Acute Effects of Hypoxia and High Intensity Interval Exercise on Health Promotion Among Male University Students

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Keywords: High Intensity Interval Exercise (HIIE), Hypoxia, Health Promotion.

Abstract: The aim of this study was to verify the acute effects of hypoxic high intensity interval exercise (HIIE) on health promotion (Blood Pressure). Ten healthy university students participated and undertook the four random exercise trials: rest in hypoxia (RH), rest in normoxia (RN), normoxic HIIE (NH), and hypoxic HIIE (HH). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were evaluated before and 30 min after each trial. Both HH and NH led to post-exercise hypotension (PEH) during the post-test 30 minutes in trials compared with RN trial, but the decrease magnitude of SBP and DBP did not reach significant trial differences ($p > .05$). Significant decrease in SBP was only found in HH trial, and the duration of PEH in HH was longer than that in NH during the 30-minute post-test observation. Exercise could make students feel happier. HIIE can lead to PEH in both normoxic and hypoxic environment, while hypoxia strengthens this effect. And HIIE help improve the affective feeling for university students.

1 INTRODUCTION

Almost 1.13 billion people in the world have hypertension, of whom two-thirds are living in low- and middle-income countries and hypertension is claimed as a global public health crisis (World Health Organization, 2021).

Studies have found that essential hypertension in adults may originate in childhood. Prevention and control of hypertension in adolescents can control the occurrence and development of cardiovascular disease in adults. University students are a very large group of adolescents. If good living habits and exercise methods are developed during their college years, it not only will be beneficial for their physical and mental health, but also has great significance to the development of country education.

As such, researchers suggest that it is preventable that blood pressure (BP) can be influenced by several issues such as height, weight, fat, daily diet, environment and physical activity (Diaz, 2013). The benefit of low to moderate intensity endurance and resistance exercise programs has been well supported by previous researches (Cardoso Jr, 2010). However, Levinger and colleagues (Levinger, 2015) reported that 60% of people could not meet the minimum-recommended level of regular physical activity, in which people found it difficult to spend at least 150 minutes per week in doing moderate-intensity aerobic exercise. Hence, “no time” could be one of the main barriers for adhering in regular low to moderate intensity exercise programs.

Given this, high intensity interval exercise (HIIE), are attracting more attention and interest from university students. Hypoxic environment has been suggested to be beneficial in clinical conditions such as coronary artery disease and chronic obstructive pulmonary disease (Burtscher, 2010). HIIE may cause stronger decrease in BP in a hypoxic environment after exercise. However, less studies have paid attention to the BP responses after hypoxic HIIE or normoxic HIIE. Consequently, the purpose of the current research was to compare the BP responses and affective feeling after hypoxic HIIE or normoxic HIIE compared to the conditions of rest in hypoxia or in normoxia in healthy male university students.

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Wei, X., Liang, X. and Wang, S.
Acute Effects of Hypoxia and High Intensity Interval Exercise on Health Promotion Among Male University Students.
DOI: 10.5220/0012018800003633
In *Proceedings of the 4th International Conference on Biotechnology and Biomedicine (ICBB 2022)*, pages 228-234
ISBN: 978-989-758-637-8

2 METHODOLOGY

The current research focused on the acute effects of HIIE under hypoxic and normoxic environment on the BP responses during and after a HIIE trial among male university students. Additionally, this study examined the correlations between BP responses and individuals' characteristics.

15 young physically inactive male university students with normotensive BP were invited to participate in the study. Finally, ten qualified male participants were recruited and completed this study.

Subjects completed a brief medical history questionnaire and a physical activity readiness questionnaire prior to participation to rule out any contraindications to performing vigorous exercise. Details of exercise testing and risks associated with the experimental procedures were explained to subjects before they provide written inform consent.

2.1 Study Design

Prior to the experiment, participants were invited to present to the laboratory for an initial visit in order to be familiar with the procedures of the experiment and to complete the anthropometric measurements. During this session, height (cm), weight (kg), body composition, and resting BP were measured. Subjects also completed a bout of cycling sprint on a cycle ergometer (Wingate Anaerobic Test protocol). During the next four visits, participants were asked to complete randomly the main experimental conditions—rest in hypoxia (RH), rest in normoxia (RN), normoxic HIIE (NH), and hypoxic HIIE (HH). All trials were separated by at least two days and conducted during 5PM and 9PM. All the four trials were performed in one month to ensure the similar physiological conditions.

Participants were asked to maintain free-living conditions during the experimental period and be instructed to abstain from strenuous exercise and consumption of alcohol for 24 hours, caffeine for 12 hours, and food for 2 hours before the beginning of each trial. Daily activities were recorded in a diary of the prior 48 hours before each trial. The levels of light, humidity, and atmospheric pressure in the laboratory were controlled to remain stable, and the temperature was controlled at 20°C.

During the periods when a trial started five minutes before and 30 minutes after, participants were asked to be seated on a chair and listened to the rhythm of 24 BPM and in an upright seated position for the recording of ambulatory BP measurement. HIIE consisted of two 30-second bouts of sprint exercise on a cycle ergometer (Monark Ergomedic 894E, Monark, Sweden) separated by four minutes of recovery. Participants performed the sprints against a braking force calculated as the kilogram of body mass multiplied by 0.075. The simulated hypoxia (AltiTrainer, SMTEC, Switzerland) was set to be equal to 2500m altitude. Subjects wore breathing masks one minute before the test. Additionally, mask was taken off immediately when the exercise ended. HR, Ratings of Perceived Exertion (RPE), Affective Scale and Blood Oxygen Saturation (SO2) were recorded during the experiment.

Participants remained seated for 10-minute period of rest before moving to the ergometer and being matched with Portapres device (Portapres Model 2, TNO Biomedical Instrumentation, Amsterdam, Netherlands). After the exercise, participants seated on the chair for 30 minutes for recording. Subjects were asked to rest on the chair immediately after the exercise.

2.2 Statistical Analysis

Statistical analyses were performed using SPSS 20.0 for Windows (SPSS Inc., Chicago, Chicago, Ill., USA). Data was reported as mean ± SD. Statistical significance was assumed at $p < 0.05$.

3 RESULTS

3.1 Subject Characteristics

Initially, 15 individuals were invited to participate in the study. Five of these potential participants were removed from the experiments as they did not meet the inclusion criteria for medical history (n=1), daily physical activity (n=2), or dropped out for personal reasons (n=2), leaving ten participants for final participation. All the enlisted participants (n=10) completed the study, and anthropometric and descriptive results are presented in Table 1. Exercise data is shown in Table 2.

Table 1: Subjects Characteristics.

	Mean	Std. Deviation
Age (year)	23.70	1.06
Height (cm)	173.5	5.26
Weight (kg)	67.37	5.91
BMI (kg/m^2)	22.36	1.09
Fat (%)	16.03	2.66
VO_{2peak} (ml/kg/min)	37.20	5.37

Table 2: Power Output and Rate of Fatigue for Sprinting Exercise.

	NH		HH	
	1_Sprint	2_Sprint	1_Sprint	2_Sprint
Absolute PP (W)	667±149	625±113	611±74.1	588±86.9
Relative PP (W/Kg)	9.99±2.44	9.31±1.68	9.14±1.49	8.75±1.30
Absolute MP (W)	454±86.1*	403±69.8	424±45.3	399±51.1
Relative MP (W/kg)	6.76±1.29*	5.99±0.96	6.31±0.55	5.91±0.45
Rate of fatigue (%)	84.1±17.7	83.8±16.3	89.2±17.8	76.4±17.1

Note. * $p < .05$ PP: peak power MP: mean power

3.2 BP Responses to Acute Hypoxia and HIIE

Pre-test values of SBP and DBP of the four trials were compared in order to ensure that these pre-test values were approximately identical. Results showed that the pre-test values of SBP and DBP were not significantly different among all trials ($p > 0.05$). These results, therefore, supported that the pre-exercise BPs of all trials are not varied with each other. The results are shown in Table 3.

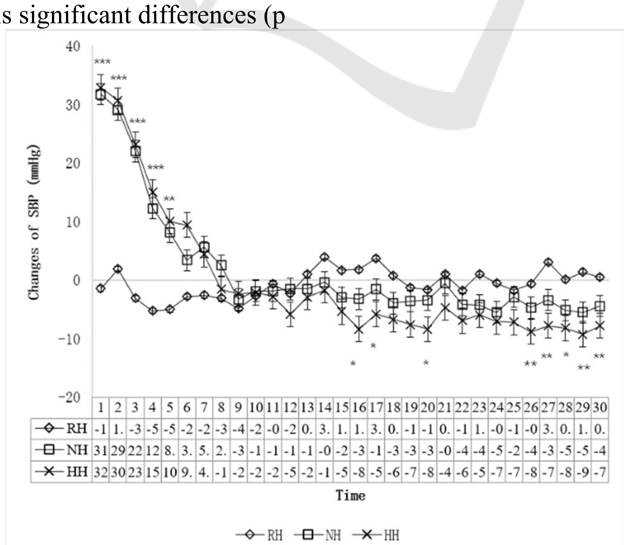
Table 3: Pre-test Values of BP Values.

	RN	RH	NH	HH	*p*
SBP (mmHg)	122±9	123±8	122±8	123±7	0.914
DBP (mmHg)	68±5	65±5	65±5	66±5	0.966

3.3 SBP Responses After Test

The changes of post-test SBP values are shown in Figure 1. Among four trials significant differences ($p < .01$) were found during the 1 to 5, 26 to 27, and 29 to 30 minutes and significant differences were found during the 16 to 17, 20, and 28 minutes.

During 1 to 5 minutes, SBP increased significantly. Specifically, SBP in the NH trial significantly increased compared with RN trial (ps < .05, .01 or .001) during 1 to 4 minutes and RH trial (ps < .05, .01 or .001) during 1 to 5 minutes. SBP in the HH trial significantly increased compared with RN trial (ps < .05 or .01) during 1 to 3 minutes and RH trial (ps < .01 or .001) during 1 to 4 minutes. SBP significant decreased after post-test 16 minutes. In post-test 17, 26, 27, and 30 minutes, significant differences were found between HH and RN ($p < .05$); in post-test 16, 28, and 29 minutes, marginal significant differences were found between HH and RH (p = .077, .084 and .055, respectively). However, no significant differences were found among NH, RN and RH ($p > .05$) tests during the post-test 30 minutes, and the same as NH and HH tests.



Note. SBP value of RN was not included in the figure as it was set to be the baseline level (i.e. zero) for the analyses.
a All values during the 30-minute recovery were separated into one data point using an interval of every minute.
* $p < .05$. ** $p < .01$. *** $p < .001$

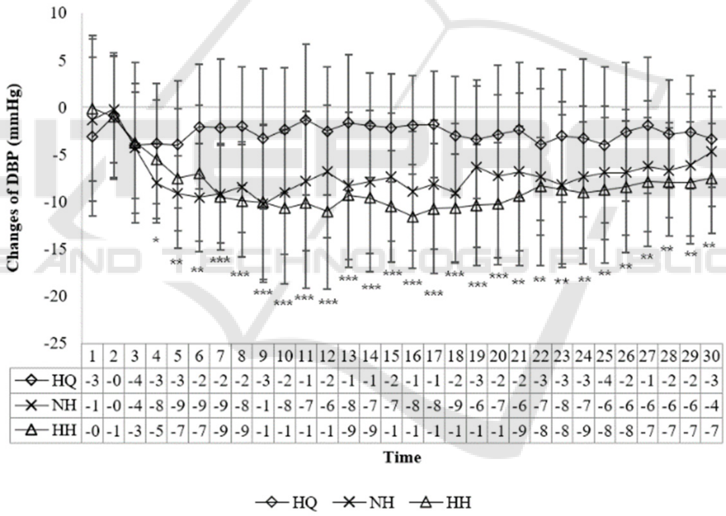
Figure 1: Changes of Post-test SBP Values Compared with RN.

3.4 DBP Responses After Test

The changes of post-test DBP values are shown in Figure 2. During the 30-minute observation after the tests of the four trials, significant results were found for most of the time period except during post-test 1 to 3 minutes (p > .05). After the 4th minute, significant or highly significant differences were found among the four trials (ps < .05, .01 or .001).

During the 30 minutes recovery, DBP values were significantly decreased in the NH trial compared with RN trial (p < .01) in the post-test 4 to 8 minutes; DBP in NH significantly decreased compared with RN (p < .05) in the post-test 9, 10, 13, 15 to 18, and 28 minutes; DBP in NH had decreased at a marginal significant level compared with RN trial in the post-test 14 (p = .055) and 26 (p = .054) minutes. DBP in NH trial were highly significantly decreased compared with RH (p < .01) in the post-test 10 and 16 minutes; DBP in NH were significantly decreased compared with RH (p < .05) in the post-test 8, 11, 13, and 14 minutes; the changes of DBP in NH were marginal significantly decreased compared with RH in the post-test 12 (p = .065), 15 (p = .067), and 17 (p = .054) minutes.

DBP in HH trial significantly decreased compared with RN (p < .01) in the post-test 7, 8, and 15 to 22 minutes; DBP in HH trial significantly decreased compared with RN (p < .05) in the post-test 9, 10, 12 to 14, and 23 to 30 minutes; DBP in HH trial had decreased at a marginal significant level compared with RN in the post-test 5 (p = .061) and 6 (p = .076) and 11 (p = .057) minutes. DBP in HH trial significantly decreased compared with RH (p < .01) in the post-test 15, 16 and 19 minutes; DBP in HH significantly decreased compared with RH (p < .05) in the post-test 11 to 14, 17, and 18 minutes; DBP in HH had decreased at a marginal significant level compared with RH in the post-test 20 (p = .054) minute. However, no significant differences were found between RN and RH (p > .05) tests during the post-test 30 minutes, and the same as NH and HH tests.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
HQ	-3	-0	-4	-3	-3	-2	-2	-2	-3	-2	-1	-2	-1	-1	-2	-1	-1	-2	-3	-2	-2	-3	-3	-3	-4	-2	-1	-2	-2	-3
NH	-1	-0	-4	-8	-9	-9	-9	-8	-1	-8	-7	-6	-8	-7	-7	-8	-8	-9	-6	-7	-6	-7	-8	-7	-6	-6	-6	-6	-6	-4
HH	-0	-1	-3	-5	-7	-7	-9	-9	-1	-1	-1	-1	-9	-9	-1	-1	-1	-1	-1	-1	-9	-8	-8	-9	-8	-8	-7	-7	-7	-7

Note. DBP value of RN was not included in the figure as it was set to be the baseline level (i.e. zero) for the analyses.
a All values during the 30-minute recovery were separated into one data point using an interval of every minute.
* p < .05. ** p < .01. *** p < .001.

Figure 2: Changes of Post-test DBP Values Compared with RN.

3.5 The Analysis of AUC

The previous results (Figure 1) showed that SBP was significantly higher than normal situation during the one to five minutes among the four trials, hence indicating that BP values did not recover from the tests. As such, the AUC was calculated from the 6th minute (Table 4). After analysis, the AUC in SBP did not have significant differences among the four tests (p > .05). However, for DBP, significant differences was found among the four tests (p < .001).

Sidak post hoc tests revealed that the AUC of DBP in HH trial significantly decreased compared with RN (p = .004), RH (p =.018) and NH (p = .023) trials. AUC of DBP in NH trial significantly decreased compared with RN trial (p = .022) and had decreased at a marginal significant level compared with RH (p = .077) trial.

Table 4: The AUC after Test.

AUC	RH	NH	HH
SBP (mmHg*min)	-5±195	-58±131	-121±204
DBP (mmHg*min)***	-63±140	-187±153	-230±142

Note. BP values of RN were not included in the table as it was set to be the baseline level (i.e. zero) for the analyses.
*** $p < .001$

3.6 Analysis of Impact Factors of PEH

Multiple stepwise regression analysis was performed to examine the relationships between independent variables, including body composition (i.e. weight, height, BMI, and fat), VO2peak, mean power in the two sprint exercise, and dependent variables, including the AUC of SBP, DBP, and MAP, after normoxic and hypoxic HIIE.

One significant result was found among all multiple regression analyses (Table 5). Regression analysis showed that the AUC of SBP in hypoxic HIIE can be significantly influenced by independent variables including body composition (i.e. weight, height, BMI, and fat), VO2peak, and mean power in the two sprint exercise. All the independent variables accounted for 92.3% the total variance of AUC of SBP in hypoxic HIIE. Among the total variance, body composition including weight, height, BMI, and fat, explained 77.7% among 92.3% of the variance. However, adding VO2peak and mean power into the model only explained 4% and 6.6% more of the total variance, respectively. Hence, VO2peak and mean power did not have much influence on the AUC of SBP in HH trial. Body composition is the most important independent.

Table 5: Regression of AUC of SBP in HH.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	β		
Model 1: $R^2 = 0.777$, $F = 8.852$, $p = 0.017^*$					
Constant	155043.692	31839.918		4.869	0.005
weight	1139.627	234.202	33.037	4.866	0.005
height	-865.446	179.22	-22.334	-4.829	0.005
BMI	-3701.543	739.998	-19.751	-5.002	0.004
Fat	58.419	21.35	0.763	2.736	0.041
Model 2: $R^2 = 0.812$, $F = 8.776$, $p = 0.028^*$					
Constant	137728.481	31802.048		4.331	0.012
weight	1014.177	233.385	29.4	4.346	0.012
height	-769.375	178.615	-19.855	-4.307	0.013
BMI	-3334.626	729.452	-17.793	-4.571	0.01
Fat	85.718	27.783	1.119	3.085	0.037
VO_{2peak}	12.405	8.942	0.327	1.387	0.238
Model 3: $R^2 = 0.923$, $F = 16.371$, $p = 0.059^c$					
Constant	147999.297	31410.378		4.712	0.042
weight	1076.648	234.76	31.211	4.586	0.044
height	-833.144	176.183	-21.5	-4.729	0.042
BMI	-3505.597	712.354	-18.705	-4.921	0.039
Fat	76.804	22.607	1.003	3.397	0.077
VO_{2peak}	18.45	8.106	0.486	2.276	0.151
MeanPower_1[a]	-1.625	0.87	-0.362	-1.869	0.203
MeanPower_2[b]	2.536	1.034	0.636	2.453	0.134

Note. The dependent variable is AUC of SBP in HH trial. The independent variables in model 1 are the body composition, including weight (kg), height (cm), BMI (kg/m^2), and fat (%). The independent variables in model 2 are the body composition and VO_{2peak} (ml/kg/min) which represents cardiopulmonary function. The independent variables in model 3 are the body composition, VO_{2peak}, and the mean power (Watt) in the two sprint exercise.

[a] the mean power in the first sprint.

[b] the mean power in the second sprint.

[c] marginal significant difference.

* $p < .05$.

3.7 Post-Exercise Affective Evaluation

Subjective feeling was evaluated after hypoxia and normoxic HIIE using Affective Scale. The feeling of happiness were significantly increased after NH and HH compared with RN.

Table 6: Affective evaluation results.

	RN	RH	NH	HH
Affective scale	0±0.82	0.33±0.82	3.89±0.99***	4±0.47***

Note. $^{***}p < .001$

4 DISCUSSION

The current study proved that acute hypoxic HIIE in hypoxic condition resulted in a more effective decrease in BP compared with normoxic condition. This is the first study to compare the acute effects of hypoxia and HIIE on PEH in male university students.

In the current study, DBP was found to have a significant decrease in normoxic HIIE compared with rest in normoxia trial, but the decrease in SBP did not reach the significant level. As the higher exercise intensity and longer duration can result in greater PEH (Cote, 2015; Eicher, 2010), this could the reason that only DBP was found decreased in this research.

More importantly, the present study found that HIIE led to PEH in both normoxic and hypoxic environment, while hypoxia strengthened this effect. In this study, the magnitude of PEH did not reach significant differences between NH and HH, but the duration of PEH was not at identical level in the two tests. Significant decreases in SBP were found in totally four minutes separated amongst the 30-minute observation after HH trial, compared with the RN trial. Kaplan (Kaplan, 2000) contended that SBP value alone has been recognized as an important cardiovascular risk factor. Other scholars also agreed that high SBP is more dangerous than high DBP alone in determining the risk of cardiovascular disease (Pescatello, 2004). Therefore, the current results that SBP was significantly decreased after hypoxic HIIE showed that effect of hypoxia might be an important factor in decreasing SBP.

In the changes of the post-exercise DBP, significant levels of PEH were found in totally 23 minutes and 13 minutes separated amongst the 30-minute observation after HH and NH trial, respectively, compared with the baseline level of RN trial. Moreover, significant levels of PEH were found in totally 11 minutes and six minutes separated amongst the 30-minute observation after HH and NH trial, respectively, compared with the baseline level of RH trial. In the current study, HIIE in both normoxic and hypoxic environment caused significant decreases in DBP. This study also found that HH trial had a longer duration of PEH than NH. Meanwhile, these results showed the durations of PEH in DBP in HH trial were longer than NH trial during all 30 minutes of post-exercise observation. These results may support the argument that HIIE in hypoxia has a greater effect on PEH than normoxia.

On the other hand, the current research also examined the AUC, which was claimed as another novel and robust approach to quantify PEH. Liu (Liu, 2012) proved that the AUC of BP was significantly associated with peak BP decrease. In the current study, AUC of DBP was found significantly higher in HH trial than in NH trial, which implied that HIIE in hypoxia caused a greater extent of PEH compared with HIIE in normoxia.

Finally, the results of multiple stepwise regression analyses showed that only AUC of SBP in HH trial was significantly influenced by the model composed of body composition (i.e. weight, height, BMI, and fat), VO2peak, and mean power in the two sprint exercise. This result partially supported the fifth hypothesis. On one hand, BMI had a negative relationship with AUC of SBP in HH trial, which implied that decreasing BMI would lead to greater AUC after hypoxic HIIE protocol. On the other hand, weight and fat both had positive relationship with SBP after hypoxic HIIE. In Forjaz and colleagues' study (Forjaz, 2000), it was found that the magnitude of PEH was stronger for participants with lighter weight and lower BMI. Nonetheless, in this study, greater PEH was discovered in participants of more weight and fat. This might be attributed to the fact that weight and BMI could not represent all dimensions of the body composition, because the relationship between BMI and body fat could be influenced by age, gender, ethnicity and race (McArdle, 2010). Nonetheless, the percent of body fat was not measured in their research, therefore, BMI might not accurately reflect the proportion of fat in the body composition, which might explain the unexpected relationship among weight, BMI, and fat and AUC of SBP after hypoxic HIIE.

Moreover, VO2peak and the mean power did not have the significant relationship with the dependent variables, implying that the AUC of SBP after exercise was largely accounted by body composition, instead of cardiopulmonary function and exercise performance. Also, this relationship was only found significant in HH trial, which suggested that hypoxic condition was an important factor that strengthened the effect of HIIE. Meanwhile, limited studies have explored the relationships among participants' body composition, VO2peak and PEH. Consequently, more studies are needed to figure out these relationships.

Mental health problems among university students is an emerging public health issue (Winzer, 2018). This study also found that the HIIE could significantly enhance the feeling of happiness for university students, which can be used for students to relieve academic pressure and has an important role in improving students' mental health.

5 CONCLUSION AND SUGGESTIONS

This research examined the acute effects of hypoxic condition and HIIE on both physical and mental health improving in inactive male university students. While HIIE in normoxic environment could lead to decrease in DBP, HIIE in hypoxic environment could decrease SBP and DBP. Although the difference of the decrease in SBP and DAP among NH and HH trial did not reach significant level, significant decrease in SBP was only found in HH trial. Moreover, the duration of PEH in HH was longer than that in NH during the 30-minute post-test observation. Therefore, hypoxic HIIE seems to be a more effective method to decrease BP than normoxic HIIE, which might serve as a protective mechanism against cardiovascular risk and the development of cardiovascular disease. This effective exercise method can be applied to university students to improve their physical function and mental state. Although hypoxia condition is hard for students for training, but it could be applied to cardiovascular disease patients, athletes or other special groups.

While this study only performed 30 minutes observation of post-exercise data collection, previous research found a small difference in the peak PEH response after one hour and 30 minutes of HIIE (Rossow, 2010). Future research may consider having a longer observation of post-exercise BP response in order to provide more evidence of PEH. In addition, current research only involved ten participants. The small sample size might be a reason that some variables such as SBP did not have significant difference. Accordingly, further studies may consider recruiting more participants.

In addition, as PEH could be affected by exercise intensity (Bonsu, 2016), hypoxic environment (Wee, 2015), and participants' characteristics (Halliwill, 2001), future studies could perform different HIIE protocols with various intensity and duration and different levels of hypoxic exposure, in different gender in order to examine the effect of exercise on physical and mental health.

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