, the activation and secretion of CK and LDH increase upon high-intensity exercise, so the serum CK and LDH levels are used to indicate muscle damage and physical condition (Brancaccio et al., 2010). Many previous studies reported that high-intensity physical activity could induce structural damage in skeletal muscles (Betts et al., 2009; Bradley et al., 2010; Brancaccio et al., 2008; Nosaka et al., 2011). In this study, however, 10-week MIIT and HIIT in middle-distance runners decreased CK and LDH. One thing to note is that the change in CK deviated between the two groups with a notable significant decrease after HIIT. Furthermore, Brancaccio et al. (2008) reported that the level of muscle damage could vary according to the physical condition through training. A recent study by Du and Sim (2021) showed that CK and LDH decreased after 8-week MIIT and HIIT in male high-school runners. This was attributed to the enhancement of the cytoprotective mechanism against damage by long-term training in runners in robust and trained physical condition. As such, in line with this study, previous studies have also shown that the activity of CK and LDH could vary according to the training intensity and level of trained physical condition, and the CK and LDH levels can be decreased in most cases through long-term training.

Meanwhile, acute high-intensity exercises could increase the generation of ROS that oxidize the tissues in the body to bring about tissue damage and an increased level of MDA (Viña et al., 2000). The body, nonetheless, has an efficient defense system to protect itself against oxidative damage, such as SOD (Bloomer, 2008; Wierzba et al., 2006), which steadily increases after exercise through regular training due to a more effective oxidative defense (Laufs et al., 2005; Miyazaki et al., 2001).

The 10-week IT at varying intensities in this study did not lead to a significant between-group difference in MDA, whose concentration did not change after training compared to before training. In contrast, a significant between-group difference in SOD was found, while the HIIT group showed a significant increase in the level of SOD. This coincided with previous studies reporting a lack of a significant change in the level of MDA that had been increased by exercise as the body's defense against ROS was improved through regular training (Miyazaki et al., 2001; Oztasan et al., 2004; Schneider et al., 2005). Schneider et al. (2005) reported that, in a trained individual, the level of MDA tended to fall after a high-intensity exercise but remained constant after a low or medium-intensity exercise. Oztasan et al. (2004) likewise reported that the level of MDA did not change significantly after a high-intensity exercise in a trained group but significantly increased in an untrained group.

As previously mentioned, antioxidant enzymes exhibit a pattern of increase with continuous exercise and in proportion to the exercise intensity, except for acute high-intensity exercises (Laufs et al., 2005; Miyazaki et al., 2001). In previous studies on nonathletic and athletic males in their 20s, who performed an acute high-intensity exercise (Gül et al., 2011; Zembron-Lacny et al., 2007), the activity of SOD did not fall or change significantly, which demonstrated that short-term exercise could not increase the activity of SOD. Additionally, Karanth et al. (2004) reported that the activity of glutathione peroxidase in skeletal muscles with high muscle mass could be increased by 20% up to 177%. Leichtweis and Ji (2001) reported that athletes possessed higher antioxidant enzyme levels than the general population, with a robust defense against free radical generation.

The results of this study showed that exercise intensity had positive effects on antioxidant enzymes. This implied that stimulation above a certain level could induce a response regarding the activity of antioxidant enzymes to protect the body against oxidative damage due to IT. In this light, the changes in MDA and SOD, with regard to controlling the antioxidant defense system in tissues, are associated with the exercise intensity and duration as well as the physical fitness or trained physical condition of an individual.

Meanwhile, the 800-m records of middle-distance runners were reduced in both groups, with a notable, stronger effect in the HIIT group. The level of SOD affected the 800-m records, but the magnitude of the effect did not vary between the two groups. The effect of MDA on the 800-m records varied between the two groups; the change in MDA did not affect the 800-m records in the HIIT group, but the effect in the MIIT group was significant.

The results collectively suggested that the HIIT at ≥90% HRR

https://doi.org/10.12965/jer.2346212.106

was more effective in reducing serum muscle damage indicators and improving the 800-m records of middle-distance runners. In addition, the level of SOD increased significantly in the HIIT group. This may be explained as follows: Throughout long-term IT, the production and activity of the antioxidant enzyme SOD increased according to the training intensity to bring about antioxidant adaptation, which led to an effective defense against the accumulation of the lipid peroxide indicator MDA caused by high-intensity exercises, thus mitigating against the damage caused by lipid peroxide.

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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https://doi.org/10.12965/jer.2346212.106