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Effect of changes in blood fatigue indicators, inflammatory markers, and stress hormone levels on 100-m records of sprinters following an 8-week intense interval training

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This study aimed to examine the changes in the blood fatigue indicators, inflammatory markers, and stress hormones following an 8-week intensity interval training in sprinters, and to investigate the effects on changes in the 100-m sprint records. Twenty sprinters from a boys' high school were equally assigned to high-intensity and medium-intensity interval training groups, and three 60-min interval training sessions were performed per week for 8 weeks, for a total of 24 sessions. Exercise intensity was defined as 85%–95% and 75%–85% of heart rate reserve for high- and medium-intensity training, respectively. At rest, both groups had an exercise intensity of 60% of the heart rate reserve. Our results showed decreased fatigue indicators, inflammatory markers, and stress hormone levels after high-intensity and medium-intensity interval training, with no difference between the training levels. In addition, the 100-m sprint records were different in high- and medium-intensity interval training groups, based on the lactate dehydrogenase and adrenocorticotropic hormone levels. In conclusion, medium-intensity interval training with a reserve heart rate of ≥75% can have a positive effect on blood fatigue indicators, inflammatory markers, and stress hormones in sprinters. Specifically, the changes in adrenocorticotropic hormone level seen in the high-intensity interval training group were found to have a significant effect on the 100-m sprinting records.

Keywords: High-intensity interval, Medium-intensity interval, Heart rate reserve, Blood fatigue indicators, Inflammatory markers, Stress hormone

INTRODUCTION

Sprinting is a competitive exercise, with the aim of running the fastest over a specified distance. The energy demand during exercise rapidly increases, which all physiological functions adapt to. For athletes, blood lactate and ammonia concentrations are directly related to muscle fatigue, and have significance as they determine the limiting factors in muscle exercises. Athletes often have to repeat high-intensity exercises during training or competitions, increasing the capacity for lactic acid and ammonia concentrations. In this regard, recovery in the shortest possible time is important in determining athletes' performance, in which the metabolism of fatigue indicators in the blood plays a significant role.

In contrast, the key factor in high-intensity interval training, which has recently been gaining attention, is to have alternating high-intensity and low-intensity exercises, with resting periods in between the intervals. High-intensity interval training can replace conventional aerobic exercises as it shows higher energy consumption during exercise and greater effects in the same period of time, in addition to reducing boredom during continued training. However, high-intensity exercises can cause muscle damage or fatigue and increase the circulating amount of stress hormones and active substances involved in the inflammatory immune response, as well as blood enzymes (Hasenoehrl et al., 2017). However, long-term regular training reduces fatigue levels (Theofilidis et al., 2018), anti-inflammatory effects, and overall stress (Timmerman et al., 2008), correlating with performance improvement.

Based on the results of these studies, interval training may show

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Table 1. Physical characteristics of subjects

Characteristic	HIIT group (n=10)	MIIT group (n=10)
Age (yr)	17.28±1.11	17.50±0.54
Height (cm)	180±6.13	178±4.79
Weight (kg)	71.28±8.97	70.52±7.52

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

varying effects on metabolic parameters, depending on the subject and exercise intensity. However, only a limited number of studies reported on the longitudinal effects on the 100-m sprinting records, according to the changes in blood fatigue indicators, inflammatory markers, and stress hormone levels following interval training of varying intensities. Therefore, it seems necessary to conduct a study on the effects of highly efficient interval training of varying intensities on the improvement of performance in adolescent sprinters.

MATERIALS AND METHODS

This study was conducted with 20 male sprinters from a high school in Tangshan city, China. The subjects were randomly assigned to ten subjects each in the high- and medium-intensity interval training groups. This study was approved by the Ethics Committee of a Tangshan Normal University (No: TSNU-2019-l01). The participants' characteristics are shown in Table 1.

The subjects' blood samples were collected before and after the 8-week program under the same conditions and time periods. After a resting period, a medical laboratory technologist withdrew blood from the subjects' forearm veins. The blood samples were centrifuged at 3,000 rpm for 30 min and stored in a freezer at -70°C. All variable analyses were performed at the medical laboratory, and the participants' lactate dehydrogenase (LDH), creatine kinase (CK), C-reactive protein (CRP), interleukin-6 (IL-6), cortisol, and adrenocorticotropic hormone (ACTH) levels were measured.

Three 60-min interval training sessions were conducted per week (on Mondays, Wednesdays, and Fridays) for 8 weeks, for a total of 24 sessions, with each session lasting 60 min. Two groups performed a 20-min warm-up exercise, including jogging and joint stretching, and performed interval training 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 interval training were 85%–95% and 75%–85% of the heart rate reserve (HRR), respectively, while the exercise intensity during the resting period for both groups was 60% of the HRR. Heart rate was measured using a smart band, and the exercise was repeated four times in each exercise group (Table 2).

Table 2. Interval training program

Group	Intensity (HRR)	Exercise program	Set	Time (min)
HIIT	Exercise intensity: HRR 85%–95% Exercise intensity at rest: HRR 60%	Warm-up: jogging, stretching		20
		Main exercise: 100-m run Ten jump squats after a 40-sec break 100-m run after jump squat Ten standing jumps after a 40-sec rest 50-m start dash after standing jumps	4	35
		Cool-down: stretching		5
MIIT	Exercise intensity: HRR 75%–85% Exercise intensity at rest: HRR 60%	Warm-up: jogging, stretching		20
		Main exercise: 100-m run Ten jump squats after a 60-sec break 100-m run after jump squat Ten standing jumps after a 60-sec rest 50-m start dash after standing jumps	4	35
		Cool-down: stretching		5

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

For the 100-m sprint, the sprinters started in a crouching position on a starting block and ran on a straight course along the 400-m track, and the time when the trunk touched the finish line was recorded. For each record, two measurements were taken, and the better recorded time down to 1/100 of a second was used.

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 fatigue indicators, inflammatory markers, and stress hormone levels between the training groups and their effects on the 100-m sprint records. The significance level was set at 0.05.

RESULTS

Changes in the LDH level

Changes in the LDH level are presented in Table 3. No interaction between the group and the time period was observed. Although no main effect in the group was observed, significant difference in the time period was observed.

Changes in the CK level

Changes in the CK level are presented in Table 4. No interaction between the group and the time period was observed. Although no main effect in the group was observed, significant dif-

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

Group	Lactate dehydrogenase level (ng/L)	
	Before training	After training
HIIT	46.15±3.19	36.12±2.36
MIIT	47.59±3.98	37.77±3.12

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=0.01 (0.928), F_{group}=1.60 (0.228), F_{time}=79.47 (0.001).

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

Group	Creatine kinase level (pg/L)	
	Before training	After training
HIIT	481.90±23.68	376.86±23.18
MIIT	481.46±32.31	385.80±22.57

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=0.05 (0.833), F_{group}=0.46 (0.508), F_{time}=172.83 (0.001).

Table 5. C-reactive protein level (μg/L) before and after training

Group	C-reactive protein level (μg/L)	
	Before training	After training
HIIT	2,396.93±321.24	1,958.50±181.47
MIIT	2,341.88±362.51	1,919.86±126.60

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=0.01 (0.921), F_{group}=0.18 (0.681), F_{time}=28.33 (0.001).

ference in the time period was observed.

Changes in the CRP level

Changes in the CRP level are presented in Table 5. No interaction between the group and the time period was observed. Although no main effect in the group was observed, significant difference in the time period was observed.

Changes in IL-6 level

Changes in IL-6 level are presented in Table 6. No interaction between the group and the time period was observed. Although no main effect in the group was observed, significant difference in the time period was observed.

Changes in the cortisol level

Changes in the cortisol level are presented in Table 7. No interaction between the group and the time period was observed. The results of the main effect demonstrated no significant difference between groups and between time periods.

Table 6. Interleukin-6 level (ng/L) before and after training

Group	Interleukin-6 level (ng/L)	
	Before training	After training
HIIT	24.77±2.65	19.75±0.93
MIIT	24.91±1.70	18.09±0.62

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=2.57 (0.133), F_{group}=1.25 (0.284), F_{time}=111.50 (0.001).

Table 7. Cortisol level (μg/L) before and after training

Group	Cortisol level (μg/L)	
	HIIT group (n=10)	MIIT group (n=10)
HIIT	190.22±39.94	212.55±11.89
MIIT	208.07±33.54	221.34±12.89

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=0.23 (0.640), F_{group}=1.53 (0.237), F_{time}=3.54 (0.082).

Table 8. Adrenocorticotropic hormone level (ng/L) before and after training

Group	Adrenocorticotropic hormone level (ng/L)	
	Before training	After training
HIIT	131.21±14.72	105.43±2.03
MIIT	131.18±15.31	113.12±4.02

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=0.83 (0.378), F_{group}=1.08 (0.317), F_{time}=26.80 (0.001).

Table 9. Changes in 100-m record times (sec) before and after training

Group	Changes in 100-m record times (sec)	
	Before training	After training
HIIT	12.33±0.87	12.08±0.83
MIIT	12.41±0.68	12.19±0.52

Values are presented as mean±standard error.
HIIT, high-intensity interval training; MIIT, medium-intensity interval training.
$F_{group*time}$=0.07 (0.797), F_{group}=0.06 (0.809), F_{time}=16.04 (0.001).

Changes in ACTH level

Changes in the ACTH level are presented in Table 8. No interaction between the group and the time period was observed. Although no main effect in the group was observed, significant difference in the time period was observed.

Changes in 100-m sprinting records

Changes in the 100-m records are presented in Table 9. No interaction between the group and the time period was observed. Although no main effect in the group was observed, significant

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Table 10. Covariate analysis on the variables

Variable	β	SE	t	P-value
CK (pg/L)	-0.003	0.002	-1.356	0.200
CRP (μg/L)	0.000	0.000	1.903	0.081
IL-6 (ng/L)	-6.469E-5	0.030	-0.002	0.998
Cortisol (μg/L)	-0.003	0.002	-1.733	0.109
LDH (ng/L)				
HIIT	-0.052	0.030	-1.734	0.134
MITT	0.026	0.014	1.835	0.126
LDH*group t=-2.366, P=0.037				
ACTH (ng/L)				
HIIT	-0.0010	0.005	-2.219	0.068
MIIT	0.004	0.005	0.714	0.507
ACTH*group t=-1.979, P=0.073				

CK, creatine kinase; CRP, c-reactive protein; IL-6, interleukin-6; LDH, lactate dehydrogenase; ACTH, adrenocorticotropic hormone; HIIT, high-intensity interval training; MIIT, medium-intensity interval training.

difference in the time period was observed.

Longitudinal effect of each variable on the 100-m sprint records

Table 10 shows the results of analysis of covariance using each variable as a covariate to determine how the change of each variable had an effect on the change in 100-m records and whether this effect was different for each group.

Other variables, with the exception of LDH and ACTH levels, did not have different effects on the 100-m sprint records of the two groups. LDH and ACTH showed different effect depending on the group with t=-2.366 (P=0.037) and t=-1.979 (P=0.073), respectively, for interaction at a significance level of 10%.

DISCUSSION

Typically, enzymes are important factors regulating energy levels required for muscle activity (Mantle and Preedy, 2002), and blood CK and LDH levels reflect the degree of muscle damage, caused by prolonged physical activity, and physical training (Galan et al., 2018). LDH activity, which is different between trained and non-trained individuals, is used as a reference value in monitoring the athletes' performance improvement, training effect analysis, and training and intensity control (Sacheck and Blumberg, 2001).

Apple and Rogers (1985) studied the change in LDH isozyme activity after a 9-week whole-body endurance training for trained male and female marathon runners, and reported a decrease in LDH activity in both males and females. Messonnier et al. (2005) conducted a 4-week high-intensity exercise program in healthy adults, which showed a decrease in LDH concentration. CK activity also increases by high-intensity physical exercise and shows different patterns depending on the degree of physical training. One-time exercise increases muscle damage by inducing muscle fatigue, but long-term regular training reduces muscle damage and damage substance under the same exercise load (Deruisseau et al., 2004). Yang (2015) reported a significant decrease in CK concentration in judo athletes after 6 weeks of high-intensity resistance training. Deruisseau et al. (2004) reported a significant decrease in CK concentrations in college students who received regular training for 12 weeks. Most of these findings suggest that CK and LDH levels in the muscles and blood are reduced with long-term training.

In this study, intergroup differences were not observed after 8 weeks of medium- and high-intensity interval training, but LDH and CK concentrations decreased compared to pre-exercise concentrations. These results are consistent with those of previous studies, which could be attributed to the strengthened mechanism for protection against cell damage following the improvement in physical strength, and long-term interval training may have a positive effect against direct cell membrane destruction and tissue necrosis, leading to fewer enzymes released from the cytoplasm to the blood.

In contrast, one-time high-intensity exercise causes muscle damage and inflammation (Galan et al., 2018). As an inflammatory cytokine, CRP is affected by high-intensity physical exercises, including long-distance running, marathon, and triathlon (Lippi et al., 2002). According to a previous study, it was reported that high-intensity resistance exercise causes muscle damage and increases the concentration of CRP (König et al., 2001). In contrast, regular exercise resolves inflammation and enhances anti-inflammatory effects (Nemet et al., 2012). Mattusch et al. (2000) examined the suppression of inflammatory response through training, and reported that CRP decreased after 9 months of endurance training in subjects who were preparing for a marathon.

In this study, the CRP and IL-6 levels decreased at rest after performing medium- and high-intensity interval training, with no significant intergroup differences. IL-6, which is an inflammatory marker, is kept at a relatively low level in the body of a normal athlete, which may be caused by reduction in fat tissues following regular interval training, resulting in a reduced number of vascular endothelial cells and macrophages and decreasing IL-6 production. Libardi et al. (2011) reported that IL-6 concentrations decreased after 16 weeks of medium- and high-intensity exercises, with no differences according to intensity. These results demonstrate that

regular exercise is effective in improving inflammation (Geffken et al., 2001; Timmerman et al., 2008), possibly because of increased adaptability of the body and physical performance in individuals after interval training, reducing the physical burden and increasing immunomodulation that could be advantageous in regulating inflammatory factors.

Exercise also imposes stress on the body, and the level of stress depends on the exercise duration, exercise intensity, and individual training level (Tianlong and Sim, 2019). Although studies examining the changes in stress hormone levels may report contradicting results, most report a significant increase during long-term exercises of at least a medium intensity, or during short-term high-intensity exercises (Duclos and Tabarin, 2016). Buono et al. (1985) reported that 12 weeks of endurance training at submaximal exercise intensity significantly decreased ACTH, and Kraemer et al. (1999) reported that ACTH significantly decreased whereas cortisol response increased in a compound exercise group, with no changes with 10 weeks of endurance training.

In this study, 8 weeks of interval training did not show a significant difference in terms of ACTH levels between the high- and medium-intensity training groups, although both groups showed decreased concentrations. In contrast, cortisol levels increased in both groups. These findings are consistent with those of Kraemer et al. (1999), which could be attributed to the increase in cortisol following exercise activating the sensitivity for the regulation of ACTH negative feedback (Viru et al., 2001). When exposed to physical and mental stress, ACTH secretion from the central nervous system and the pituitary gland is accelerated, but the body's stress response may improve through the repetitive process of continued interval training. Furthermore, ACTH secretion is less in athletes compared to that in the general population (Duclos and Tabarin, 2016), possibly because of the decrease in antidiuretic hormone and lactic acid concentration following regular exercise.

Our study results show that interval training of at least a medium intensity has a positive effect on blood stress hormones in sprinters. Meanwhile, the changes in LDH and ACTH had different effects on the 100-m sprint records between the two groups. Specifically, the change in ACTH had an effect on the high-intensity group.

In summary, the 8-week interval training significantly changed the levels of blood fatigue indicators, inflammatory markers, and stress hormones in sprinters, with no significant difference between high- and medium-intensity training. It is therefore believed that a training intensity of ≥75% of the HRR was above the threshold that could affect the changes in blood markers and 100-m sprint records in both groups.

CONFLICT OF INTEREST

No potential conflict of interest to this article was reported.

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REFERENCES

Apple FS, Rogers MA. Skeletal muscle lactate dehydrogenase isozyme alterations in men and women marathon runners. J Appl Physiol 1985;61:477-481.

Buono MJ, Yeager JE, Hodgdon JA. Plasma adrenocorticotropin and cortisol responses to brief high-intensity exercise in humans. J Appl Physiol 1985;61:1337-1339.

Deruisseau KC, Roberts LM, Kushnick MR, Evans AM, Austin K, Haymes EM. Iron status of young males and females performing weight-training exercise. Med Sci Sports Exerc 2004;36:241-248.

Duclos M, Tabarin A. Exercise and the hypothalamo-pituitary-adrenal axis. Front Home Res 2016;47:12-26.

Galan BS, Carvalho FG, Santos PC, Gobbi RB, Kalva-Filho CA, Papoti M, da Silva AS, Freitas EC. Effects of taurine on markers of muscle damage, inflammatory response and physical performance in triathletes. J Sports Med Phys Fitness 2018;58:1318-1324.

Geffken DF, Cushman M, Burke GL, Polak JF, Sakkinen PA, Tracy RP. Association between physical activity and markers of inflammation in a healthy elderly population. Am J Epidemiol 2001;153:242-250.

Hasenoehrl T, Wessner B, Tschan H, Vidotto C, Crevenna R, Csapo R. Eccentric resistance training intensity may affect the severity of exercise induced muscle damage. J Sports Med Phys Fitness 2017;57:1195-1204.

König D, Wagner KH, Elmadfa I, Berg A. Exercise and oxidative stress: significance of antioxidants with reference to inflammatory, muscular, and systemic stress. Exerc Immunol Rev 2001;7:108-133.

Kraemer WJ, Fleck SJ, Maresh CM, Ratamess NA, Gordon SE, Goetz KL, Harman EA, Frykman PN, Volek JS, Mazzetti SA, Fry AC, Marchitelli LJ, Patton JF. Acute hormonal responses to a single bout of heavy resistance exercise in trained power lifters and untrained men. Can J Appl Physiol 1999;24:524-537.

Libardi CA, Souza GV, Gáspari AF, Dos Santos CF, Leite ST, Dias R, Frollini AB, Brunelli DT, Cavaglieri CR, Madruga VA, Chacon-Mikahil MP. Effects of concurrent training on interleukin-6, tumour necrosis factor-alpha and C-reactive protein in middle-aged men. J Sports Sci 2011;29:1573-1581.

Lippi G, Bassi A, Guidi G, Zatti M. Relation between regular aerobic phys-

 https://doi.org/10.12965/jer.2142536.268

ical exercise and inflammatory markers. Am J Cardiol 2002;90:820.

Mantle D, Preedy VR. Adverse and beneficial functions of proteolytic enzymes in skeletal muscle. An overview. Adverse Drug React Toxicol Rev 2002;21:31-49.

Mattusch F, Dufaux B, Heine O, Mertens I, Rost R. Reduction of the plasma concentration of C-reactive protein following nine months of endurance training. Int J Sports Med 2000;21:21-24.

Messonnier L, Denis C, Prieur F, Lacour JR. Are the effects of training on fat metabolism involved in the improvement of performance during high-intensity exercise? Eur J Appl Physiol 2005;94:434-441.

Nemet D, Portal S, Zadik Z, Pilz-Burstein R, Adler-Portal D, Meckel Y, Eliakim A. Training increases anabolic response and reduces inflammatory response to a single practice in elite male adolescent volleyball players. J Pediatr Endocrinol Metab 2012;25:875-880.

Sacheck JM, Blumberg JB. Role of vitamin E and oxidative stress in exercise. Nutrition 2001;17:809-814.

Theofilidis G, Bogdanis GC, Koutedakis Y, Karatzaferi C. Monitoring exercise-induced muscle fatigue and adaptation: making sense of popular of emerging indices and biomarkers. Sports (Basel) 2018;26:153.

Tianlong D, Sim YJ. Effects of different recovery methods on postboxing sparring fatigue substance and stress hormones. J Exerc Rehabil 2019;15:258-263.

Timmerman KL, Flynn MG, Coen PM, Markofski MM, Pence BD. Exercise training-induced lowering of inflammatory (CD14+CD16+) monocytes: a role in the anti-inflammatory influence of exercise? J Leukoc Biol 2008;84:1271-1278.

Viru AM, Hackney AC, Välja E, Karelson K, Janson T, Viru M. Influence of prolonged continuous exercise on hormone responses to subsequent exercise in humans. Eur J Appl Physiol 2001;85:578-585.

Yang SH. The influence of judo masters' pre-season winter hard-training on fatigue substance, muscle injury marker and inflammation markers. Exerc Sci 2015;24:39-48.