



Effects of Whole-Body Vibration Combined with Blood Flow Restriction and Systemic Hypoxia on Body Composition and Physical Performance in Overweight University Students

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Abstract

Study purpose. This study investigated the effects of whole-body vibration (WBV) combined with blood flow restriction (BFR) and hypoxic exposure (HYP) on body composition and physical performance in overweight university students.

Materials and methods. Twenty-nine male university students with overweight were divided into 3 groups: 1) whole-body vibration (WBV), 2) whole-body vibration plus blood flow restriction (WBV+BFR, 60% of occlusion pressure) and 3) whole-body vibration plus hypoxic exposure (WBV+HYP, $FiO_2 = 15.8\%$). Training included 10 sets of intermittent WBV exercise (30-35 Hz in frequency and high amplitude) 20 min/day and 3 days/week. Body composition along with physical performance was measured before (2-3 days prior) and after (2-3 days post) an 8-week training period.

Results. The results of this study were as followed, after training, the maximum strength (1RM) in the leg press and leg curl were significantly increased in the WBV+HYP group (28.31%, $p = 0.016$ and 13.56%, $p = 0.017$) compared with the WBV group (17.68% and 2.88) respectively. Similarly, the WBV+HYP group showed a substantial increase in muscle endurance in the leg extension and leg curl (28.57%, $p = 0.013$ and 34.38% $p = 0.049$) when compared to the WBV group (5.33% and 13.20%) respectively.

Conclusions. Whole-body vibration combined with blood flow restriction and hypoxic exposure were effective in improving body composition and physical fitness. Performing the procedure can also be adjusted according to convenience and suitability for each individual. It is a guideline for preventing, treating, and promoting health among overweight adolescents.

Keywords: whole-body vibration, blood flow restriction, systemic hypoxia, body composition, physical performance, overweight.

Introduction

Whole-body vibration machine is an exercise machine designed to increase muscle activation in the form of vibration with frequency and amplitude. The duration of vibration can be set for each training session. At present,

whole-body vibration machine is popular and used more in medical, health and fitness fields. The main goal of its use is to improve physical performance (Park et al., 2015), especially muscular strength and power (Bosco et al., 1999) with a variety of training, such as static and dynamic training and a combination of static and dynamic training. The exercises for this machine can be designed in a variety of ways to suit the user and the training goals. However, different configurations of whole-body vibration parameters will produce different results (Luo et al., 2005).

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Exercise training combined with blood flow restriction applies a tourniquet on the upper extremities of the body, i.e., the upper arms and legs. Low-load resistance training with blood flow restriction (Pearson & Hussain, 2015) at 20-30% 1RM can stimulate muscle development comparable to that of the traditional high-load resistance training at 70-80% 1RM (Kim et al., 2017; Manimmanakorn et al., 2013; Vechin et al., 2015). Previous studies investigated the acute effects of whole-body vibration combined with blood flow restriction. It was found that there was an increase in the EMG values from the rectus femoris and vastus lateralis (Cai et al., 2018; Centner et al., 2019). A study of long-term exposure to WBV exercise by Cai et al. (2021) investigated the effects of whole-body vibration combined with blood flow restriction on muscle performance with a training period of 8 weeks. The study revealed that thigh muscle mass significantly increased by 3%. Moreover, 1RM leg press and muscle endurance significantly increased when compared with WBV only (Cai et al., 2021). In addition, a study by Centner et al. (2020) performed WBV+BFR training in healthy women. After 10 weeks of training, there was an increase in the muscle cross-sectional area compared to WBV only. While, muscular strength and jump performance were not significantly different between groups (Centner et al., 2020). Therefore, continuous training of WBV+BFR seems to be a training method that can improve muscle mass, strength and endurance among those who have not been trained before or those who have limited exercise at high intensity. However, it needs to be confirmed in future research studies.

Nowadays, altitude/hypoxic training is used to develop the physical performance of athletes. A simulated altitude is used along with various training programs to promote positive adaptation of the body, which can help prevent and treat various diseases (Millet et al., 2016; Verges et al., 2015). Camacho-Cardenosa et al. (2020) conducted a study on the effects of whole-body vibration under hypoxic exposure ($FiO_2=16.1\%$) on muscle mass and functional mobility in older adults. The results showed that after 18 weeks of training, there was no difference in any parameters in the two groups. This may be due to the basic characteristics of the population, the training program and the degree of hypoxia that may be insufficient to contribute to the development of muscle mass and functional mobility (Camacho-Cardenosa et al., 2020). Although, previous studies on WBV + HYP were rarely conducted. Thus, further research should be conducted to determine whether breathing under hypoxia is an effective form of training in therapeutics or if it could be a potentially harmful way. However, it depends on the degree of hypoxia, frequency, duration of training and training programs.

Therefore, the researchers were interested in studying and comparing the effects of whole-body vibration combined with blood flow restriction and hypoxic training on body composition and physical performance of overweight male students.

Materials and methods

Study participants

Twenty-nine male overweight students from Ubon Ratchathani Rajabhat University (mean age 20.17 ± 0.96 years) volunteered for this study. The inclusion criteria were as

follows: participants measured and reported as overweight ($BMI = 23.0-24.9 \text{ kg/m}^2$), likely to be untrained and no WBV exercise program within the past 3 months, reported no exposure to an altitude of more than 1,000 meters (3,300 feet) within the last 3 months, no history of severe acute mountain sickness and no contraindicative for WBV exercise. Participants provided written informed consent from all the participants after being informed about the study's details, purpose and procedures. The study was approved by Sisaket Rajabhat University Human Ethics Committee (HE661014).

Study organization

The participants were randomly divided into three experimental groups based on the level of oxygen concentration and occlusion pressure: whole-body vibration exercise while breathing room air (normobaric WBV exercise; WBV, $n = 10$), whole-body vibration plus blood flow restriction (WBV+BFR exercise at 60% of occlusion pressure, WBV+BFR; $n = 9$) and whole-body vibration exercise plus hypoxic exposure (hypoxic WBV exercise while breathing 15.8% oxygen concentration; WBV+HYP, $n = 10$). All the participants were measured at baseline and after eight weeks of training (Between 2 to 3 days before and after the last training session) (Fig. 1).

Training program

All groups performed the vibration exercise in a standing position, doing the static squat position at 100° knee flexion on a whole-body vibration (Power plate Pro5 Silver, USA). The whole-body vibration frequency was set at 30 Hz and high amplitude. All participants performed a total of 10 sets, 1 minute each and 1 minute rest between sets. After the 5th set, the participants can rest for 2 minutes between sets. During the rest, they can move freely. In the whole-body vibration plus blood flow restriction group, cuffs (Vald Performance: AirBands, Australia) were wrapped around the thighs (mid-thigh circumference) at 60% of cuff pressure (60% of each individual's arterial occlusion). In the whole-body vibration exercise plus hypoxic exposure group, breathing training was performed using the hypoxicator device (Hypoxicator: altitude training systems-hypoxic unit, Australia) and the oxygen concentration was set at 15.8% ($FiO_2 = 15.8\%$) an altitude ~ 2200 meter above sea level. After 4 weeks of training, the progressive overload was observed by raising the frequency to 35 Hz for 20 min/day, 3 days/week for a continuous period of 8 weeks. The oxygen saturation (SpO_2) was measured throughout the training period using a finger pulse oximeter (Pulse oximeter by beurer model: po30). The heart rate was measured using a heart rate monitor (Polar H10, Finland) and recorded over the course of the training.

Exercise testing

The data were collected from all three groups before and after 8 weeks of training with the following tests. 1) Body composition test: body weight, BMI, percentage of body fat, fat mass, fat-free mass, skeletal muscle mass (right and left leg) and visceral adipose tissue were measured. The subjects were asked to stand on the machine (body composition;

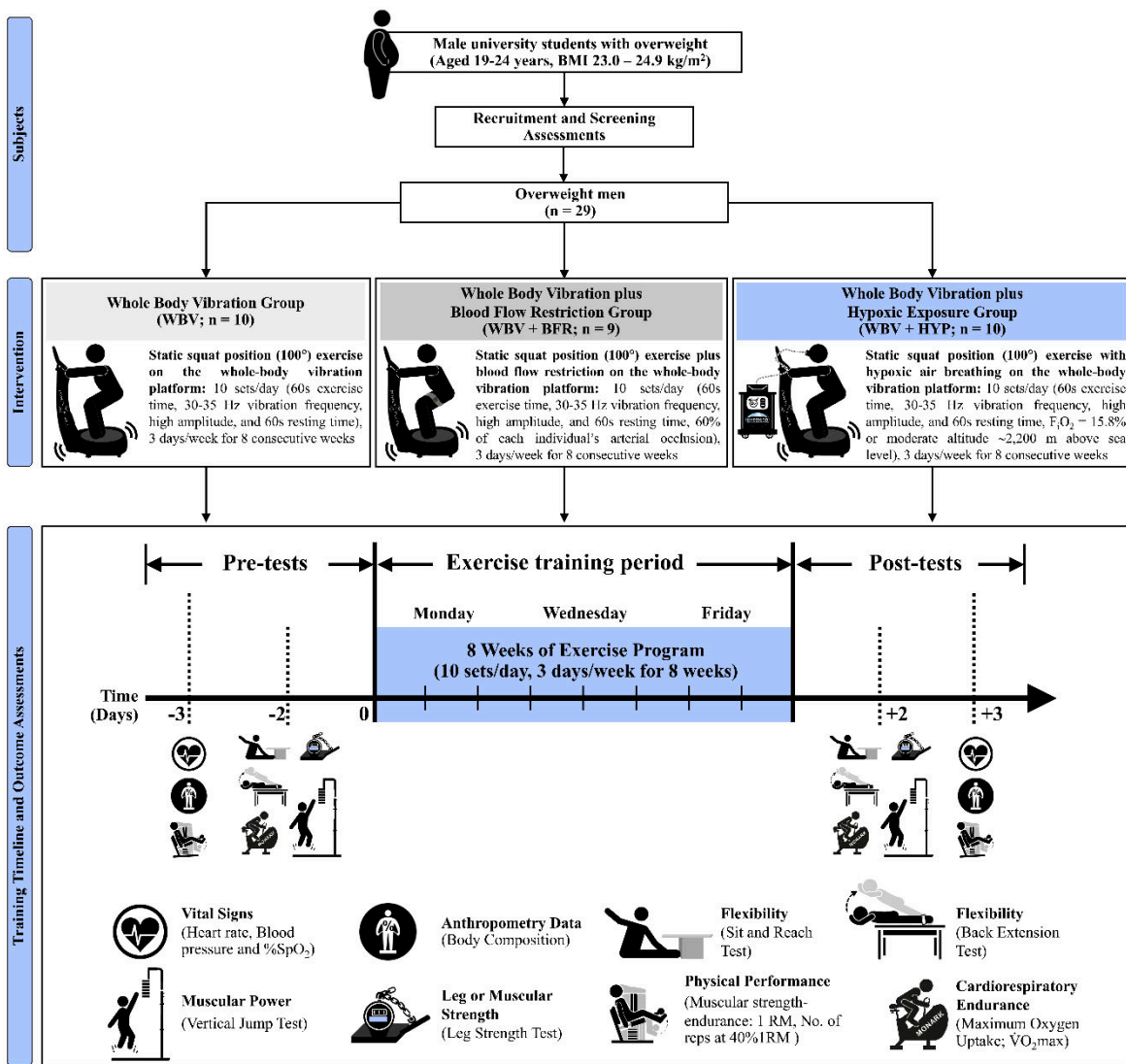


Fig. 1. Outline of training and testing schedule. Abbreviations: reps, repetition; MHR, maximum heart rate

seca mBCA, Germany) with their shoes off. 2) Flexibility test: Hamstring and lower back muscles were tested with a standing trunk flexion meter (Flexion-D Takei physical fitness test; T.K.K. 5403, Japan), and the trunk muscles were tested by a trunk extension meter (Extension-D Takei physical fitness test; T.K.K. 5404, Japan). 3) Leg strength test: The leg muscular strength was tested by using a back strength dynamometer (Back-A Takei physical fitness test; T.K.K. 5002, Japan). The subjects stood on the machine and bent their knees while grasping the handle of the machine, adjusted the angle of the knee joint to the ready position, applied force from the leg until the chain was fixed and applied the full force until it reached the maximum value. 4) Muscle strength test: Maximum strength (1-Repetition maximum: 1RM) was tested on a stationary machine in knee extension (Nautilus IMPACT S1312, USA), knee flexion (Nautilus IMPACT S1301, USA) and leg press (Nautilus ONE S6LP, USA). The subjects were asked to do 3 exercises

using an indirect method and predicted the 1RM value from the equation: $1RM = \text{weight lift} / 1.0278 - (0.0278 \times \text{reps})$ (Brzycki, 1988). 5) Muscle endurance test: The number of reps was tested on a stationary machine in knee extension (Nautilus IMPACT S1312, USA) and knee flexion (Nautilus IMPACT S1301, USA). The subjects performed 2 exercises at 40% 1RM and repeated them several times until the force decreased to 60% of the default value. The number of times they can do was recorded. 6) Maximum oxygen uptake test: Cardiorespiratory endurance was tested in an indirect way by cycling according to the Astrand method - rhyming under the supervision of the researcher throughout the assessment (Monark 828E, Sweden). 7) Muscle power: It was tested by using a vertical jump tester (Vertec vertical jump tester, United States). The subjects stood in the starting position and flexed their knees to jump as high as possible (the maximum effort countermovement jump test), using the hands to touch the height indicator bar. The test was performed twice, and

the maximum jump height was recorded. The value of the maximum jump height was subtracted from the value of the height while touching the height indicator bar.

Statistical analysis

Statistical analyses were performed using SPSS 26 (IBM Corp. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp). Data are presented as mean ± standard deviation (SD). Data normality was evaluated by using the Shapiro-Wilk test. The analysis of covariance (ANCOVA) with a post-hoc Bonferroni adjustment was used to evaluate differences in body composition and physical performance between groups. A paired t-test (comparison between values obtained before and after intervention) was completed. Alpha intervals for all testing were set at $p < 0.05$.

Results

The participants characteristics and baseline measured in the 3 training groups are presented in Table 1. No significant differences existed among the groups (WBV, WBV+BFR and WBV+HYP) for any variable.

Eight weeks of whole-body vibration exercise plus hypoxic exposure ($FiO_2 = 15.8\%$) increased skeletal muscle mass and skeletal muscle mass of right leg by 2.90% and 2.82% respectively (Table 2). Despite this increase in the WBV+HYP group, changes in skeletal muscle mass as a result of training (baseline to post-intervention) were not significantly different between groups.

Table 3 shows the mean values of physical performance before and after 8 weeks of training. It was found that the WBV+BFR and WBV+HYP group showed substantially improvement in back extension (9.07% and 10.35% respectively, $p < 0.05$), compared to their baseline (Fig. 2).

In particular, after 8 weeks of training, the maximum strength (1RM) in the leg press and leg curl were significantly increased in the WBV+HYP group (28.31%, $p = 0.016$ and 13.56%, $p = 0.017$) compared with the WBV group (17.68% and 2.88%) respectively (Fig. 3). Similarly, WBV+HYP group showed a substantial increase in muscle endurance in the leg extension and leg curl (28.57%, $p = 0.013$ and 34.38% $p = 0.049$) when compared to the WBV group (5.33% and 13.20%) respectively (Fig. 4). Despite this increase in the whole-body vibration plus hypoxic exposure group, changes in maximum oxygen uptake (29.34 ± 8.53 ml/kg/min and

Table 1. Participants characteristics in the 3 training groups

Characteristics	WBV (n = 10)	WBV+BFR (n = 9)	WBV+HYP (n = 10)
Age (y)	19.70±1.42	20.44±1.01	19.60±1.07
Weight (kg)	83.99±25.49	82.98±13.37	83.56±15.39
Height (cm)	176.70±6.80	171.22±7.28	175.40±4.90
BMI (kg/m ²)	27.53±8.76	28.48±3.39	27.08±4.81
Resting heart rate (b/m)	85.86±9.26	84.17±4.67	81.86±10.64
SpO ₂ (%)	98.43±0.53	98.38±0.52	98.56±0.53
SBP (mmHg)	129.75±7.85	127.13±6.81	129.78±8.04
DBP (mmHg)	80.11±13.55	74.11±6.64	72.33±5.61

Description: WBV; whole-body vibration, WBV+BFR; whole-body vibration plus blood flow restriction, WBV+HYP; whole-body vibration exercise plus hypoxic exposure; BMI; body mass index; SpO₂ = resting arterial oxygen saturation; SBP = systolic blood pressure; DBP = diastolic blood pressure. Values are mean ± SD

Table 2. Mean changes in body composition in all 3 training groups after 8-week training

Body composition	WBV (n = 10)			WBV+BFR (n = 9)			WBV+HYP (n = 10)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change	Pre-test	Post-test	% change
Weight (kg)	83.99±25.49	83.48±24.43	-0.60	82.98±13.37	83.40±13.62	0.50	83.56±15.39	83.91±14.46	0.42
BMI (kg/m ²)	27.53±8.76	27.36±8.32	-0.62	28.48±3.39	28.60±3.29	0.41	27.08±4.81	27.16±4.40	0.27
Fat-Free mass (kg)	64.77±8.05	65.40±9.24	0.98	61.69±8.35	62.38±8.27	1.11	61.20±2.57	61.85±2.70	1.06
Fat mass (%)	22.78±10.21	22.75±9.14	-0.11	26.90±3.84	26.63±3.39	-1.01	25.55±8.32	25.25±9.29	-1.17
Skeletal muscle mass (kg)	31.84±5.29	32.26±5.62	1.29	31.76±4.71	32.06±4.66	0.94	30.18±2.57	31.05±2.62	2.90*
Skeletal muscle mass of right leg (kg)	7.17±1.51	7.30±1.60	1.71	6.22±0.71	6.32±0.60	1.67	6.38±0.35	6.56±0.35	2.82*
Skeletal muscle mass of left leg (kg)	6.92±1.43	7.02±1.62	1.33	6.18±0.68	6.28±0.60	1.68	6.62±0.67	6.74±0.63	1.88
Visceral adipose tissue (L)	3.51±3.94	3.27±3.01	-6.91	3.60±1.04	3.39±1.17	-5.99	3.03±1.50	2.79±1.19	-8.02

Description: *Significant $p < 0.05$ (pre vs post)

Table 3. Mean changes in physical performance in all 3 training groups after 8-week training.

Variables	WBV (n = 10)			WBV+BFR (n = 9)			WBV+HYP (n = 10)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change	Pre-test	Post-test	% change
Flexibility									
Sit and reach test (cm)	18.73±6.29	20.20±5.85	7.83	14.22±7.28	15.52±7.03	9.14	13.13±4.46	14.45±4.25	10.03
Back extension test (cm)	34.12±5.91	36.75±7.52	7.72	33.09±6.36	36.09±6.27	9.07*	31.40±4.52	34.65±2.89	10.35*
Muscular strength									
Leg strength (kg/body weight)	1.56±0.42	1.71±0.42	9.15	1.35±0.25	1.55±0.39	15.02*	1.51±0.45	1.86±0.58	22.84*
Maximum strength (1RM)									
Leg press (kg)	107.05±14.42	125.97±17.09	17.68*	98.83±23.66	110.51±26.46	11.82*	113.13±19.64	145.15±16.77	28.31*†
Leg extension (kg)	164.57±17.60	174.43±23.37	5.99*	170.00±38.27	190.29±34.98	11.93*	160.50±24.51	186.50±38.17	16.20*
Leg curl (kg)	99.75±14.13	102.63±13.62	2.88	106.71±12.98	112.29±13.67	5.22*	106.20±23.76	120.60±20.44	13.56*†
Muscular endurance (Number of Reps at 40% 1RM)									
Leg extension (reps)	28.13±5.77	29.63±4.57	5.33	29.67±8.71	33.83±8.23	14.04*	26.60±7.09	34.20±7.33	28.57*†
Leg curl (reps)	28.14±5.79	31.86±5.55	13.20*	31.17±7.22	36.33±8.29	16.58*	32.00±7.07	43.00±9.80	34.38*†
Cardiorespiratory endurance									
VO ₂ max (ml/kg/min)	29.19±6.19	31.52±5.31	8.00	31.98±4.45	35.43±6.98	10.79*	29.34±8.53	34.59±9.10	17.88*
Muscular power									
Vertical jump (cm)	32.63±8.47	33.00±8.33	1.15	33.83±8.42	35.33±7.81	4.43	31.20±8.17	34.20±6.83	9.62*

Description: *Significant $p < 0.05$ (pre vs post), †Significant $p < 0.05$ (WBV vs WBV+HYP)

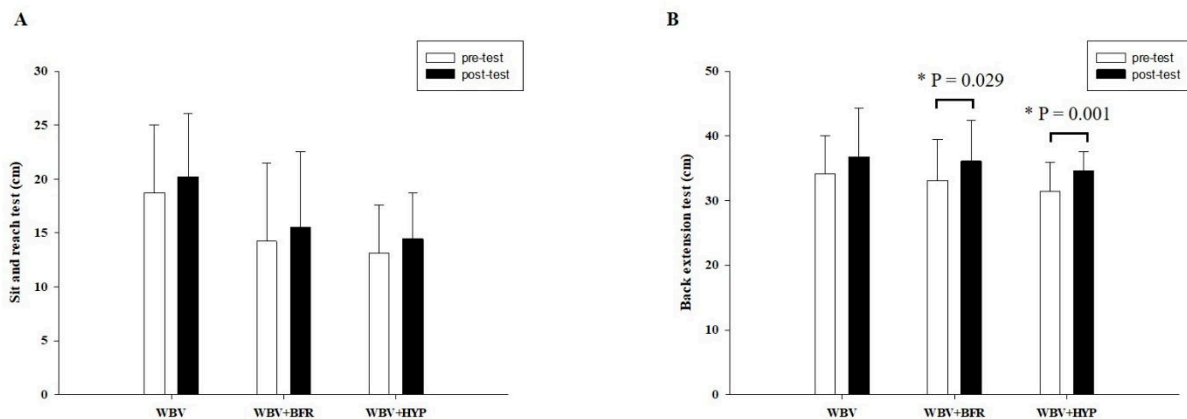


Fig. 2. Changes in flexibility (A; Sit and reach test and B; Back extension test) before and after 8-week of the training period. Values are present as mean \pm SD. *Significant $p < 0.05$ (pre vs post)

34.59 \pm 9.10 ml/kg/min) and vertical jump (31.20 \pm 8.17 cm and 34.20 \pm 6.83 cm, baseline and post-intervention mean \pm SD respectively) as a result of training (baseline to post-intervention) were not significantly different between groups (Fig. 4).

Discussion

This research investigated and compared the effects of whole-body vibration combined with blood flow restriction and hypoxic exposure. Previous studies found that training with a whole-body vibration machine can help improve muscle performance (Berner et al., 2020). Training with

blood flow restriction can also help improve muscular strength (Cai et al., 2021). Training with hypoxic exposure, a new form of training, may also change the physiological mechanisms of training (Park et al., 2020). Therefore, this study was conducted to test the responses to the training among overweight adolescents.

In terms of body composition, any good changes or relatively obvious changes were not found. Only the WBV+HYP group had a significant increase in muscle mass and leg muscles (right side). Moreover, the fat mass and fat of the three groups did not change. However, a study by Park et al. (2020) showed that whole-body vibration training was effective in reducing body fat (Park et al., 2020). A research

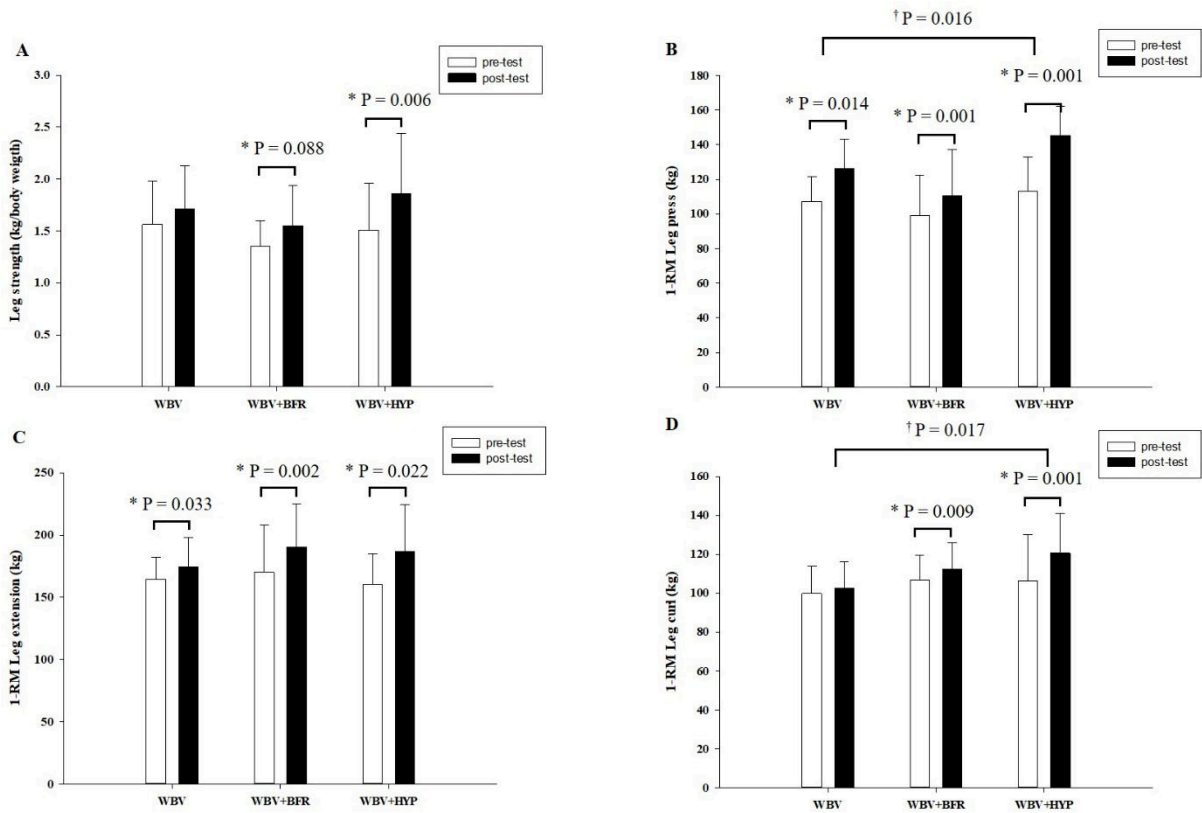


Fig. 3. Changes in muscular strength (A; Leg strength, B; 1-RM Leg press, C; 1-RM Leg extension and D; 1-RM Leg curl) before and after 8-week of the training period. Values are present as mean \pm SD. *Significant $p < 0.05$ (pre vs post), †Significant $p < 0.05$ (WBV vs WBV+HYP)

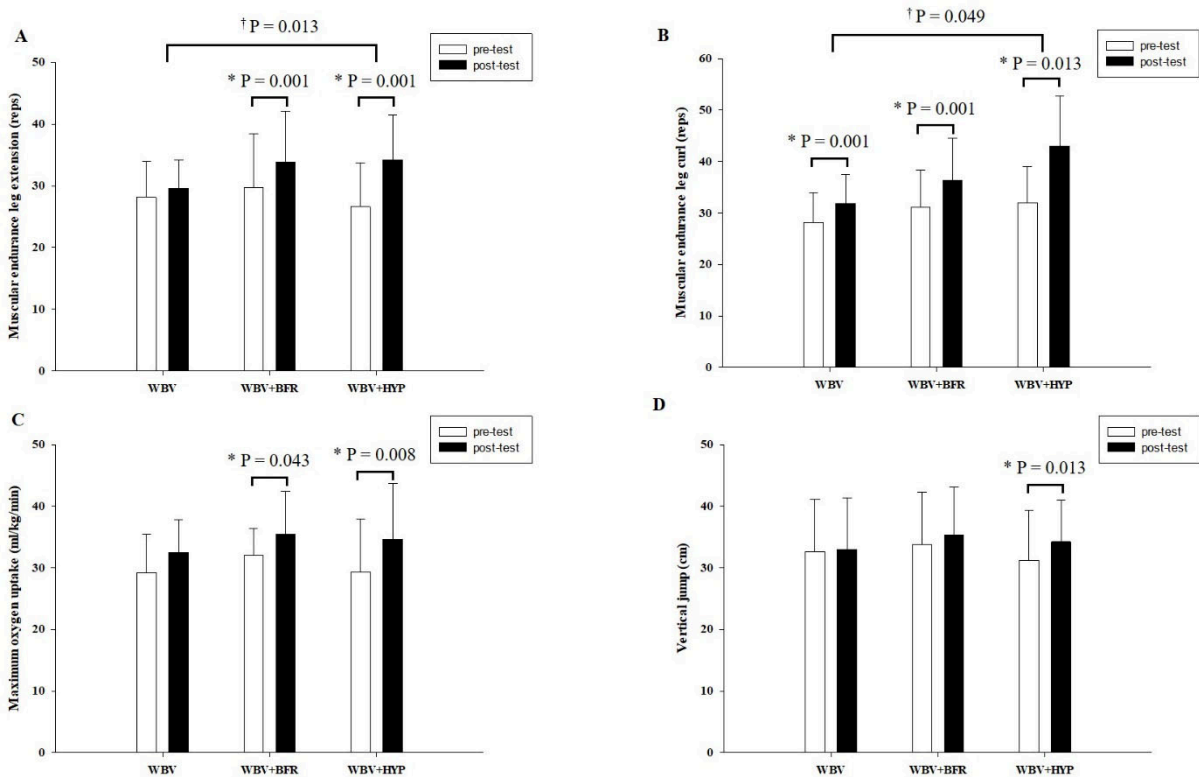


Fig. 4. Changes in muscular endurance, cardiorespiratory endurance and muscular power (A; Muscular endurance leg extension, B; Muscular endurance leg curl, C; Maximum oxygen uptake and D; Vertical jump) before and after 8-week of the training period. Values are present as mean \pm SD. *Significant $p < 0.05$ (pre vs post), †Significant $p < 0.05$ (WBV vs WBV+HYP)

study by Vissers et al. (2010) also found that after training with a whole-body vibration machine for 6 months, body fat can be reduced (Vissers et al., 2010). Therefore, the following research hypothesis was developed: The duration of the experiment may affect the changes, which may take 10 weeks or more and the factors such as the subjects' diet and energy balance may also affect the changes. A study by Bellia et al. (2013) found significant changes in fat mass when whole body vibration training was combined with diet control. It may also be an important factor in increasing muscle mass although there was no significant change in overall muscle mass (Bellia et al., 2013). This is different from a study by Cai et al. (2021) which found that the BFR group had changes in leg muscle mass (Cai et al., 2021). However, the WBV+HYP group had significant changes in leg and right leg muscle mass. This is the factor that requires further study for hypoxic exposure or systemic hypoxia training.

Flexibility was significantly changed in the WBV+BFR and WBV+HYP groups in back extension, indicating that combined whole-body vibration training was effective in improving flexibility. In a study by Đorđević et al. (2022), an experiment was conducted among gymnasts and significant changes in flexibility was found (Đorđević et al., 2022). That is, the static squat position at 100° knee flexion can stimulate the muscles in thighs and core. The subjects must maintain a straight posture which may cause changes in strength and flexibility in the lumbar muscles.

Overall, changes in muscular strength in all three groups tended to improve. This is consistent with previous studies that blood flow restriction training was found to improve muscular strength (Cai et al., 2021; Cohen et al., 2022) or even whole-body vibration training alone can also increase muscular strength (Berner et al., 2020; Hegazy et al., 2021; Lai et al., 2021). This was especially true in the WBV+HYP group, where changes were similar to those in the BFR group. This may be caused by physiological changes during hypoxic training. Previous studies also found changes in muscular strength (Inness et al., 2016). As for muscular endurance, quite obvious changes were found in the WBV+BFR and WBV+HYP groups in accordance with the principles of stimulation and development during training (Plotkin et al., 2022). Most tests focused on muscle repetitions that measure endurance, and whole-body vibration training was shown to help improve this aspect of fitness (Cai et al., 2021; Kholvadia & Baard, 2012; Osawa et al., 2011). In addition, whole-body vibration combined with blood flow restriction or hypoxic exposure may help confirm that blood flow and oxygen restriction affect muscle response (Jessee et al., 2018; Kacin & Strazar, 2011; Manimmanakorn et al., 2013) although the training is in the muscle contraction posture. It is also expected that if it is practiced with postures that include movement, it may result in increased muscle endurance.

Muscular power was only changed in the WBV+HYP group. It is consistent with a study by Inness et al. (2016) where changes in maximum muscular power were found in heavy resistance training in hypoxia (Inness et al., 2016). However, there are few studies on the muscular power of whole-body vibration training. In this research, whole-body vibration training may not be the most effective way to develop muscular power. Further study is required.

In the WBV+BFR and WBV+HYP groups, significant changes in $VO_2\max$ occurred after 8 weeks of training.

Previous studies showed that hypoxic exposure can help improve $VO_2\max$ (Deldicque, 2022; Westmacott et al., 2022), and it can be clearly seen when FiO_2 is lower than 13.8%. In terms of physiological factors, vascular endothelial growth factor (VEGF) is stimulated by hypoxia (Downs et al., 2014; Shimizu et al., 2016), and it may be the factor that can increase the ability to manage and control oxygen levels during exercise.

In this research, the following research gaps and limitations can be found. The basic factors of the subjects, including age, gender and experience with exercise training may affect the level of change. In addition, a longer period of time (12 weeks to 6 months) is required. Moreover, frequency of training and the intensity of hypoxia may result in more pronounced changes. Suitability and safety between the training programs and the subjects should be considered. Also, other factors that can be controlled or monitored, such as diet, stress, and rest may help identify the cause of changes.

Conclusions

Whole-body vibration combined with blood flow restriction and hypoxic exposure were effective in improving body composition and physical fitness. In particular, the group that combined training with hypoxic exposure showed good changes in maximum muscular strength in leg press and leg curl, and muscular endurance in leg extension and leg curl when compared to the group trained with the whole-body vibration machine alone. This is useful in choosing the form of training that can help develop various aspects of physical fitness for beginners or people who are unable to choose the type of exercise. The combination of whole-body vibration training with blood flow restriction and hypoxic exposure can effectively improve physical fitness. It can also be adjusted according to convenience and suitability for each individual. It is a guideline for preventing, treating, and promoting health among overweight adolescents.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Вплив біомеханічної стимуляції в поєднанні з обмеженням кровотоку та системною гіпоксією на композицію тіла та фізичну продуктивність студентів університету з надмірною вагою

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 10 с., 3 табл., 4 рис., 33 джерела.

Мета дослідження. У цьому дослідженні вивчався вплив біомеханічної стимуляції (БМС) у поєднанні з обмеженням кровотоку (ОК) та гіпоксичним впливом (ГВ) на композицію тіла та фізичну продуктивність студентів університету з надмірною вагою.

Матеріали та методи. Двадцять дев'ять студентів чоловічої статі з надмірною вагою були розподілені на 3 групи: 1) біомеханічна стимуляція (БМС), 2) біомеханічна стимуляція плюс обмеження кровотоку (БМС+ОК, 60% оклюзійного тиску) і 3) біомеханічна стимуляція плюс гіпоксичний вплив (БМС+ГВ, FiO₂ = 15,8%). Тренування включало 10 сеансів виконання інтервальних фізичних вправ на основі БМС (частота 30-35 Гц і висока амплітуда) по 20 хв/день і 3 дні на тиждень. Показники композиції тіла разом з фізичною продуктивністю вимірювалися до (2-3 дні) і після (2-3 дні) 8-тижневого періоду тренувань.

Результати. Результати проведеного дослідження були наступними: після тренування показники максимальної сили (1RM) у жимі ногами та згинанні ніг значно зросли у досліджуваній групі, що проходила процедури БМС +ГВ (28,31%,

$p = 0,016$ та $13,56\%$, $p = 0,017$) порівняно з групою, де була проведена БМС ($17,68\%$ та $2,88$), відповідно. Аналогічно, у учасників досліджуваної групи, що проходила процедури БМС+ГВ спостерігалось значне збільшення показників м'язової витривалості у розгинанні та згинанні ніг ($28,57\%$, $p = 0,013$ та $34,38\%$, $p = 0,049$) порівняно з групою, в якій була застосована БМС ($5,33\%$ та $13,20\%$), відповідно.

Висновки. Біомеханічна стимуляція в поєднанні з обмеженням кровотоку та гіпоксичним впливом показали свою ефективність у покращенні композиції тіла та фізичної підготовленості. Проведення процедури також можна регулювати відповідно до вимог та індивідуальних особливостей кожної особи. Дана методика є керівним принципом для профілактики, лікування та підтримки здорового способу життя серед підлітків з надмірною вагою.

Ключові слова: біомеханічна стимуляція, обмеження кровотоку, системна гіпоксія, композиція тіла, фізична продуктивність, надмірна вага

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