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HIGH-INTENSITY INTERVAL EXERCISE WITH BLOOD FLOW RESTRICTION IMPROVES VASCULAR FUNCTION IN OBESE MALE ADOLESCENTS

Thitiwat Noikhammueang[1ABCD] and Witid Mitranun[1ABCD]

[1]Srinakharinwirot University

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: Witid Mitranun, E-mail: mitranunwitid@hotmail.com
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Abstract

Study purpose. Obesity, a chronic metabolic disease is on the rise among children and adolescents and is a leading cause of mortality in adults worldwide. It is imperative to prevent obesity in children to lower the risk of adult obesity and cardiovascular diseases. Considering the effectiveness of exercise program, high-intensity interval exercise with blood flow restriction (HIIE-BFR) may have potential beneficial effects on the vascular functions of obese individuals. This study aimed to compare the acute effects of supramaximal high-intensity interval exercise (HIIE-SUPRA) and HIIE-BFR on the vascular function in obese adolescents.

Materials and methods. The subjects were adolescent males aged 13 to 15. The crossover study was divided into two trials. The first trial was a pilot study involving five obese adolescent males whose heart rates were evaluated under four conditions of exercise: 1) HIIE-SUPRA at 170% (VO_2peak), 2) HIIE-BFR at 85% VO_2peak with 40% arterial occlusion pressure (AOP), 3) 60% AOP, and 4) 80% AOP. The second trial was conducted on ten obese adolescent males who performed HIIE-SUPRA and HIIE-BFR exercises separately, each for at least three days. Data collection was done to analyze the vascular function parameters before and after exercising (immediately, 10 min, 30 min, and 60 min after).

Results. The results of the first trial showed that the mean heart rate of HIIE-BFR at 40% AOP was similar to that of HIIE-SUPRA ($p>0.05$). In the second trial, both types of exercises showed similar outcomes, with increased flow-mediated dilatation (FMD), while brachial-ankle pulse wave velocity (baPWV) decreased after exercise as compared to the baseline values (before exercise) ($p<0.05$). However, HIIE-BFR at 40% AOP demonstrated a lower rate of perceived exertion (RPE) as compared to HIIE-SUPRA ($p<0.05$).

Conclusions. HIIE-BFR at 40% AOP was effective in regulating the RPE and acutely increasing the vascular function after exercise in obese adolescents, similar to HIIE-SUPRA.

Keywords: flow-mediated dilatation, pulse wave velocity, endothelial function, obesity.

Introduction

Obesity is a chronic metabolic disorder that causes endothelial cell dysfunction and is linked to decreased vascular function, i.e., flow-mediated dilatation (FMD) (Tremblay et al., 2019; Zhai et al., 2020; Kwaifa et al., 2020). Recently, a rise in childhood and adolescence obesity has been observed worldwide with a parallel increase in mortality rate linked to high BMI and cardiovascular disease (Collaborators, 2017). Therefore, preventing childhood obesity is critical for lowering the risk of adult obesity and cardiovascular diseases. Obese adolescents have lower physical fitness than normal-weight adolescents (Vandoni et al., 2021), which may be attributed to a negative opinion of exercise, a preference for spending their time alone rather than with others (Salvy et al., 2012), a change in the emotional state, and lesser willingness to participate in long-term workouts (Alberga et al., 2019). ACSM (2020) guidelines advocate moderate-intensity continuous exercise for 150 min per week for obese individuals to improve their cardiac functions and increase energy metabolism (Liguori, 2020; Fragnani et al., 2017). Interval exercise is a time-saving strategy linked to good health (Gibala et al., 2018; MacInnis & Gibala, 2017). An earlier study found that obese male children had higher FMD and lower brachial-ankle pulse wave velocity (baPWV) following immediate supramaximal high-intensity interval training (170% VO_2peak) than that before exercise (Chuensiri et al., 2015). Therefore, supramaximal high-intensity interval exercise (HIIE-

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SUPRA) might elicit great health benefits in obese children. However, a high rate of perceived exertion (RPE) may be a cause of concern in these cases.

Blood flow restriction (BFR) exercise is currently gaining popularity as a low-intensity workout that applies external pressure to the arm or leg, decreasing the strain on the joints and muscles. Unlike conventional exercises, it has no harmful effects on the body (Brandner et al., 2018). Previous studies have found that exercise with BFR causes physiological adaptation (increased heart rate), similar to high-intensity exercise in obese adults (Karabulut et al., 2017), athletes (Willis et al., 2016), and hypertensive elderly people (Barili et al., 2018). Regarding vascular function, BFR does not cause damage to the blood vessels during either walking or resistance exercises (Stray-Gundersen et al., 2020; da Cunha et al., 2020). Aerobic exercise with BFR could significantly increase the heart rate when compared to aerobic exercise alone (Barili et al., 2018; Thomas et al., 2018). Hence, HIIE-BFR might have the potential to maximize vascular function while regulating the RPE.

Despite the beneficial effects of HIIE-SUPRA on vascular function, it may be difficult to generalize these findings in adolescents with obesity and low physical fitness. Considering the effectiveness of the exercise program, high-intensity interval exercise (lower workload program when compared to HIIE-SUPRA) with BFR might be a prospective option in adolescents. We hypothesized that HIIE-BFR could yield acute effects on vascular functions comparable to HIIE-SUPRA and might even be more effective in lowering RPE.

Materials and methods

Study Participants

Ten obese male adolescents of Thailand, aged 13-15 years, with a BMI ≥ 1.5 standard deviation above the growth reference data for boys, based on the growth reference criteria of subjects aged 6-19 years, were selected for the study. Participants were excluded from the study if they scored highly on screening tests: Physical Activity Readiness Questionnaires, PAR-Q, or if they had any conditions affecting their musculoskeletal, cardiovascular, respiratory systems, or brain that would impact the results of the study. Written informed consent was obtained from all the participants and their parents prior to the study. The study was approved by the Ethics Committee of Srinakharinwirot University in Thailand (No. SWUEC-G-331/2563E) and conducted in accordance with the Declaration of Helsinki. The protocol was registered on www.thaiclinicaltrials.org (Identifier: TCTR20210716008).

Study Protocol

The study was conducted using a crossover design that included two trials: a pilot study in the first trial, and a comparison of HIIE-SUPRA with HIIE-BFR in the second trial. General physiological traits including body composition, resting heart rate, and blood pressure were assessed. Each person's total arterial occlusion pressure (AOP) for the lower limb (posterior tibialis artery) was measured using a vascular Doppler probe (Duplex Assist Range ACC214, Huntleigh Healthcare, UK). The AOP was marked at the lowest cuff pressure at which there was no pulse and was used as the pressure for the BFR trial. Cycling with and without BFR was performed once during the familiarization period. On the initial visit to the laboratory, baseline FMD and baPWV were measured. These measurements were followed by FMD and baPWV measurements immediately following exercise and three times post-exercise (after 10 min, 30 min, and 60 min). Following completion, cycle ergometer's peak oxygen consumption (VO_2peak) test was conducted to determine the load to be employed during the cycling interval workout. After the completion of the exercise, the exercise pleasure scale (EES) was evaluated (Martinez et al., 2015).

All subjects were instructed to fast for at least 6 hours or eat a light meal for at least 2-3 hours before the vascular function test and take rest for at least 8 hours. The participants were asked not to exercise, consume caffeine, vitamin C, alcohol, medicines, or supplements that might affect vascular function, or smoke, at least 6 hours before the test.

The participants spent 10 minutes for warming up and stretching, followed by 5 minutes of cycling at 50% VO_2peak (50 rpm), 4 minutes of maintaining exercise intensity at 90 rpm, and 5 minutes of cooling down. Eight 20-second bouts of cycling high-intensity interval training were followed by ten seconds of rest per bout (Chuensiri et al., 2015). While exercising, heart rate and RPE were monitored continuously.

1. Pilot Study

Five obese adolescent males took part in the pilot study that involved cycling under four different exercise conditions: 1) HIIE-SUPRA at 170% VO_2peak; 2) HIIE-BFR at 85% VO_2peak with BFR pressure at 40% AOP; 3) 60% AOP and, 4) 80% AOP. Cuff belts (8 cm wide) were wrapped over the proximal regions of both legs during interval exercise with the BFR protocol, and each activity was carried out independently for at least three days. The results of the first trial, which had a mean heart rate similar to that of HIIE-SUPRA, were applied to the second trial.

2. HIIE-SUPRA and HIIE-BFR condition

A crossover design was used in this study (Fig. 1). We compared BFR exercise with a similar mean heart rate to HIIE-SUPRA at 170% VO_2peak in ten obese teenagers who were randomly allocated into two groups: Groups A and B. They are involved cycling interval under two exercise condition: 1) HIIE-SUPRA at 170% VO_2peak; 2) HIIE-BFR at 85% VO_2peak. Each activity was performed separately over a period of at least three days without repeating the protocol sequence within or between the experiments.

Measurement

General physical characteristics

Body composition was measured using an electrical body composition analyzer (Tanita, Japan). Heart rates were assessed using a heart rate monitor (H10, Polar, Finland) at the initial visit, during interval exercise, immediately after the exercise, and three times after the exercise (after 10 min, 30 min, and 60 min).

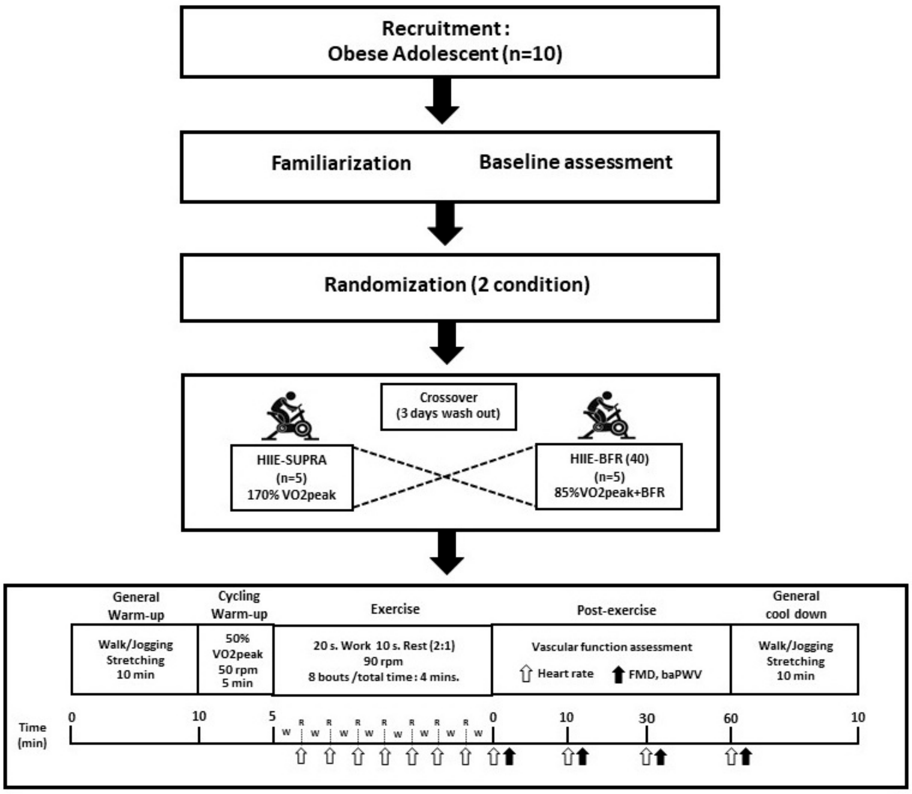

Fig. 1. HIIE-SUPRA and HIIE-BFR exercise protocol. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction

Cardiopulmonary gas exchange analysis equipment was used to calculate the peak oxygen demand (VO_2peak) (Cardio Coach, KORR Medical Technologies, USA). The participants were asked to complete a graded exercise test on a cycling ergometer (Monark Ergomedic 894E Peak Bike) applied by Chuensiri (2015), with the grade and intensity increasing by 20 watts every 3 min until exhaustion or other symptoms indicating maximum potential, such as shortness of breath, dizziness, or participants asking to stop the test. During the cycling interval exercise, the peak workload was used to determine the load.

Vascular function

FMD of the brachial artery was measured using an ultrasound machine (Vivid i-GE Healthcare Cardiovascular Ultrasound System, Tirat Carmel, Israel). The brachial artery was visualized in the longitudinal plane, above the antecubital fossa. After 15 min of supine rest, the subjects had a blood pressure cuff wrapped over their right forearms. Baseline data were monitored for 1 min before being quickly inflated to 50 mmHg above the systolic blood pressure for 5 min and then deflated for 5 min (Mitranun et al., 2014). Ultrasound images were uploaded to a digital software (Brachial Analyzer, Medical imaging application, USA) for offline analysis of vascular data.

The FMD was computed as: (maximum diameter - baseline diameter) × 100 / baseline diameter.

baPWV is a non-invasive vascular screening device (OMRON; Colin VP-1000 plus, Kyoto, Japan) that uses four cuffs placed on both arms and ankles to evaluate arterial stiffness. The individuals were assessed in a supine position, and baPWV was used to compute the time intervals of the brachial waveform and the matching maximum of the ankle waveform. The pressure waveform between the left and right brachial arteries and the posterior tibial artery were examined. The distances between baPWV measurement locations were automatically computed based on the individual's heights.

Statistical Analyses

The data is presented as mean and standard deviation. The Shapiro-Wilk test was used to verify data normality. The difference between the mean heart rates of the pilot study was determined using a one-way repeated-measures analysis of variance (ANOVA) followed by Bonferroni's multiple comparison test. In the second trial, vascular function parameters were compared using a 2 × 5 (group × time) two-way repeated-measures ANOVA. A post-hoc Bonferroni test was used for multiple comparisons. A paired sample t-test was used to assess differences in RPE and exercise enjoyment scales. The significance threshold was set at $p<0.05$.

Results

The mean heart rate was found to be similar under all exercise conditions ($p>0.05$). HIIE-BFR at 40% AOP showed a mean heart rate equivalent to that of HIIE-SUPRA ($p>0.05$) (Fig. 2). The anthropometric data (height, weight, and VO_2max) of the participants are presented in Table 1.

We observed that FMD increased under both workout conditions. The primary outcome of the study was that no significant difference was found between the two exercise conditions in terms of FMD, as shown in Fig. 3.

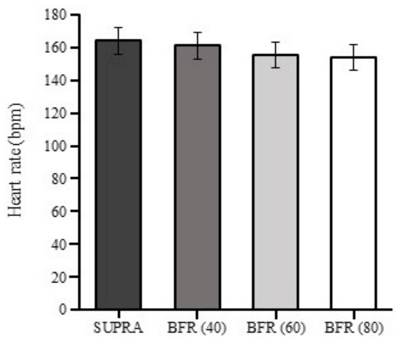

Fig. 2. Comparison of heart rate average during exercise for all pilot study conditions. Abbreviations: SUPRA, supramaximal; BFR, blood flow restriction

Table 1. Participant characteristics.

Variable	Mean	Standard deviation
Age (years)	13.40	0.52
Weight (kg)	82.55	17.60
Height (cm)	165.20	10.18
Body mass index (BMI, kg/m^2)	29.93	3.48
Fat percentage (%)	46.17	8.90
Maximum heart rate (bpm)	198.60	0.52
Resting heart rate (bpm)	90.00	9.73
Systolic blood pressure (SYS, mmHg)	129.00	11.32
Diastolic blood pressure (DIA, mmHg)	76.50	6.41
Peak oxygen consumption (VO_2peak, ml/kg/min)	22.01	8.41
Flow-mediated dilatation (FMD, %)	7.68	3.21
Brachial-ankle pulse wave velocity (baPWV, cm/s)	943.05	112.84

Sample size; 10 subjects

However, when comparing the baseline values with that at 60 min after exercise, it was found that FMD measurements immediately (0 min) and 10 min after HIIE-SUPRA were significantly ($p<0.05$) greater than those at the three time-points (baseline, 30 min, and 60 min). When HIIE-BFR at 40% AOP was observed at the second time point (10 min) after exercise, there was a significant difference ($p<0.05$) greater than baseline and 60 min after activity. Furthermore, the FMD at 30 min after exercise was significantly ($p<0.05$) higher than that at 60 min.

Both protocols showed a decrease in baPWV following exercise, with no significant differences between the two conditions (Fig. 4).

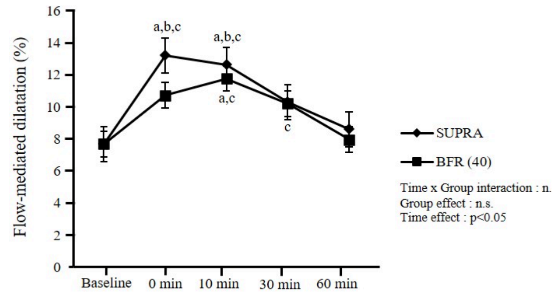

Fig. 3. Flow-mediated dilation change over time during HIIE-SUPRA and HIIE-BFR exercise protocol. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction. Different letters indicate significant differences over time for each condition. a: $p<0.05$, vs. baseline, b: $p<0.05$ vs. 30 min and c: $p<0.05$ vs. 60 min

As shown in Fig.5, after immediate exercise, systolic blood pressure was significantly higher ($p<0.05$) than that at 10 min, 30 min, and 60 min after performing both workouts.

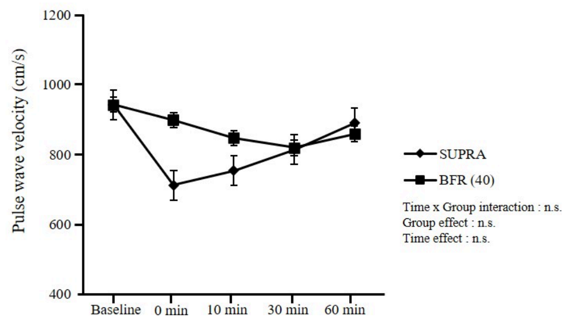

Fig. 4. Brachial Pulse wave velocity change over time during HIIE-SUPRA and HIIE-BFR exercise protocol. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction

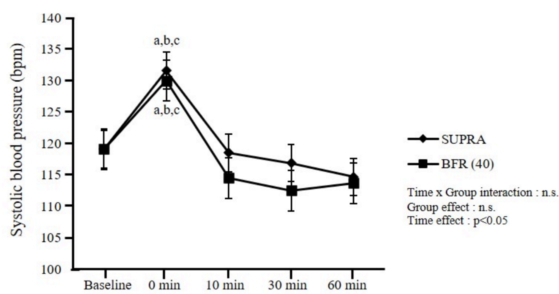

Fig. 5. Systolic blood pressure change over time during HIIE-SUPRA and HIIE-BFR exercise protocol. Different letters indicate significant differences over time for each condition. a: $p<0.05$ vs 10 min, b: $p<0.05$ vs. 30 min and c: $p<0.05$ vs. 60 min. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction

There was no significant difference in diastolic blood pressure or mean arterial pressure between the conditions and time of total exercise (Fig. 6 and Fig. 7).

Finally, we discovered that HIIE-BFR (40) had a significantly lower ($p<0.05$) rating of perceived exertion than HIIE-SUPRA (Fig. 8).

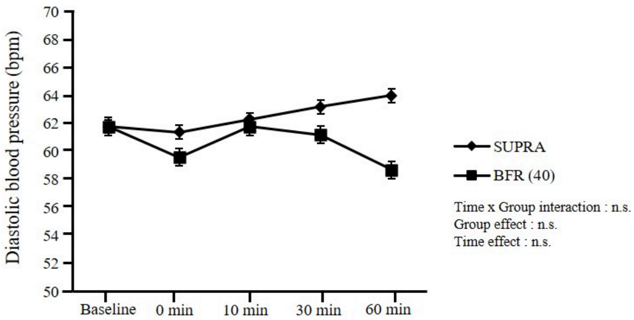

Fig. 6 Diastolic blood pressure change over time during HIIE-SUPRA and HIIE-BFR exercise protocol. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction.

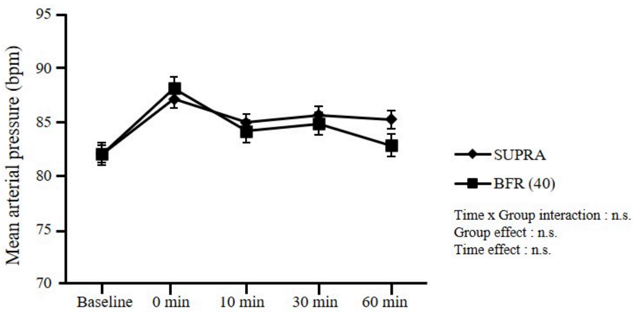

Fig. 7 Mean arterial pressure change over time during HIIE-SUPRA and HIIE-BFR exercise protocol. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction

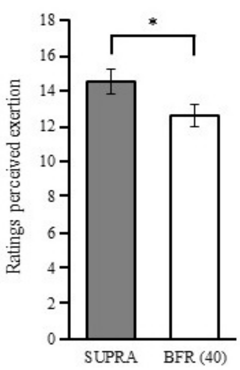

Fig. 8 Comparison rating perceived exertion during HIIE-SUPRA and HIIE-BFR exercise protocol. Abbreviations: HIIE-SUPRA, supramaximal high-intensity interval exercise; HIIE-BFR, high-intensity interval exercise with blood flow restriction

Discussion

HIIE-BFR is expected to maximize vascular function while regulating the RPE in obese individuals. In the current study, we compared the acute effects of HIIE-SUPRA and HIIE-BFR on vascular function in obese adolescents. The major findings of this investigation were as follows: (1) HIIE-BFR at 40% AOP achieved mean heart rate similar to that with HIIE-SUPRA; (2) both types of exercise showed similar outcomes: FMD increased and baPWV decreased; however, not significantly for the vascular function at 40% AOP compared to HIIE-SUPRA condition. These results suggest that HIIE-BFR at 40% AOP has a similar effect on vascular function as compared to that of HIIE-SUPRA in obese male adolescents. Moreover, the HIIE-BFR at 40% AOP showed an improvement in RPE. To our knowledge, this is the first study to investigate the acute effects of heart rate on HIIT-BFR workouts at different pressures, as well as the vascular function between HIIE-SUPRA and HIIE-BFR in obese male adolescents in Thailand.

Some of the reasons for obese adolescents are low physical fitness due to their preference to spend time alone rather than with others, negative attitudes toward exercise (Salvy et al., 2012), changes in emotional state, and hesitancy to exercise for long duration (Alberga et al., 2019). Therefore, short-duration exercises are challenging for obese people. A previous study revealed that a single session of high-intensity intermittent exercise (VO_2peak: 170%) increased the heart rate to approximately 93% of maximum heart rate in obese boys (Chuensiri et al., 2015). In this study, the HIIE-SUPRA condition increased the heart rate of obese adolescents to approximately 82% of HRmax. Furthermore, we observed that HIIE-BFR at 40% AOP in a single session boosted HR during exercise to approximately 81% of HRmax.

BFR exercise is an alternative to conventional exercise regimes and is commonly performed at a low load intensity (Freitas et al., 2021; Lorenz et al., 2021). It is a training approach that restricts arterial blood flow to the muscles while blocking venous blood return during exercise, by wrapping a tourniquet around the muscle and increasing the external pressure (Scott et al., 2015; Patterson et al., 2019). As a result, BFR training may decrease both oxygen delivery and metabolite clearance, creating a more stressful environment and stimulating physiological adaptations, such as increased heart rate and blood pressure (Pope et al., 2013; Bennett et al., 2019). Many studies have shown that exercise with BFR causes an increase in HR in athletes (Willis et al., 2016), inactive adult obesity (Karabulut et al., 2017), hypertensive elderly women (Barili et al., 2018), and healthy males (Silva et al., 2021). Thus, low-intensity exercise combined with BFR appears to have the same effect on the cardiovascular system as high-intensity exercise. In addition, other studies found that continued low-intensity aerobic exercise with BFR did not cause changes in vascular function after 8 weeks (Beak et al., 2022), while low-intensity resistance exercise with BFR promotes vascular function similar to traditional high-intensity resistance exercise (Santos et al., 2015). High-intensity aerobic exercise in combination with BFR is worth researching.

In the vascular function effect, both the HIIE-SUPRA and HIIE-BFR at 40% AOP exercise conditions improved vascular function as measured by FMD, a non-invasive technique for assessing vascular endothelial function and evaluating changes in brachial artery diameter following an increase in shear stress caused by reactive hyperemia (Mitranun et al., 2014; Ghiadoni et al., 2015; Thijssen et al., 2019). We discovered a 5.54% change in the HIIE-SUPRA condition and a 3.05% change in the HIIE-BFR at 40% AOP condition immediately after the exercise compared to the baseline, then increased for up to 60 min, returning to near baseline. The findings of our study were unexpected because they showed that external compression and low-intensity exercise had the same beneficial effects on blood vessels as high-intensity training. Although there are few studies that assess vascular function in BFR exercise, our results are consistent with a previous study that revealed a 7.49% change of FMD in obese boys immediately after high-intensity intermittent exercise at 170% VO_2max (Chuensiri et al., 2015). A recent study in adults found that interval exercise with a cross-trainer combined with BFR training substantially improved acute response FMD as compared to that with routine training (Wlodarczyk et al., 2022). Additionally, in the present study, the baPWV decreased under both conditions. This is one of the key indicators of arterial stiffness assessment and is the most commonly used technique (Lee et al., 2019). In a previous study, baPWV decreased after acute aerobic exercise in the non-hypertensive and hypertensive groups (Zang et al., 2022). Furthermore, meta-analysis studies have shown that 30 min after aerobic and interval exercises, there is a significant reduction in acute baPWV (Saz-Lara et al., 2021). Thus, the HIIE-BFR exercise trial was effective in improving vascular function in obese male adolescents.

The mechanism of increased vascular function with BFR exercise may be related to the generation of vasodilators. When the tourniquet is relaxed, the blood flow increases dramatically, resulting in increased blood shear stress and blood vessel expansion (Pignanelli et al., 2021). Previous studies in young inactive and exercise trained groups discovered an increase in FMD 30 min after leg press workouts with a cuff wrap placed on the arm (Buchanan et al., 2021). Furthermore, walking interval exercises with BFR did not impair vascular function efficiency (Stray-Gundersen et al., 2020). It could be inferred that when blood flow is restricted during exercise, the blood is retained, which raises blood circulation within the arteries when the pressure from the tourniquet is released. This might elevate shear stress and increase the secretion of a vasodilator (nitric oxide), which enhances vascular function (Pignanelli et al., 2021). This outcome was comparable to that of supramaximal workouts. This could be related to systemic hemodynamics, which causes blood vessels to dilate even in non-constricted locations. Although the vascular response mechanisms of BFR exercise may be difficult to understand and not technically measured, this study clearly showed that HIIE in combination with BFR had a similar effect on vascular function as HIIE-SUPRA.

Our study had some advantages, such as the ability to assess multiple time points of FMD and baPWV. In addition, there have been no reports of injuries after exercise. However, this study has several limitations. First, this study included only adolescent males and had a small sample size. Second, pressure control during exercise might be difficult under non-automatic BFR exercise equipment. Third, we investigated only the acute phase of vascular function following exercise. Further studies are needed to design an exercise program for either short-term or long-term training, as well as to monitor changes in vascular function in obese adolescents.

Conclusions

HIIE-BFR at 40% AOP improved vascular function in obese adolescent equivalent to that of HIIE-SUPRA following a single exercise session. HIIE-BFR at 40% AOP was effective in regulating RPE and acutely increasing vascular function after exercise, similar to that observed with HIIE-SUPRA in obese adolescents. As a result, we believe that HIIE-BFR at 40% AOP can improve vascular function and may be a suitable exercise for obese adolescents.

Acknowledgment

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Conflict of interest

We declare that there are no conflicts of interest regarding this research.

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ВИСОКОІНТЕНСИВНІ ІНТЕРВАЛЬНІ ВПРАВИ З ОБМЕЖЕННЯМ КРОВОТОКУ ПОКРАЩУЮТЬ РОБОТУ СУДИН У ПІДЛІТКІВ ЧОЛОВІЧОЇ СТАТІ З ОЖИРІННЯМ

Тітіват Нойхаммуеан[1ABCD], Вітід Мітранун[1ABCD]

[1]Університет Срінахарінвірот

Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 1 табл., 8 рис., 38 джерел.

Мета дослідження. Ожиріння, хронічне метаболічне захворювання, стрімко поширюється серед дітей і підлітків і є основною причиною смертності дорослих в усьому світі. Вкрай необхідно попередити ожиріння в дітей, щоб знизити ризик розвитку ожиріння та серцево-судинних захворювань у дорослому віці. Беручи до уваги ефективність програми вправ, високоінтенсивні інтервальні вправи з обмеженням кровотоку (HIIE-BFR) можуть мати потенційний сприятливий вплив на функції судин у людей з ожирінням. Метою цього дослідження було порівняння негайного впливу супрамаксимальних високоінтенсивних інтервальних вправ (HIIE-SUPRA) і HIIE-BFR на роботу судин у підлітків з ожирінням.

Матеріали та методи. Учасниками дослідження були підлітки чоловічої статі віком від 13 до 15 років. Перехресне дослідження було розділене на два випробування. Перше випробування було пілотним дослідженням за участю п'яти підлітків чоловічої статі з ожирінням, частоту серцевих скорочень яких оцінювали за чотирьох режимів виконання вправ: 1) HIIE-SUPRA за рівня 170% пікового споживання кисню (VO_2peak), 2) HIIE-BFR за рівня 85% VO_2peak та за рівня 40% тиску оклюзії артерії (AOP), 3) за рівня 60% AOP та 4) за рівня 80% AOP. Друге випробування було проведене на десяти підлітках чоловічої статі з ожирінням, які виконували вправи HIIE-SUPRA та HIIE-BFR окремо, кожний вид вправ протягом принаймні трьох днів. Збір даних для аналізу параметрів роботи судин проводили до та після тренування (негайно, через 10 хв, 30 хв та 60 хв після).

Результати. Результати першого дослідження показали, що середня частота серцевих скорочень у режимі HIIE-BFR за рівня 40% AOP була аналогічною до частоти серцевих скорочень у режимі HIIE-SUPRA ($p>0,05$). У другому дослідженні обидва типи вправ показали аналогічні результати зі збільшенням потік-опосередкованого розширення (FMD), при цьому швидкість пульсової хвилі в плечощиколотковому відділі (baPWV) зменшилася після виконання вправ порівняно з базовими значеннями (до виконання вправ) ($p<0,05$). Проте режим HIIE-BFR за рівня 40% AOP продемонстрував нижчий рівень індивідуального сприйняття навантаження (RPE) порівняно з режимом HIIE-SUPRA ($p<0,05$).

Висновки. Режим HIIE-BFR за рівня 40% AOP був ефективним у регулюванні RPE та негайному посиленні роботи судин після виконання вправ у підлітків із ожирінням, аналогічно до режиму HIIE-SUPRA.

Ключові слова: потік-опосередковане розширення, швидкість пульсової хвилі, ендотеліальна функція, ожиріння.

Information about the authors:

Noikhammueang, Thitiwat: nuengdinho19@gmail.com; https://orcid.org/0000-0002-3839-504X; Department of Sports Science, Srinakharinwirot University, 114 Soi Sukhumvit 23, Khlong Toei Nuea, Watthana, Bangkok 10110, Thailand.

Mitranun, Witid: mitranunwitid@hotmail.com; https://orcid.org/0000-0002-9334-2696; Department of Sports Science, Srinakharinwirot University, 114 Soi Sukhumvit 23, Khlong Toei Nuea, Watthana, Bangkok 10110, Thailand.

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