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MUSCLE MASS AND MUSCLE STRENGTH FOLLOWING 6 WEEKS OF BLOOD FLOW RESTRICTION COMBINE WITH LOW-INTENSITY STRENGTH TRAINING IN OVERWEIGHT ADOLESCENTS

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

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Abstract

Background and Study purpose. Blood flow restriction training is a new training technique that involves low-intensity exercise and can generate physiological changes equivalent to high-intensity exercise. The aim of this study is to assess the impact of blood flow restriction in conjunction with low-intensity resistance exercise on muscle mass and muscle strength among overweight adolescents, in comparison to conventional resistance exercise.

Materials and methods. The study involved two randomized groups: an experimental group, which performed 40% of one repetition maximum (1RM) resistance exercise combined with 60% of arterial occlusion pressure (AOP), and a traditional resistance exercise group, which performed 70% of 1RM resistance exercise. All participants underwent pre-test and post-test evaluations for body composition, 1RM, and muscle circumference. The training program lasted for six weeks and consisted of upper and lower body training, including exercises such as leg press, leg curl, arm curl, and arm extension.

Results. The group that underwent low-load blood flow restriction (LLBFR) training showed a notable increase in muscle mass ($p<0.049$) as well as arm and leg circumference ($p<0.047$ and $p<0.046$, respectively) compared to before the training program, similar to the results of high-intensity resistance exercise.

Conclusions. Combining blood flow restriction with low-intensity resistance training is a potentially effective approach to increase muscle size and strength, especially in overweight adolescents. Moreover, this type of training can decrease the amount of exercise load, making it a feasible option for individuals who may not tolerate high loads due to certain medical conditions or other limitations.

Keywords: resistance exercise, overweight, vascular occlusion, blood flow restriction, local hypoxia, low-intensity.

Introduction

For almost two decades, overweight and obesity have been recognized as significant health concerns globally (WHO., 2000). Both developed and developing countries are experiencing a rise in these conditions Lang & Froelicher. (2006). According to the World Health Organization (WHO), there were 1.6 billion overweight adults, over 400 million obese adults, and at least 20 million overweight children under five years old. If current trends persist, these numbers are expected to increase to 2.3 billion overweight and 700 million obese individuals. Overweight and obesity are major public health concerns worldwide and are associated with various chronic diseases, such as hyperlipidemia, type 2 diabetes, atherosclerosis, liver disease, cancer, and neurodegenerative diseases that can lead to reduced quality of life and increased mortality rates. It is crucial to address this issue through lifestyle modifications, such as increased physical activity and a healthy diet, to prevent and manage obesity-related health problems (Teufel et al., 2021).

As it lowers body weight, total fat, visceral fat, intrahepatic fat, and blood pressure, moderate-intensity aerobic exercise is an effective treatment for adult overweight/obesity, whereas moderate-intensity resistance exercise can help maintain lean body mass during weight loss (Oppert et al., 2021). However, those with excessive body weight/obesity, the elderly, recuperating athletes, or those with no prior training experience who cannot endure significant mechanical pressure on the joints during high-resistance

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training may sustain sports injuries from high-intensity strength or aerobic training. These risks have been discussed in numerous studies. For example, a high body mass index and percent body fat are associated with significant increases in muscle injury markers following high-intensity exercise (Kim & Yoon., 2021), and high-intensity running, cycling, and swimming can harm muscles in athletes (Huang et al., 2019). However, Blood flow restriction training has been shown to aid in the rehabilitation of knee injuries and improve musculoskeletal system recovery. By applying external pressure to the limb using devices such as inflatable cuffs or elastic bandages, blood flow restriction can partially block arterial blood flow and occlude venous blood flow in the pressured limbs, which can reduce muscle damage and promote muscle recovery. Some studies have also suggested that blood flow restriction training can improve muscle strength and hypertrophy in athletes recovering from injury or surgery (Castilla et al., 2021; Wortman et al., 2021).

Blood flow restriction training has been developed as an alternative to high-intensity training for individuals who cannot tolerate high mechanical pressure. This technique involves applying external pressure to the limb during exercise, partially blocking arterial blood flow and occluding venous blood flow in the pressured limbs (Perera et al., 2022). This produces the effect of intensive training while using lower resistance or endurance exercises. Previous studies have demonstrated that blood flow restriction training can increase muscle mass and strength, improve muscle fitness, aerobic capacity, knee rehabilitation, acute bone formation markers and hormonal responses, and athletic performance in various populations (Korkmaz et al., 2022; Sun., 2022; Bemben et al., 2022). However, there is limited research on the effects of low-intensity resistance training combined with blood flow restriction on muscle mass and strength in overweight adolescents. Therefore, our study aims to investigate the effects of this type of training on body composition parameters, muscle mass, and strength, and compare them to a high-intensity resistance training group.

Material and methods

Participants

The study recruited 30 participants who were considered overweight based on a BMI between 25 and 29.9 and engaged in recreational exercise. The participants were considered recreational, meaning they engaged in exercise for leisure and not as part of a structured training program. The sample size was determined based on an estimated effect size of 0.25, with a significance level of $p \leq 0.05$ and a statistical power greater than 0.80, resulting in a required sample size of n = 30 (Curty et al., 2018). Individuals with vascular health issues such as hypertension, deep vein thrombosis, or distended varicose veins, as well as those with a history of medical treatment or drug use, were excluded from the study. All participants were given detailed explanations of the experiment's purpose, procedures, and methods and voluntarily provided informed consent before participating. The thirty participants were randomly assigned to either the group that received 40% of one-rep max (1RM) resistance exercise with 60% of arterial occlusion pressure (AOP) for blood flow restriction (n=15) or the group that underwent traditional resistance exercise group, which performed 70% of 1RM resistance exercise high-intensity resistance training (n=15). An independent t-test was conducted to compare the age, height, weight, and body mass index (BMI) between the two groups, revealing no statistically significant differences ($p > 0.05$). The study's procedures, methods, and consent form were approved by the Human Research Ethics Committee of Walailak University (approval number: WUEC-23-084-01), and the study was conducted from March to June 2023.

Study design

In this study, a randomized trial design was used, and the participants were divided into two groups using the randomized block approach. The two groups were the blood flow restriction combine with low-intensity resistance training (LTBFR) group and the high-intensity resistance training (HT) group, as shown in Figure 1.

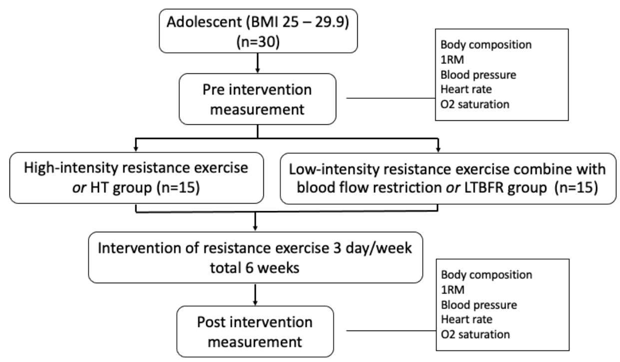

Fig. 1. The outline of the groups of the study

To be eligible for participation in this study, individuals had to be capable of performing their daily activities without experiencing persistent depression and should have adequate social support. Those who could not exercise safely, had a generalized anxiety disorder, changed their medication or therapy within the past three months, experienced an acute injury or illness while exercising, or engaged in alcohol/substance misuse or smoking were excluded from the study. Participants were instructed to refrain from self-medication, notify the study's medical director if they developed a fever or acute infection or started using new medication, and avoid making any changes to their diet during the study period.

Experimental procedures

Body composition

Prior to the exercise session, body composition was assessed by measuring height, body weight (BW), and body mass index (BMI) using a body composition monitor (Tanita model UM-076) in accordance with the manufacturer's guidelines.

Determination of arterial occlusion pressure

Leg and Arm Circumference

Before determining the arterial occlusion pressure, measurements were taken for the circumference of both the legs and arms. A tape measure was used to measure the distance from the acromion process to the olecranon process on the arm, and a mark was made at a point located 50% distal to the acromion process. Similarly, the circumference of the right thigh was measured at a point corresponding to 33% of the distance from the inguinal crease to the top of the patella. These measurements were obtained at designated marks to ensure precise and accurate application sites for the cuffs.

Brachial systolic and brachial diastolic blood pressure

Brachial systolic and diastolic blood pressure were assessed using an appropriately sized automatic blood pressure cuff (Allwell, Model BSX593). Measurements for systolic brachial blood pressure (SBP) and diastolic brachial blood pressure (DBP) were taken in duplicate, and the average of these values was used for analysis.

Training protocol

The study's procedure commenced by measuring baseline factors, including body composition, muscle mass, and muscle strength. Two groups were then evaluated:

1. The first group performed resistance exercise using 40% of their one-repetition maximum (1RM) in combination with 60% of the arterial occlusion pressure (AOP) for blood flow restriction.

2. The second group engaged in traditional resistance exercise using 70% of their 1RM.

Both groups participated in 60-minute sessions, conducted three times per week, for a duration of six weeks. Throughout the study, all measurements and training sessions were conducted in a controlled environment, maintaining a constant temperature and humidity level. Figure 2 provides a visual representation of the experimental setup.

Blood flow restriction determining – Cuff Pressure

The level of pressure needed to block blood flow in a limb, known as arterial occlusion pressure (AOP), varies depending on factors such as the shape, width, and length of the tourniquet, limb size, and individual blood pressure. In this study, the pressure used to limit blood flow during resistance exercise was set at 60% of the AOP, which can be achieved by inflating the exercise cuff until blood flow stops completely (100% of AOP).

The Arterial Occlusion Pressure (mmHg) for 100% of AOP (Loenneke et al., 2015) was calculated as follows:

Lower Body = 0.912 (SBP) + 0.734 (DBP) + 5.893 (Thigh circumference (cm)) – 220.046

Upper Body = 0.667 (SBP) + 0.399 (DBP) + 1.461 (Arm circumference (cm)) – 17.236

Then, for blood flow restriction combined with 40% of 1RM of low-intensity exercise, use a percentage of that pressure as 60% of AOP during exercise.

After a 10-minute rest period, specialized blood pressure cuffs made of nylon (5 cm wide) were applied to the proximal portions of each arm. These cuffs were connected to a cuff inflator system to regulate pressure. A pressure equivalent to 60% of the AOP was targeted for each arm. To determine the appropriate pressure, the arterial occlusion pressure (AOP) was estimated using specific formulas for both upper body parts, which amounted to around 80 - 110 mmHg for the upper body (calculation for individual participant). Throughout the training period, the O2 saturation was continuously measured to monitor oxygen levels. Upon completion of this session, the cuffs were removed from the arms, and participants were instructed to rest quietly in the relax position with normal blood flow for an additional 5 minutes.

Following the 5 minute rest period with normal blood flow, the cuffs for leg (10 cm wide) were applied to the proximal portions of each leg. Similarly, a pressure equivalent to 60% of the AOP was targeted for each leg. To determine the appropriate pressure, the arterial occlusion pressure (AOP) was estimated using specific formulas for lower body parts, which amounted to around 130-250 mmHg for the lower body (calculation for individual participant). Throughout the training period, the O_2 saturation was continuously measured to monitor oxygen levels. Upon completion of this session, the cuffs were removed from the arms, and participants were instructed to rest quietly in the supine position with normal blood flow for an additional 5 minutes (Loenneke et al., 2015).

Resistance training intervention

The participants in the study performed resistance training three times a week for six weeks, on Mondays, Wednes-

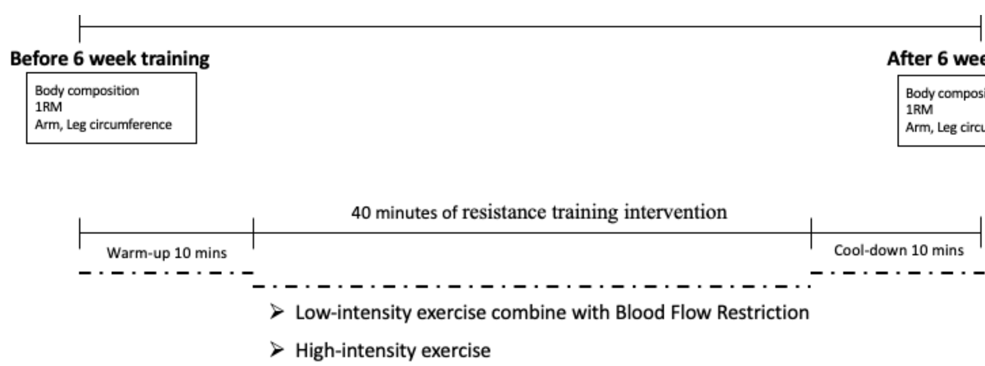

Fig. 2. The outline of the time schedule of the study

days, and Fridays from 4:00-7:00 PM. Each session lasted 60 minutes and focused on upper and lower body physicality. The participants determined their one-repetition maximum (1RM) for the biceps curl, triceps extension, leg extension, and leg press. The resistance training program consisted of four stations, with each station performing three sets of three reps. The low-intensity resistance training group with 60% arterial occlusion pressure (AOP) of blood flow restriction used 40% of their 1RM, while the high-intensity resistance training group used 70% of 1RM and was evaluated before and after week six. The training sessions included 10 minutes of warming up and stretching in standing and sitting poses, followed by 40 minutes of resistance training at the four stations, and a 10-minute cool-down period (Table 1 shows the details of the training program).

Table 1. Components of the resistance training intervention (three times/week for six weeks)

Components	Set	Repetitions
Upper body		
Biceps curl	3-5	12-15
Triceps extension	3-5	12-15
Lower body		
Leg extension	3-5	12-15
Leg press	3-5	12-15

One repetition maximum (1-RM)

To assess changes in muscle strength, the researchers measured the one-repetition maximum (1-RM) for the participants. The 1-RM leg press and 1-RM leg extension were evaluated using a bilateral leg press machine and a bilateral leg extension machine (Spirit, UK) respectively. For the 1-RM biceps curl test, the bilateral machine triceps extension with the dominant arm was used. Additionally, the 1-RM triceps extension was measured using the triceps extension machine (Spirit, UK). These specific tests were chosen to determine an individual's maximum strength in the targeted muscle groups. The data obtained from these tests provided valuable insights into changes in muscle strength over time and were essential in designing appropriate exercise programs tailored to each participant's needs.

Statistical analysis

Data values are presented as the mean ± standard error of the mean (SEM). IBM SPSS Statistics 26 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Paired sample t-tests were used for comparisons between groups. One-way analysis of variance (ANOVA) with Tukey's post-hoc test was performed to evaluate significant differences between the groups. Statistical significance was set at $P < 0.05$.

Results

Demographic characteristic of the participants

Thirty participants were screened between March and June 2023 and were randomly assigned to one of two groups (n = 15 each). The first group underwent a low-intensity resistance training program with 40% of 1RM combined with blood flow restriction training at 60% of AOP, while the second group received high-intensity resistance training at 70% of 1RM. The baseline characteristics, including mean age (year), height (cm), body weight (kg), and body mass index (kg/m^2), were measured and found to have no statistically significant differences between the two groups, as shown in Table 2.

Comparison of participant muscle mass before and after the test

Table 3 and Figure 3 display the mean values of pre- and post-test for the two groups. In the LTBFR group, the mean muscle mass after the LTBFR training was significantly

Table 2. Demographic characteristics of the participants at baseline

Characteristics	LTBFR (n=15)	HT (n=15)	95% CI	p-value
Age (year)	20.15 ± 0.19	20.00 ± 0.28	-0.85 to 0.54	0.652
Height (cm)	170.62 ± 1.36	168.62 ± 2.88	-8.56 to 4.56	0.535
Weight (kg)	76.94 ± 3.24	77.81 ± 5.56	-12.41 to 14.15	0.894
BMI (kg/m2)	27.61 ± 0.95	27.17 ± 1.38	-3.89 to 3.01	0.796

Data are presented as mean ± standard error of the mean (SEM), with unpaired t-test. BMI, body mass index

Table 3. Comparison of pre- and post-test muscle mass for the 40% of 1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR)

Characteristics	n	Muscle Mass (kg)		Difference between means	% Change	p-value
		Pre-test	Post-test			
LTBFR	15	50.55 ± 2.97	58.21 ± 2.23*	7.66 ± 3.71	15.15	0.049
HT	15	54.77 ± 3.81	65.32 ± 3.40*	10.55 ± 5.11	19.24	0.049

Data are represented as the mean ± standard error of the mean (SEM). *P < 0.05 indicates significant difference when compared with pre- and post-test demographics for the 40%1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR) participants group. Data were compared between pre- and post- group using an unpaired t-test

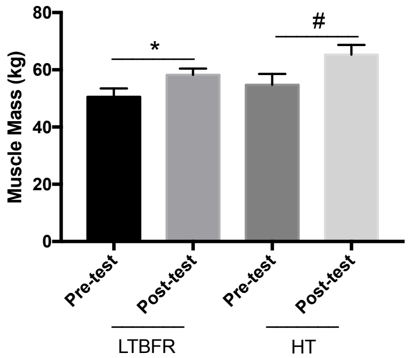

Fig. 3. Comparison of pre- and post-test muscle mass both the 40% of 1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR) and high intensity resistance training (HT)

higher than the mean muscle mass before LTBFR training ($p < 0.049$). Similarly, in the HT group, the mean muscle mass after the HT training was significantly higher than the mean muscle mass before HT training ($p < 0.049$), as shown in Figure 3.

Increasing of arm circumference and leg circumference following the intervention

Based on Table 4 and Figure 3, it appears that both LTBFR and HT training resulted in significant increases in arm and leg circumference. Specifically, LTBFR training resulted in a significant increase in arm circumference ($p<0.036$) while HT training resulted in a significant increase in both arm ($p<0.047$) and leg ($p<0.046$) circumference. The percent change in circumference was higher for HT training in the arm (10.15%) compared to LTBFR training (8.87%), while the percent change in leg circumference was higher for LTBFR training (8.65%) compared to HT training (9.97%). Overall, it seems that both LTBFR and HT training were effective in increasing arm and leg circumference.

Increasing of One- repetition maximum (1RM) following the intervention

Table 5 and Figure 5 display the results of the pre- and post-tests for one-repetition maximum (1RM). The data shows that both LTBFR and HT interventions resulted in a significant increase in 1RM compared to before training. The percent increase in leg extension and leg press for LTBFR

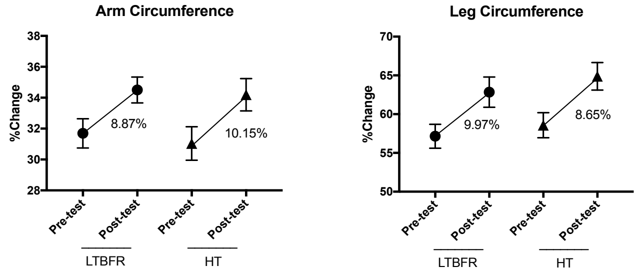

Fig. 4. Percent change of arm and leg circumference of pre- and post-test for LTBFR and HT group

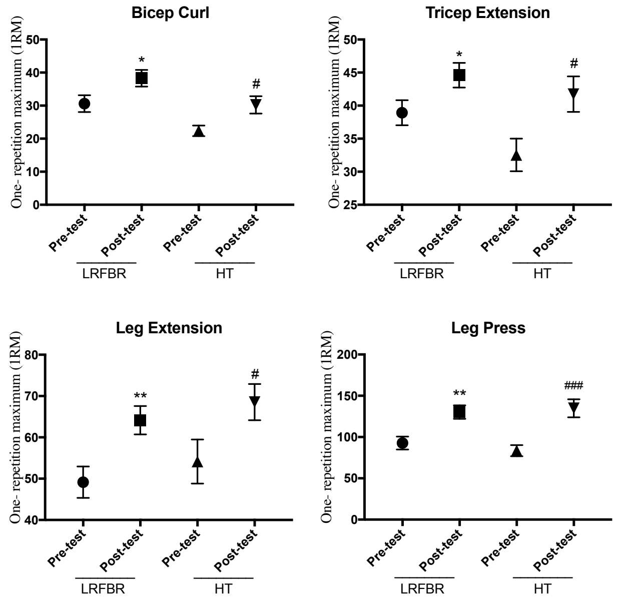

Fig. 5. One-repetition maximum (1RM) of pre- and post-test for the 40% of 1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR) and high intensity resistance training (HT)

training was higher than for HT training, with increases of 30.52% and 40.38%, respectively, for LTBFR and 26.56% and 61.36%, respectively, for HT.

Discussion

The objective of our study was to assess the impact of combining low-intensity resistance training with blood flow restriction on muscle mass and strength in overweight adolescent. Our main discovery was that after six weeks

Table 4. Arm and leg circumference of pre- and post-test for the 40% of 1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR) and high intensity resistance training (HT)

Resistance training station	LTBFR (n=15)		% Change	p-value	HT (n=15)		% Change	p-value
	Pre-test	Post-test			Pre-test	Post-test		
Arm circumference (cm)	31.69 ± 0.94	34.50 ± 0.84*	8.87	0.036	31.04 ± 1.08	34.19 ± 1.05#	10.15	0.047
Leg circumference (cm)	57.15 ± 1.55	62.85 ± 1.95*	9.97	0.031	58.58 ± 1.61	63.65 ± 1.79#	8.65	0.046

Data are represented as the mean ± SEM. *P < 0.05 indicates significant difference when compared with pre- and post-test demographics for the 40% of 1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR) participants group, #P < 0.05 indicates significant difference when compared with pre- and post-test demographics for the 70% of 1RM of high-intensity participants group. Data were compared between pre- and post- group using an unpaired t-test

Table 5. One-repetition maximum (1RM) of pre- and post-test for the 40% of 1RM of low-intensity combined with 60% of AOP of blood flow restriction (LTBFR) and high intensity resistance training (HT)

Resistance training station	LTBFR (n=15)		% Change	p-value	HT (n=15)		% Change	p-value
	Pre-test	Post-test			Pre-test	Post-test		
Biceps curl (kg)	30.66 ± 2.55	38.31 ± 2.53*	25.11	0.042	22.38 ± 1.59	30.23 ± 2.62#	35.08	0.017
Triceps extension (kg)	38.92 ± 1.89	44.61 ± 1.86*	14.62	0.043	32.54 ± 2.47	41.73 ± 2.69#	28.24	0.019
Leg extension (kg)	49.15 ± 3.79	64.15 ± 3.43**	30.52	0.007	54.15 ± 5.32	68.54 ± 4.38#	26.56	0.048
Leg press (kg)	92.77 ± 7.86	130.23 ± 8.13**	40.38	0.003	83.54 ± 6.71	134.80 ± 10.88###	61.36	0.0005

Data are represented as the mean ± SEM. Data were compared between pre- and post- group using an unpaired t-test.

of this training, there was a significant increase in muscle mass (15.15%) compared to the baseline measurement. Both LTBFR and HT interventions resulted in significant increases in muscle mass after 6 weeks of training. The muscle hypertrophy potential was determined by calculating the percentage increase in muscle mass, and the results showed that LTBFR had a 15.15% increase in muscle mass and HT had a 19.24% increase, indicating that both interventions had similar levels of muscle growth. The effect sizes observed suggest that the results are reliable and consistent with previous studies on various populations (Centner et al., 2019; Zhang et al., 2022; Lixandrão et al., 2018) including individuals with musculoskeletal injuries (Hughes et al., 2017). The values obtained in the current study are similar to the findings of a previous study that showed that two weeks of twice-daily squat and leg curl training with BFR produced thigh muscle hypertrophy of 0.32% per session (Abe et al., 2005) and increases thigh muscle cross-sectional area as well as maximal muscle strength (Yasuda et al., 2016). However, the cellular and molecular mechanisms underlying the hypertrophic response to LTBFR training are not fully understood. Skeletal muscle hypertrophy is generally attributed to an increase in protein accretion, or the accumulation of contractile protein (Schiaffino et al., 2021). This happens when the balance between protein synthesis and degradation shifts toward synthesis. Skeletal muscle is a flexible tissue that can adapt to even minor changes in nutrition and physical activity. Resistance exercise, in particular, causes a slight increase in muscle protein breakdown (Schiaffino et al., 2021; Atherton et al., 2010; Morton et al., 2015), but it also stimulates muscle protein synthesis to a greater extent. When resistance exercise is done before consuming protein, the two stimuli complement each other, resulting in even greater muscle protein synthesis than muscle protein breakdown (Glynn et al., 2010). Repeated sessions of resistance exercise and protein intake lead to an increase in skeletal muscle protein accumulation, also known as hypertrophy (Cermak et al., 2012). Typically, the load required to stimulate this level of protein synthesis is believed to by in excess 8-10 sets of resistance exercise at a 70-80% of 1RM of resistance training (Dreyer et al., 2006). Interestingly, a single bout of knee extension exercise combine with blood flow restriction elicits the same level of protein synthesis with a lower repetition count and 20% of 1RM of resistance training. Recent research has shown that a single bout of low-intensity knee extension exercise with blood flow restriction at 20% of 1RM intensity can increase thigh muscle protein synthesis (Fujita et al., 2007). The combination of low intensity resistance exercise and blood flow restriction has been shown to increase protein synthesis and result in muscle hypertrophy. This effect is believed to be due to the unique physiological response of blood flow restriction, which limits blood flow to the working muscle, creating a hypoxic environment that stimulates the release of growth factors and enhances muscle protein synthesis (Lim & Goh., 2022). The lower intensity and repetition count required to achieve this effect with blood flow restriction compared to traditional high-intensity resistance exercise makes it a promising tool for individuals who may not be able to tolerate high-intensity exercise or who are looking for a more time-efficient approach to building muscle mass.

The physical effects of LTBFR resistance training may be influenced by metabolic stress, as the mechanical strain induced by LTBFR resistance training is thought to be similar to that of traditional high-intensity resistance training (Pearson & Hussain., 2015). It has been suggested that, compared to lower-intensity resistance training, blood flow restriction training results in lower oxygen bioavailability, which leads to the onset of anaerobic glycolysis in muscles and the accumulation of fatigue metabolites such as lactate product (Fry et al., 2010; Shimizu et al., 2016; Takarada et al., 2000). Recently, Fujita and Yasuda observed an increase in muscle protein synthesis and ribosomal S6 kinase 1 (S6K1) phosphorylation following a single session of blood flow restriction combined with low-intensity resistance exercise. These changes in transcriptional factors associated with muscle hypertrophy after LTBFR may be attributed to the up-regulation of genes related to hypertrophy, such as phosphoinositide 3- kinase (PI3K), protein kinase B (AKT), and mTOR (Yasuda et al., 2009). Drummond et al. also found that the brief periods of hypoxia and reperfusion induced by BFR activate the mTOR pathway, promoting cell survival and growth adaptations in skeletal muscle. Furthermore, the up-regulation of vascular endothelial growth factor (VEGF), a crucial modulator in vasculogenesis and angiogenesis, is necessary for hypertrophy and can be stimulated by hypoxia and lactate accumulation (Drummond et al., 2008; Simons et al., 2016). These mechanisms are associated with local hormone secretion, cell swelling, muscle damage, and increased production of reactive oxygen species, all of which contribute to anabolic muscle phenomena (Loenneke et al., 2012).

With regard to muscle strength the present study showed that estimated 1RM in biceps curl, triceps extension, leg extension and leg press increased significantly after 6-week resistance training in the blood flow restriction group.

To summarize, the study found that both LTBFR and HT interventions resulted in significant increases in overall strength and power, as measured by 1RM, after 6 weeks of training. The HT group had a greater increase in 1RM compared to the LTBFR group, suggesting that high-intensity resistance training may be more effective for increasing muscle strength. However, LTBFR resistance training still offered superior increases in muscle strength compared to the baseline measurement. Additionally, when comparing specific exercises, percent change in muscle strength was higher for the LTBFR group for biceps curl, triceps extension, leg curl, and leg press. The results of the study showed that LTBFR training led to greater strength gains in the leg extension compared to HT training. Specifically, there was an average percent change of 30.52% in the LTBFR group and 14.91% in the HT group. These findings are consistent with previous research, such as a study by Fujita et al. (2008) which found significant increases in maximal leg extension strength after a two-week training program that included lactic acid accumulation (Fujita et al., 2008). Indeed, the increase in fast-twitch muscle fiber activation and the accumulation of lactic acid in muscle fibers are potential mechanisms that may explain the strength gains observed in the LTBFR group (Takarada et al., 2000; Loenneke et al., 2012). Additionally, the increase in serum growth hormone concentrations in the blood flow restriction group may have contributed to the observed muscle hypertrophy and neuromuscular adaptation (Miller et al., 2021; Yinghao et al., 2021; Fekri-Kourabbaslou et al., 2022). These metabolic and neurohormonal changes induced by blood flow restriction may have stimulated anabolic pathways and protein synthesis in the muscle, leading to hypertrophy and strength gains.

While the present study demonstrated promising results, there are some limitations to be acknowledged. Firstly, the study only included overweight adolescents, so it is unclear whether similar results would be observed in other populations, such as athletes or elderly individuals. Secondly, the study did not investigate potential sex differences in the response to blood flow restriction combine with resistance training, which should be explored in future research. Additionally, while the study suggested that blood flow restriction with resistance training may improve vascular endothelial function and peripheral blood circulation (Green et al., 2004; Miyauchi et al., 2003), further investigation is necessary to confirm these mechanisms. For example, measuring vascular endothelial growth factor and mammalian target of rapamycin, its regulates cell proliferation, would help clarify these mechanisms (Shimizu et al., 2016). Overall, despite these limitations, the combination of low-intensity resistance training with blood flow restriction appears to be a promising strategy for promoting muscle hypertrophy and strength, particularly in overweight adolescents. Further research is needed to fully understand the underlying mechanisms and to determine the effectiveness of this training in other populations.

Conclusions

That is a significant finding, low-intensity resistance training combined with blood flow restriction can be a feasible substitute for high-intensity resistance training in promoting muscle strength and hypertrophy in overweight adolescents, which may benefit those who cannot or choose not to perform high-intensity resistance training. However, these findings should be confirmed by additional research, which should also examine the potential long-term impacts of LTBFR on muscle mass and strength. Moreover, further research is needed to investigate the effects of LTBFR on other populations.

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Conflict of interest

The authors declare that there is no conflict of interest.

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М'ЯЗОВА МАСА ТА М'ЯЗОВА СИЛА ПІСЛЯ 6 ТИЖНІВ ТРЕНУВАНЬ З ОБМЕЖЕННЯМ КРОВОТОКУ В ПОЄДНАННІ З НИЗЬКОІНТЕНСИВНИМИ СИЛОВИМИ ТРЕНУВАННЯМИ У ПІДЛІТКІВ ІЗ НАДМІРНОЮ ВАГОЮ

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

Реферат. Стаття: 10 с., 5 табл., 5 рис., 43 джерела.

Історія питання та мета дослідження. Тренування з обмеженням кровотоку – це нова техніка тренувань, яка включає вправи низької інтенсивності та може викликати фізіологічні зміни, еквівалентні вправам високої інтенсивності. Метою цього дослідження є оцінка впливу обмеження кровотоку в поєднанні з низькоінтенсивними вправами з опором на м'язову масу та м'язову силу в підлітків із надмірною вагою порівняно зі звичайними вправами з опором.

Матеріали та методи. У дослідженні взяли участь дві рандомізовані групи: експериментальна група, яка виконувала вправи з опором на рівні 40% одноповторного максимуму (1ПМ) у поєднанні з рівнем 60% тиску артеріальної оклюзії (ТАО), і група звичайних вправ з опором, яка виконувала вправи з опором на рівні 70% 1ПМ. Усі учасники пройшли оцінювання складу тіла, 1ПМ та окружності м'язів до та після тестування. Програма тренувань тривала шість тижнів і складалася з тренувань м'язів верхньої та нижньої частини тіла, включаючи такі вправи, як жим ногами, згинання ніг, згинання рук і розгинання рук.

Результати. Група, яка проходила тренування з обмеженням кровотоку з низьким навантаженням (LLBFR), продемонструвала помітне збільшення м'язової маси ($p<0{,}049$), а також окружності рук і ніг ($p<0{,}047$ та $p<0{,}046$ відповідно) порівняно з відповідними показниками до початку програми тренувань, подібне до результатів високоінтенсивних вправ з опором.

Висновки. Поєднання тренувань з обмеженням кровотоку з низькоінтенсивними тренуваннями з опором є потенційно ефективним підходом до збільшення розміру та сили м'язів, особливо у підлітків із надмірною вагою. Більше того, цей тип тренувань може зменшити обсяг фізичного навантаження, що робить його можливим варіантом для осіб, які можуть не переносити високі навантаження через певні медичні стани чи інші обмеження.

Ключові слова: вправи з опором, з надлишковою вагою, оклюзія судин, обмеження кровотоку, локальна гіпоксія, низькоінтенсивний.

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