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Acute Effects of Normoxic and Hypoxic High-Intensity Interval Exercise on Hemodynamics and Cutaneous Blood Flow in Youth Soccer Players

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ABSTRACT

Suwannarat R, Srihirun K, Brito J, Suksom D. Acute effects of Normoxic and Hypoxic High-Intensity Interval Exercise on Hemodynamics and Cutaneous Blood Flow in Youth Soccer Players. **JEPonline** 2017;20(2):92-98. The purpose of this study was to determine the acute effects of High-Intensity Interval Exercise (HIIE) in normoxia and hypoxia on hemodynamics and cutaneous blood flow in youth soccer players. Fifteen male soccer players (age, 13 yrs) were recruited to participate in this study. All subjects performed 4 sets of 4 min of running at 90 to 95% of HR max alternated with 3 min of running at 60 to 70% of HR max in both normoxic (21% O_2) and hypoxic (15.3% O_2) conditions on separated weeks. The subjects' hemodynamics were determined using a non-invasive impedance cardiography device during both exercise sessions continuously. Cutaneous blood flow and vascular reactivity were measured using laser doppler flowmetry device before and after each exercise session. The findings indicate that heart rate, stroke volume, and cardiac output during HIIE were significantly greater ($P<0.05$) in hypoxia compared with normoxia. Peak cutaneous blood flow increased to a greater extent ($P<0.05$) after HIIE in hypoxia than normoxia. There was no change in % post occlusive reactive hyperemia after HIIE in both normoxia and hypoxia. Thus, the HIIE in hypoxia had more intense effects on hemodynamics and cutaneous blood flow than normoxia in youth soccer players. However, no change of micro-vascular reactivity was found after HIIE in both normoxia and hypoxia.

Key Words: Cutaneous Blood Flow, Hemodynamics, High-Intensity Interval Exercise (HIIE), Normobaric Hypoxia

INTRODUCTION

In soccer, optimal performance encompasses the integration of physiological, technical, and tactical skills (1). Soccer match play has been classified as a high-intensity intermittent sport, with players ordinarily running 10 to 12 km at 80 to 90% of maximum heart rate (2). High intensity interval exercise (HIIE) is characterized by repeated periods of strenuous exercise interspersed with periods of recovery (3), which leads to the need for improvement in improved aerobic (4,5) and anaerobic capacity (6,7) in soccer players. Also, soccer players need to develop speed endurance and running fatigue resistance (8).

Altitude and hypoxic training are a common practice for improving aerobic capacity and endurance performance. Theoretically, the stress of hypoxic exposure, in addition to training stress, accentuates the training adaptations experienced with normal endurance training plus it leads to a greater improvement in athletic performance (9). It is believed that adding the stress hypoxia during HIIE would produce a greater influence on the physiological change in athletes compared to training at sea level (10). Thus, the “live low, train high” procedure has been developed for athletes who live in the normoxic condition, but train in the natural, hypobaric or simulated normobaric hypoxic condition (11).

Little is known regarding the effects of hypoxic training integrated with HIIE on hemodynamics and microvascular function in athletes. Therefore, the purpose of this study was to determine the acute effects of HIIE in hypoxia on heart rate, stroke volume, and cardiac output during exercise as well as measuring resting cutaneous blood flow and post occlusive reactive hyperemia at pre- and post-exercise in youth soccer players. To assess the impact of different conditions, we compared the subjects’ hemodynamic responses and their microvascular reactivity following HIIE in hypoxia and normoxia conditions. This study hypothesized that HIIE in hypoxia condition would result in a more intense effect on hemodynamics and cutaneous blood flow in soccer players than normoxic condition.

METHODS

Subjects

Fifteen male soccer players (age, 13 yrs; height, 162.1 ± 7.8 cm; weight, 49.0 ± 9.8 kg) who played soccer for at least 2 yrs prior to participating in this study were recruited. All subjects and their parents gave their written informed consents before participation. The study was approved by the Ethics Review Committee at Chulalongkorn University. Medical history was obtained. Subjects with hypertension, asthma, and cardiovascular disease were excluded.

Procedures

The subjects were examined in a crossover design of high-intensity interval exercise (HIIE) at normoxia (21% O_2) and normobaric hypoxia (15.3% O_2) on two visits to the laboratory. Both examinations were separated by at least 7 days. All subjects were asked to refrain from strenuous physical activities before each test. The measurements including resting body composition, hemodynamic variables, and cutaneous blood flow at pre- and post-HIIE. The HIIE consisted of 4 sets of 4 min of 90 to 95% of maximal heart rate, which was alternated with 3 min at 60 to 70% of maximal heart rate. All experiments were conducted in an air-conditioned laboratory with the room temperature at 25^{o}C.

Experimental Protocol

Body Composition and Hemodynamics Variables

The subjects' body composition (i.e., height, weight, and percent body fat) was determined by the bioelectrical impedance method using a standardized body composition analyzer (bioelectrical impedance analyzer, ioi 353, Jawon Medical, Korea). Resting heart rate and blood pressure were measured with a semi-automated blood pressure device (CARESCAPE V100, GE Dinamap, USA). The hemodynamic variables [heart rate, HR; stroke volume, SV; and cardiac output, CO] were continuously recorded using an impedance cardiography device (PhysioFlow® PF07 Enduro™, USA).

Cutaneous Blood Flow

Cutaneous blood flow was measured on the ventral part of right wrist while the subject was in a supine position using a laser doppler flowmetry (DRT4 MoorLAB, Moor Instrument, Devon, UK). After a 5 min basal cutaneous blood flow recording, a cuff was placed on the forearm proximal to doppler probe and inflated to a supra-systolic pressure for 5 min. The cuff was released after a 5-min occlusion to induce a transient increase in blood flow that was expressed as a peak cutaneous blood flow. Post-occlusive reactive hyperemia (PORH), an index of microvascular function was calculated as (peak cutaneous blood flow – baseline cutaneous blood flow)/baseline cutaneous blood flow × 100 (12).

Statistical Analyses

Data were analyzed using SPSS statistical software (SPSS version 17.0, SPSS Inc.,Chicago, IL). Prior to the parametric tests, the tests for normal distribution were performed and verified. Paired sample *t*-test was used to compare between pretest and posttest within group. Independent sample *t*-test was used to compare between-group differences. Descriptive data are expressed as mean ± SD, and the α-level was set at $P<0.05$ for statistical significance.

RESULTS

The subjects' resting body composition, heart rate, and blood pressure are shown in Table 1. The mean values of weight, body fat, BMI, and heart rate were lower (all $P<0.05$), while heart rate, systolic blood pressure, diastolic blood pressure, and mean blood pressure were higher (all $P<0.05$) following HIIE in both at the normoxia and the hypoxia conditions.

Table 1. Resting Body Composition, Heart Rate and Blood Pressure at Pre-and Post-HIIE in Normoxia and Hypoxia.

Variable	HIIE at Normoxia		HIIE at Hypoxia	
	Pre	Post	Pre	Post
Weight (kg)	49.3 ± 9.8	48.5 ± 9.6*	49.19 ± 9.5	48.4 ± 9.5*
Body Fat (%)	9.0 ± 5.1	7.8 ± 4.5*	7.8 ± 4.4	7.1 ± 4.3*
BMI ($kg \cdot m^{-2}$)	18.6 ± 2.3	17.3 ± 2.3*	18.3 ± 2.2	17.8 ± 2.2*
HR ($beats \cdot min^{-1}$)	80.7 ± 6.7	94.4 ± 3.7*	85.0 ± 12.4	98.3 ± 8.6*
SBP (mmHg)	116.3 ± 9.8	119.1 ± 9.5*	117.7 ± 8.4	119.6 ± 8.6*
DBP (mmHg)	70.0 ± 4.5	72.1 ± 4.7*	70.3 ± 5.7	72.9 ± 5.5*
MBP (mmHg)	81.0 ± 9.1	83.5 ± 8.8*	81.9 ± 5.4	84.2 ± 5.5*

Data are mean ± SD. **BMI** = body mass index, **HR** = heart rate, **SBP** = systolic blood pressure, **DBP** = diastolic blood pressure, **MBP** = mean blood pressure. *$P<0.05$ pre vs. post in the same group

As illustrated in Figure 1, the time course of hemodynamics variables, stroke volume and cardiac output, were higher (P<0.05) during HIIE in hypoxia than in normoxia.

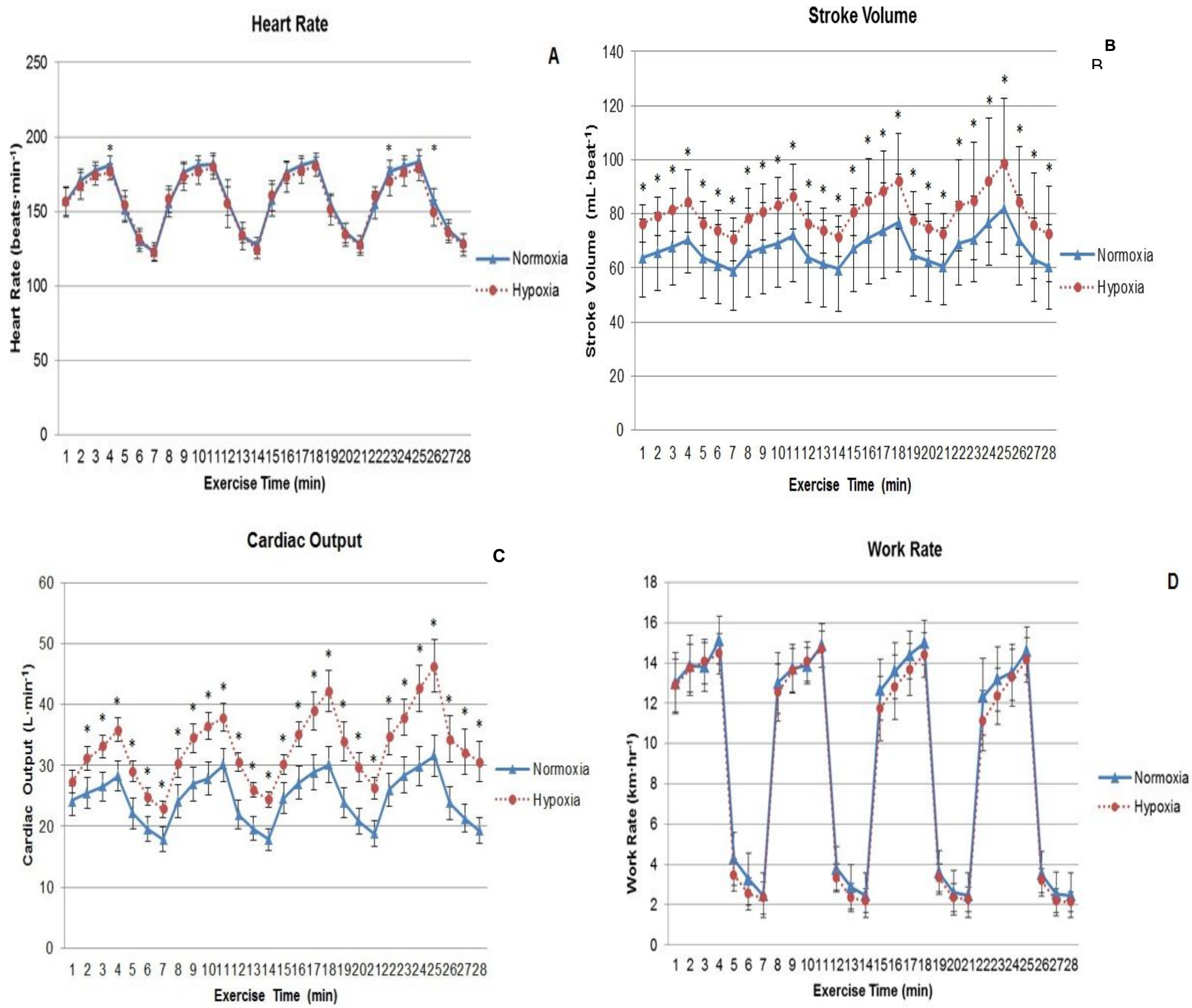

Figure 1. Hemodynamics: (A) Heart Rate; (B) Stroke Volume; (C) Cardiac Output; and (D) Work Rate Response to HIIE in Normoxia and Hypoxia. *P<0.05 normoxia vs. hypoxia

As show in Figure 2, peak cutaneous blood flow was higher after HIIE in both normoxia and hypoxia and peak cutaneous blood flow was higher in hypoxia than in normoxia (P<0.05). However, there was no change in PORH after HIIE in both normoxia and hypoxia.

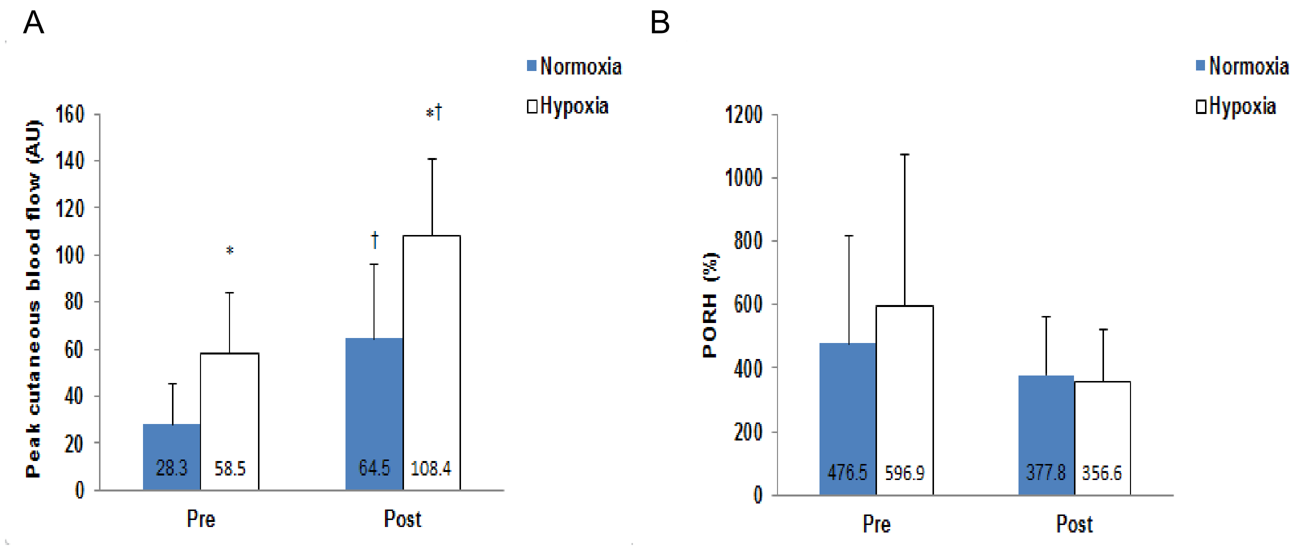

Figure 2. Cutaneous Blood Flow: (A) Peak Cutaneous Blood Flow and (B) Post-Occlusive Reactive Hyperemia (PORH) at Pre- and Post-HIIE in Normoxia and Hypoxia. †$P<0.05$ pre vs. post; *$P<0.05$ normoxia vs. hypoxia

DISCUSSION

The major findings of this study were that the youth soccer players demonstrated a higher stroke volume, cardiac output, and peak cutaneous blood flow following HIIE in hypoxia than in normoxia. However, either HIIE in normoxia or hypoxia did not have an influence on the subjects' microvascular reactivity as no change of PORH was found after HIIE in both normoxia and hypoxia.

In the current study, blood flow related phase shifts of transthoracic electric signals for continuous noninvasive cardiac hemodynamics were monitored. The results showed that performing the same exercise workload during normoxia and hypoxia, HIIE in hypoxia resulted in a higher stroke volume and cardiac output than normoxia. Hypoxic (15.3% of O_2) HIIE regimen augmented those hemodynamic variables possibly via sympathetic activation and circulating catecholamines. The hypoxia-induced tachycardia led to an increase in cardiac output that occurred from an increase in sympathetic activity, given that plasma norepinephrine concentration has been found elevated in previous studies that tested acute hypoxia at rest or exercise (13,14). Since 77% of total cardiac output was directed to the working legs, 14 to 16% to the respiratory muscles and 7 to 9% to other metabolically active tissues (15), the elevated cardiac output evoked by hypoxia might have beneficial effects for exercise performance in youth soccer players.

The present study demonstrates that youth soccer players performing HIIE exhibit an increased peak cutaneous blood flow that was significantly higher in hypoxia when compared to normoxia. These findings indicate that HIIE was sufficient to enhance skin blood flow perfusion. This response might be due to reaching the core temperature threshold, which is when the skin blood flow begins to rise as HIIE progresses (16). This response suggests that HIIE reflects the onset of active vasodilator activity in either normoxic or hypoxic conditions, but does so better in the hypoxia condition. However, we did not observe any significant difference in PORH after HIIE in both normoxic and hypoxic conditions. Improving endothelial function might occur as a result of regular exercise, mainly when intensity is high enough to increase blood flow and shear stress repeatedly that leads to improve endothelial nitric oxide bioavailability (17). In general, it seems that one single bout of HIIE in either normoxia or hypoxia was insufficient to induce a significant increase in microvascular reactivity.

CONCLUSION

Based on the data from the present study, the HIIE in hypoxia condition had more intense effects on hemodynamics and cutaneous blood flow in youth soccer players than the normoxic condition. Our findings suggest that HIIE in hypoxia might be an effective training regimen for youth soccer players to improve aerobic fitness and performance during match play.

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