SPORT TK-EuroAmerican Journal of Sport Sciences

https://revistas.um.es/sportk Online ISSN: 2340-8812

Received: **25/02/2025.** Accepted: **04/07/2025.** Published: **10/10/2025**

Effects of high-intensity interval training on hemoglobin levels and oxygen saturation in healthy males

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ABSTRACT

The aim of the study was to examine the effects of high-intensity interval training (HIIT) with high-intensity continuous training (HICT) on increasing hemoglobin levels and oxygen saturation in healthy men. This study used a quasi-experiment with a pre-test-post-test group design. A total of 40 healthy male adolescents, aged 19-22 years, with a body mass index (BMI) of 20-24 kg/m^2 and normal blood pressure, were recruited from university students and given HIIT and HICT intervention programs for 30 minutes. Hemoglobin levels were measured using Mission® Hemoglobin Test Strips, while oxygen saturation (SpO_2) and heart rate (HR) were measured using an Oxyone Pulse Oximeter. The mean pre-HIIT and HICT hemoglobin levels were 16.86 ± 1.39 vs 16.34 ± 1.28 g/dL ($p = 0.221$), and post-intervention were 18.36 ± 0.96 vs 15.41 ± 1.55 g/dL ($p = 0.000$). SpO_2 pre-values between HIIT and HICT were 96.75 ± 1.37 vs 96.45 ± 1.36 % ($p = 0.491$), and post-values were 97.85 ± 1.23 vs 96.15 ± 1.35 % ($p = 0.000$). HR pre-values between HIIT and HICT were 71.40 ± 7.03 vs 71.20 ± 7.98 bpm ($p = 0.933$), and post-values were 81.25 ± 11.79 vs 97.05 ± 5.54 bpm ($p = 0.000$). The study concluded that HIIT was effective in increasing hemoglobin and SpO_2 levels as an indicator of cardiorespiratory fitness compared to HICT. Furthermore, HIIT was also found to be more effective at speeding up HR recovery.

KEYWORDS

HIIT; Hemoglobin; Oxygen Saturation; Heart Rate; Healthy Males

1. INTRODUCTION

Lack of oxygen in the body has a very detrimental impact (Midha et al., 2023). This is because oxygen plays a central role in cellular homeostasis (Adebayo & Nakshatri, 2022). Oxygen is tightly regulated in the body because hypoxemia can cause many acute side effects on individual organ systems (Hafen et al., 2022). Approximately 50% of highly trained athletes exhibit exercise-induced arterial hypoxemia (Ohya et al., 2016). Hypoxia is a condition in which the body or specific body parts lack adequate oxygen supply at the tissue level (Bhattacharjee et al., 2023). Oxygen levels in the blood can be measured using pulse oximetry (Ehrenfeld et al., 2010). Pulse oximetry is a non-invasive monitor that measures oxygen saturation in the blood by shining a light at a certain wavelength through tissue (Torp et al., 2022). Oxygen saturation uses wavelengths in the range of 680-870 nm to separate oxygenated/deoxygenated hemoglobin (Magasich-Airola et al., 2023). Oxygen binds to hemoglobin and is circulated in the blood vessels from the lungs to all body tissues to meet metabolic needs (Chen et al., 2023; Cherian, 2022; Cohn, 2015).

Oxygen is a necessary catalyst for mitochondria to produce Adenosine triphosphate (ATP) and other intracellular reactions (Yuan et al., 2023). The use of hypoxia-induced factor stabilizers is expected to aid in the cure of anemia but, in the long term, has the potential to lead to worsened cardiovascular and metabolic outcomes (Kanbay et al., 2023). Cardiovascular disease is the leading cause of death globally (Gaidai et al., 2023), and metabolism is the sum of the life-giving chemical processes that occur in cells (Prouteau & Loewith, 2018).

Exercise has a powerful effect on metabolism, not only because of its well-known influence on skeletal muscle metabolism but also as a result of the metabolic adaptations exerted on many other tissues (Thyfault & Bergouignan et al., 2020), and oxygen is a critical regulator of cellular function and phenotype (Sitte et al., 2023). Abouzeid et al. (2023) stated that the high-intensity interval training (HIIT) program increased cardiorespiratory fitness and hematological variables. Another opinion by Valkenborghs et al. (2022) shows that the most common characteristic of a training program is an aerobic exercise with moderate to vigorous intensity which is performed for 30-45 minutes 3 times per week. Meta-analysis revealed significant improvements in cardiorespiratory fitness, functional fitness, and physical fitness related to overall health (Valkenborghs et al., 2022). This statement shows that aerobic exercise is agreed upon as the most recommended method to improve cardiorespiratory fitness due to the involvement of oxygen regulation during exercise. However, research by Tamayo Acosta et al. (2022) reported that HIIT was considered more effective in increasing cardiorespiratory fitness through increasing $\dot{V}O_2max$ than aerobic exercise. These results are still controversial regarding how to improve cardiorespiratory fitness.

Cardiac output, pulmonary function, blood oxygen-carrying capacity, and peripheral arteriovenous oxygen extraction capacity are physiological determinants of cardiorespiratory fitness and are also known as cardiorespiratory limiting factors (Nilsen et al., 2023). This shows that many variables can be indicators of the level of cardiorespiratory fitness, so we want to measure the level of cardiorespiratory fitness by measuring hemoglobin to determine the quality of oxygen binding in circulation and oxygen concentration in the blood to determine the quantity of oxygen circulated to meet oxygen demand in cellular metabolism. Therefore, this study aims to prove the effect of HIIT with HICT on increasing hemoglobin levels and oxygen saturation in healthy males.

2. METHODS

2.1. Design and Participants

This research was a quasi-experiment with a pre-test-post-test group design. A total of 40 healthy male adolescents, aged 19-22 years, with body mass index (BMI) of 20-24 kg/m^2, and having normal blood pressure were recruited from students of the Department of Sports Science, Faculty of Sports Science, State University of Malang. All sample members involved in this experiment were non-athletes, without a smoking history or even alcohol consumption. During the experiment period, it was ensured that all sample members were not participating in any external sports activity or exercise. All subjects received an explanation before participating in the study and voluntarily declared their participation in the study as evidenced by filling out and signing an informed consent. All protocols implemented in this study complied with the Helsinki World Medical Association Declaration on the ethical conduct of research involving human subjects.

2.2. Intervention Programs

The high-intensity interval training (HIIT) and high-intensity continuous training (HICT) intervention programs were implemented and accompanied by professional staff from the Department of Sports Science, Faculty of Sports Science, State University of Malang, East Java 65145, Indonesia. HIIT is carried out for 30 minutes with details of 5 minutes of warming up with an intensity of 50-60% HRmax, with the core exercise carried out by pedaling an ergo cycle Monark model 829 E which is carried out at intervals with an intensity of 80-90% HRmax for 30 seconds followed by active rest for 150 seconds with an intensity of 60% HRmax and performed 10 repetitions, 5 minutes of cooling down with an intensity of 50-60% HRmax. HICT is performed for 30 minutes with details of 5 minutes of warming up with an intensity of 50-60% HRmax, the core exercise is carried out by pedaling the ergo cycle Monark model 829 E which is carried out continuously with an intensity of 80-90% HRmax for 20 minutes, 5 minutes of cooling down with intensity 50-60% HRmax. The HRmax determination uses the 220-age in years formulation (Pranoto et al., 2023). HR monitoring during the intervention using the Polar H10 Heart Rate Sensor (Permana et al., 2022).

2.3. Measurements

The data collection process was carried out by measuring anthropometry which included height and weight using the Seca 213 Price Stadiometer. Calculation of BMI uses the formula for body weight (kg) divided by body height (m^2) (Raharjo et al., 2021). Blood pressure (systolic and diastolic) was measured using the OMRON model JPN 600 digital tension meter (Andiana et al., 2022). Measurement of oxygen saturation (SpO_2) and heart rate (HR) using an Oxyone Pulse Oximeter. Body temperature was measured using the OMRON Digital Thermometer Model Mc-246. Hemoglobin levels were measured using Mission Hemoglobin (Mission® Hb Test Strips, San Diego, CA, USA) which was carried on the tip of the middle finger.

2.4. Statistical Analysis

Data analysis techniques used paired sample t-test and independent sample t-test with a significant level of 5%. All statistical analysis were conducted using SPSS version 21 software (IBM SPSS® Statistics, Chicago, USA).

3. RESULTS

The results of the analysis of hemoglobin levels, oxygen saturation (SpO_2), body temperature (BT), and reduced heart rate (HR) between pre and post in both groups are presented in Figure 1 and Table 2.

Table 1. The physical characteristics of the research subjects

Parameters	n	HIIT	HICT	p-values
Age (yrs)	20	21.20±1.24	20.90±1.25	0.451
Height (m)	20	1.67±0.05	1.66±0.04	0.481
Weight (kg)	20	62.22±5.11	59.95±5.01	0.165
BMI (kg/m^2)	20	22.26±0.99	21.73±1.25	0.145
SBP (mmHg)	20	115.15±5.42	114.70±3.84	0.764
DBP (mmHg)	20	71.30±4.17	72.80±4.67	0.291
HR (bpm)	20	71.40±7.03	70.20±7.54	0.606
SpO_2 (%)	20	96.75±1.37	96.45±1.36	0.491
BT (°C)	20	35.51±0.57	35.72±0.66	0.279

Note. *BMI: Body mass index; BT: body temperature; DBP: Diastolic blood pressure; HICT: High-intensity continuous training; HIIT: High-intensity interval training; HR: Heart rate; SBP: systolic blood pressure; SpO_2: Oxygen saturation.*

According to Table 1, there were not any statistically significant differences in age, anthropometric measures, blood pressure, heart rate, oxygen saturation or body temperature between the subjects placed in HIIT and HICT groups (p > 005), indicating similarity between subjects at baseline

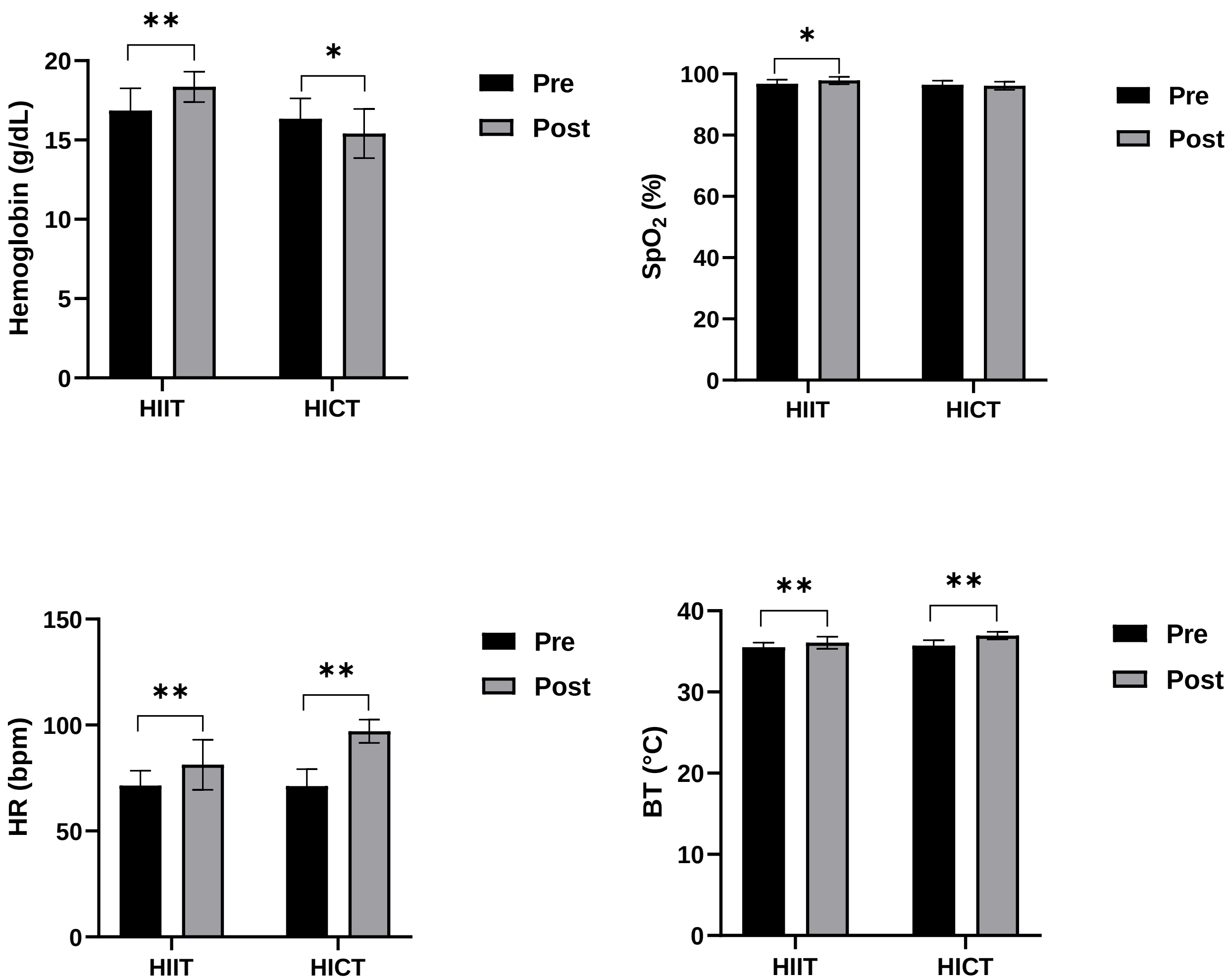

Figure 1. The analysis of hemoglobin levels, SpO_2, HR, BT, and BT between pre and post on HIIT and HICT

Note. *(*)Significant at pre ($p \leq 0.05$). (**)Significant at pre ($p \leq 0.001$). Data were displayed mean±SD. Different tests using paired sample t-test (p-value).*

Table 2 presents the comparison of physiological responses—hemoglobin levels, oxygen saturation (SpO_2), heart rate (HR), and body temperature (BT)—between the HIIT and HICT groups, measured before (pre) and after (post) the training sessions.

Table 2. The analysis of hemoglobin levels, SpO_2, HR, and BT between HIIT and HICT at pre and post delta

Parameters	n	HIIT	HICT	p-values
Hemoglobin (g/dL)				
Pre	20	16.86±1.39	16.34±1.28	0.221
Post	20	18.36±0.96**	15.41±1.55	0.000
Delta (Δ)	20	1.49±1.36**	-0.93±1.68	0.000
Oxygen Saturation (%)				
Pre	20	96.75±1.37	96.45±1.36	0.491
Post	20	97.85±1.23**	96.15±1.35	0.000
Delta (Δ)	20	1.10±1.89*	-0.30±1.75	0.020
Heart Rate (bpm)				
Pre	20	71.40±7.03	71.20±7.98	0.933
Post	20	81.25±11.79**	97.05±5.54	0.000
Delta (Δ)	20	9.85±11.60**	25.85±8.03	0.000
Body Temperature (°C)				
Pre	20	35.51±0.57	35.72±0.66	0.279
Post	20	36.08±0.75	36.94±0.47††	0.000
Delta (Δ)	20	0.58±0.66	1.22±0.68†	0.004

Note. *(*)Significant at HICT ($p \leq 0.05$). (**)Significant at HICT ($p \leq 0.001$). (†)Significant at HIIT ($p \leq 0.05$). (††)Significant at HIIT ($p \leq 0.001$). Data were displayed mean±SD. Different tests using independent sample t-test (p-value).*

Table 2 showed significant changes in hemoglobin, oxygen saturation, heart rate, and body temperature after training ($p < 0.05$). HIIT was considered more effective than HICT.

4. DISCUSSION

Based on the results of the study, it was shown that HIIT and MICT significantly increased hemoglobin levels, oxygen saturation (SpO_2), and body temperature (BT) and accelerated the decrease in heart rate (HR) in healthy male adolescents (Figure 1). However, HIIT was considered more effective than HICT (Table 2).

These results are in line with the research of Abouzeid et al. (2023) who reported that HIIT significantly improved cardiorespiratory fitness and hematological variables. Research by Valkenborghs et al. (2022) found different results that the most common exercise to improve cardiorespiratory was moderate to vigorous intensity aerobic exercise performed for 30-45 minutes 3 days/week. However, the results by Tamayo Acosta et al. (2022) state that HIIT is considered more effective in improving cardiorespiratory fitness than aerobic exercise. HIIT has been promoted as a time-saving exercise strategy to improve health and fitness in children and adolescents (Poon et al., 2023). Individuals who do regular exercise have been associated with a reduced risk of cardiovascular disease and increased cardiorespiratory fitness compared to individuals with less physical activity (Chang et al., 2023). Therefore, the implementation of the HIIT program properly and correctly is proven to be effective in improving cardiorespiratory fitness by increasing hematological variables, including increasing hemoglobin levels, SpO_2, and decreasing HR immediately after exercise.

The enhanced adaptations observed in the HIIT group are explained through alternate efforts and recoveries, placing greater physiological loads on the cardiorespiratory systems. Intermittent form of pattern is likely to enhance erythropoiesis, oxygen delivery, and metabolic efficiency over continuous high-intensity exercise. Also, increased heart rate and oxygen saturation responses reflect better autonomic function and faster recovery after HIIT sessions

5. CONCLUSIONS

Based on the results of the current study it can be concluded that high-intensity continuous training (HIIT) effectively increases hemoglobin and SpO_2 levels as indicators of cardiorespiratory fitness compared to high-intensity continuous training (HICT) in healthy male adolescents. HIIT is also considered more effective in accelerating heart rate recovery than HICT.

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AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

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