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Original Article

Effect of blood flow restriction training with strengthening exercises in individuals with rounded shoulder posture: A randomized controlled trial

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Abstract
Blood flow restriction (BFR) training has been advocated as an alternative approach for improving muscle strength to correct round shoulder posture (RSP) conditions. Therefore, this study aimed to evaluate the effects of strengthening exercise (SE) with and without BFR training on muscle strength, muscle thickness, RSP, and total scapular distance (TSD) in participants with RSP. This study enrolled a total of 28 healthy participants with RSP. They were randomly assigned to the BFR+SE (n = 14) or the SE group (n = 14). Both groups underwent supervised rehabilitation three times weekly for four consecutive weeks. The BFR+SE group was applied with a cuff around the proximal arm at 50% of arterial occlusion pressure in addition to the SE program, whereas the SE group received the sham BFR alone. Muscle strength, muscle thickness, RSP, and TSD were measured before and after 4 weeks of the intervention. Compared with baseline, both groups showed significant improvement in the rhomboid major, serratus anterior (SA), middle trapezius, and lower trapezius (LT) muscle strength, RSP, and TSD over a 4-week intervention (all $P < 0.05$). Moreover, the BFR+SE group exhibit significant improvements in the thickness of LT and SA muscle compared with that before training (all $P < 0.01$). In addition, the BFR+SE group produced superior benefits over the SE group for all the above variables examined. This finding indicated that BFR programs over 4 weeks are more effective in improving muscle strength, muscle thickness, RSP, and TSD. This information could be a reference for physical therapists when designing exercise programs to correct RSP.
Key Words: **Round shoulder posture, Occlusion, Muscle strength, Muscle thickness**

Introduction

Muscular and skeletal structures can change shape as a result of physical inactivity and poor posture habits in daily life. According to a recent study on participants aged 20–50 years, approximately 73% of workers had right rounded shoulder posture (RSP) and 66% had left RSP. Faulty postures, such as uneven shoulder levels, concern 36% of adolescents and university students who roll their shoulders (Mosaad et al., 2020; Guduru et al., 2022). RSP is characterized by an anteriorly tipped, protracted, and downwardly rotated scapula with increased cervical lordosis and upper thoracic kyphosis (Wong et al., 2010). RSP has various causes. Muscle imbalance in the scapulothoracic region occurred when the pectoralis minor (PM) muscle was shortened, the middle trapezius (MT), lower trapezius (LT), rhomboid major (RM), and serratus anterior (SA) muscles were weak or lengthened, and the LT and SA muscles had decreased thickness (Smith et al., 2002; Cool et al., 2007). RSP can also lead to an increase in the total scapula distance. These changes cause muscle stress and tension around the head, neck, and shoulder pain with function loss (Bae & Lee, 2011).

The treatment for this condition is an important factor in RSP rehabilitation. Many previous studies have investigated various methods to treat RSP, such as LT- and SA-strengthening exercises (SE), PM stretching, shoulder brace or taping to correct the altered posture, and manual therapy (Hajihosseini et al., 2019; Fathollahnejad et al., 2019; Lee et al., 2015). SE of the PM and shoulder brace application can help restore the length of the PM and correct the RSP. In addition, the posterior tilting exercise after PM stretching was effective for activating the LT. However, the size of the shoulder brace is limited, which may not be suitable for each user's body, especially in users with a short torso, causing excessive pressure on the top of the shoulder joint while moving it (Lee et al., 2015). A previous study reported that an elastic band exercise program is effective in lengthening the pectoralis muscle, increasing the thickness of the upper trapezius (UT), and correcting RSP. However, this study selectively measured the thickness of the UT, pectoralis major, and RM in participants with RSP, but not the thickness of LT and SA, which create a balance, decreasing the anterior glide of the humerus head, and helping elevate the scapula (Fathollahnejad et al., 2019). Therefore, muscle strength cannot be considered. In addition, changes take effect after a long training period and immediate follow-up is required after treatment, resulting in uncertainty. However, most rehabilitation programs have been limited because a heavy

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load could not be applied; thus, they may not fully activate muscle contraction and metabolic stress, which provide an important signal for increasing muscle strength and hypertrophy. Thus, determining a new rehabilitation strategy, which maximizes upper extremity muscle activation and adaptation and minimizes excessive fatigue, is important to manage individuals with RSP.

Blood flow restriction (BFR) training consists of placing a cuff around the proximal muscle to maintain arterial flow and restrict venous return during exercise, resulting in local hypoxia (Loenneke et al., 2012). BFR training has been used for maintaining and promoting strength or hypertrophy in patients with musculoskeletal conditions. (Killinger et al., 2020; Burkhardt et al., 2021). BFR training combined with 20%–30% 1Repetition maximum (RM) for 2 weeks was reported to be effective in increasing muscle strength and inducing hypertrophy similar to the traditional high load resistance exercise (70%–80% 1 RM) (Scott et al., 2016). Recent studies found that BFR training not only results in greater activation of distal muscles but also proximal muscles to the occlusion area (Werasirirat & Yimlamai, 2022b). Furthermore, BFR training can increase the amplitude of motor-evoked potential in corticospinal excitability, which improves the strength of remote muscles (Patterson & Ferguson, 2011). BFR training combined with 20%1RM was used to increase rotator cuff and deltoid muscle strength, muscle mass, and endurance in healthy individuals (Lambert et al., 2021). In one study, BFR training with resistance exercises (i.e., bench press, scapular retraction, shoulder external rotation, and bent-over rows) for 4 weeks was reported to improve the strength of the pectoralis major, LT, RM, SA, and rotator cuff muscles (Green et al., 2020). Moreover, a recent study demonstrated that BFR training with SE for 8 weeks can increase muscle strength, circumference, and muscle excitation of the LT, SA, shoulder abductors, shoulder external rotators, and elbow flexors in healthy individuals (Jales et al., 2022). The most likely mechanism for increasing muscle strength and thickness is muscle hypoxia and metabolic stress, which increase the production of proteins and hormones that aid in muscle growth and enhance the recruitment of high-threshold motor units and type 2 muscle fibers (Lauver et al., 2017; Suga et al., 2012; Yanagisawa & Sanomura, 2017; Counts et al., 2016). Collectively, BFR+SE may be an alternative strategy to promote muscle strength, muscle thickness, and decrease RSP and total scapular distance (TSD). To our knowledge, no study has compared the effectiveness of BFR+SE on muscle strength, muscle thickness, RSP, and TSD in RSP.

Therefore, this study aimed to evaluate the effectiveness of BFR+SE in comparison with SE alone in improving muscle strength, muscle thickness, RSP, and TSD in RSP. We hypothesized that BFR+SE would enhance shoulder muscle strength and thickness, leading to improved RSP and decreased TSD incurred by RSP compared with SE alone.

Materials and methods

Participants

Twenty-eight healthy individuals with RSPs aged between 18 and 25 years participated in this study. In all tests and exercises, the dominant side referred to the arm used for eating or writing. The principal investigator, who had 10 years of clinical experience, confirmed RSP using a caliper. As a simple measurement for RSP, the distance between the posterior border of the acromion and the table with the participant in the supine position was measured. The supine measurement of RSP could avoid measurement variations caused by humeral rotation and unwanted scapular movement (Nijs et al., 2005). RSP was defined as a score ≥2.5 cm (Yaver, 2002). Then, the participants were matched by sex and RSP scores and randomly allocated to the BFR+SE group (n = 14) or the SE group (n = 14, Figure 1).

Participants were enrolled in the study when the distance between the table and the acromion was ≥2.5 cm with a rounded shoulder. Individuals who had a history of cervical or shoulder injury or surgery, shoulder fracture, shoulder instability (a positive result on the apprehension test), shoulder impingement syndrome (a positive result on the Neer and Hawkins test), neurological deficit, infection or inflammation arthritis in the cervical spine or shoulder joint, physical therapy of the shoulder joint within the last week, uncontrolled hypertension, and cardiovascular disease were excluded from the study.

All participants were informed of the procedures, benefits, and risks of the study, and they provided written informed consent before enrolment. The study was approved by the Research and Innovation Administration of Burapha University Ethics Committee and followed the principles of the Declaration of Helsinki (IRB1-015/2566).

Study design

This study used a single-blinded, randomized, parallel, controlled design to compare the effects of BFR training with and without SE on muscle strength, muscle thickness, RSP, and TSD in healthy individuals with RSP. The study involved two testing sessions: at the beginning (pre-training) and 4 weeks (post-training) after an intervention. All participants engaged in their assigned treatment protocols 3 days a week for 4 weeks under the supervision of a researcher. Dependent variables included the RM, SA, MT, and LT strength; LT and SA thickness; RSP; and TSD. Before the study, participants were familiarized with all the testing apparatus and exercise protocol. Before the measurement, all participants were instructed to avoid any strenuous exercises for 24 h and refrain from caffeine intake.

Sample size calculation

A priori sample size was calculated based on our pilot data for the average muscle strength of the LT with an estimated effect size of 1.14, alpha level of 0.05, and desired power of 80% using G*Power v 3.1.9.2. Based on the sample size estimation, a minimum of 28 participants (n = 14/group) was required.

Intervention

BFR training

A pneumatic occlusion cuff with 8–10 cm width and 75–80 cm length (Large STRAIGHT Cuffs: HS1003, H Plus cuff, Santa Barbara, CA, USA) was used for the BFR training. The participants were asked to lie in a supine position and rest for 5 min. Then, an appropriate-sized cuff was placed around the proximal arm of the participant's dominant limb and a hand-held portable Doppler probe (SD3 Vascular, Edan Instrument, Inc., Shenzhen, China) was used to evaluate the participant's brachial artery at the dominant side by inflating the cuff to 50% of each participant's personalized arterial occlusion pressure. The BFR cuff of the participants in the BFR+SE group remained inflated throughout the rehabilitation program and deflated during rests between trials. For the control condition (SE group), participants wore a BFR cuff like that of the experimental group, except that this cuff was not inflated.

SE

The program began with a 5-min SE to increase the flexibility of the PM. The SE program included the following exercises: (1) For dynamic resisted hug for the SA, the participants held both ends of the elastic band, which was placed behind the upper thorax. Both arms were then advanced with the elbows semiflexed. (2) For the scapular retraction exercise, the participants extended their arms in front at 90°and placed them shoulder-width apart. Their palms were oriented to face the ground and they held the elastic band. They then stretched the elastic band by squeezing the scapulars without shrugging their shoulders. (3) For the scapular upward rotation exercise, the participants stepped on the elastic band, held the elastic band with both hands, and kept the hand low in their neutral position. They then bent the arm forward with the elbow straightened. (4) For the band seated row, the participants placed the elastic band around their feet at the middle of the band in a long sitting. The participants stretched the elastic band toward their waistline while squeezing the shoulder blades. (5) For SE targeting the periscapular muscles (Y to W, L to Y positions and scapular protraction). For Y to W, the participants flexed and abducted their arms to 120°, thumbs pointed up, and raised arms 4–5 inches while keeping the scapula retracted. Then, they flexed their elbows and moved the shoulder into an extension. For L to Y, the participants abducted their arms and flexed elbows 90° with the retracted scapula and externally rotated arms. After that, the arms were raised above the head and the elbows fully extended to form a "Y." For scapular protraction, the participants retracted their shoulders with the forearms and toes supporting the body on the floor in a prone hip bridge. Then, they pushed up while protracting the scapula and preventing scapular winging. They rested between each repetition for 30 s, and between each trial, they rested for 1 min. SEs were progressively performed in three sets, with 10 repetitions. The protocol was performed for 30 min for 4 weeks (three sessions per week) (Fathollahnejad et al., 2019; Kim et al., 2016). All training sessions were conducted in a laboratory under the supervision of the same registered physical therapist. The participants did not take part in any other exercises except for the exercise programs provided in this study.

Outcome measurements

Muscle strength

A hand-held dynamometer (microFET2; Hoggan Health Industries Inc., West Jordan, UT, USA) was used to determine the shoulder muscles (i.e., RB, SA, MT, and LT) as previously described (Gillet et al., 2017). Isometric contraction lasted for 3 s and an audible beep from the equipment signaled the start and end of each movement's evaluation. Each test was performed twice under vocal encouragement with a 30-s rest period in between. The assessor stabilized the opposite shoulder and scapula in all positions. The positions of participants and order of testing were as follows: first, prone with the arm abducted 90° for the MT and 120° for the LT, prone with the hand behind the back for the RM and finally sitting with the shoulder in flexion 120° for the SA. The intraclass correlation coefficient (ICC) for the RM, SA, MT, and LT were good (ICC [3,k] = 0.95, 0.92, 0.96, and 0.87, respectively).

Muscle thickness

All measurements were performed on the dominant side. The thicknesses of the LT and SA during contraction were measured using a B-mode diagnostic ultrasound system (M5 series, Shenzhen Mindray Bio-Medical Electronics Co., Shenzhen, China) with a 3.5–13-MHz linear transducer, linear array probe with a 38-mm probe surface length, and frequency of 8 MHz (7L4s, Shenzhen Mindray Bio-Medical Electronics Co., Shenzhen, China) (Collebrusco et al., 2017). The thickness of the LT was evaluated with the participants lying prone with the head and neck in neutral alignment. The shoulder was abducted 120° with the elbow extended and the thumb pointing upward. The probe location was marked centrally and horizontally over the spinous process of the fifth thoracic vertebrae (T5) and moved 2 cm transversely to the LT. The thickness of the SA was measured in the sitting position with the shoulder in 120° flexion and the elbow in full extension. The probe was placed horizontally on the inferior angle of the scapula and moved laterally to the mid-axillary line (Koo et al., 2022; Seitz et al., 2015). An image was captured and the average thickness of three measurements was recorded for analysis. Image processing and analysis were performed by tracing the muscle border using ImageJ version 1.51 (Wayne Rasband, NIH, Bethesda, MD, USA). The ICCs for the thickness of the LT and SA were good (ICC[3,k] = 0.92 and 0.90, respectively).

RSP

The RSP was evaluated with the participants lying supine with both arms placed on the side and the forearm supine. The assessor palpated the posterior aspect of the acromion process and marked it with a black pen and the distance between the posterior aspects of the acromion and the examination table was measured using a tape line and recorded in centimeters (Kumkumwar et al., 2019). All measurements were obtained three times and the average was used as the final value. The ICC for the RSP was good (ICC[3,k] = 0.97).

TSD

The TSD was measured with the participants standing and both hands on the sides. The measurement started from the third thoracic vertebrae to the inferior angle of the acromion and the length of the scapula was measured using a tape line and recorded in inches from the inferior angle of the acromion to the root of the scapula (Kumkumwar et al., 2019). The average of three measurements was used. The ICC for the TSD was good (ICC[3,k] = 0.96).

Statistical analysis

All results were analyzed using IBM SPSS version 26 (IBM Corp., Armonk, NY, USA). The descriptive statistics for demographic data were expressed as mean and standard deviation. The Shapiro–Wilk test was used to check whether the data were normally distributed. The independent sample *t*-test and paired *t*-test were applied to compare mean differences in all dependent variables between groups and within groups (pre- and post-test). Cohen effect size (*d*) and associated 95% confidence intervals were calculated to estimate the magnitude and precision of group differences of each measure. Effect sizes were interpreted as ≥0.80, large; 0.50–0.79, moderate; 0.20–0.49, small; and <0.2, trivial (Cohen, 1992). A *P*-value of <0.05 was considered significant.

Results

In total, 31 participants with RSP were screened for eligibility to participate in this study. Three participants were excluded (one had a history of shoulder impingement syndrome and two refused to participate in the study). Therefore, a total of 28 participants with RSP were included in the study (Figure 1). After enrolment, one participant (one from the BFR+SE group) was dropped out and excluded from the analysis. No significant differences in participant characteristics at baseline were found between groups (*P* >0.05, Table 1).

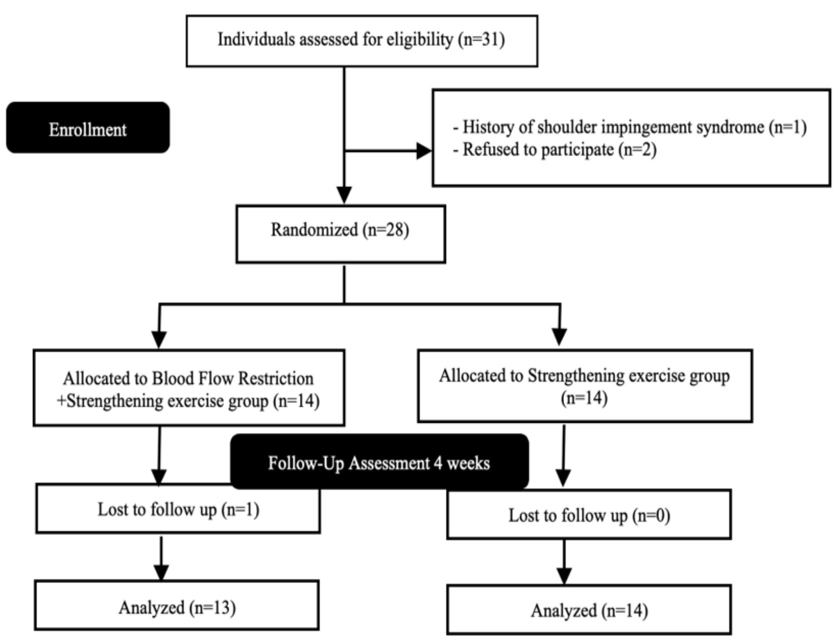

Figure 1. Flow chart of the participants

Table 1. Baseline characteristics of the participants

	BFR+SE (n = 14)	SE (n = 14)
Sex, men:women	4:10	4:10
Age (years)	20.14 ± 1.17	20.07 ± 0.27
Weight (kg)	59.00 ± 8.37	60.00 ± 10.27
Height (m)	1.60 ± 0.06	1.64 ± 0.09
Body mass index (kg/m^2)	22.93 ± 2.72	22.13 ± 2.87
RSP (cm)	5.59 ± 0.96	5.02 ± 0.72

Values were presented as mean ± standard deviation
Abbreviations: BFR, blood flow restriction; cm, centimeters; kg, kilograms; m, meter; SE, strengthening exercise.

Muscle strength

As shown in Figure 2A–D, the BFR+SE group displayed significant improvements in the mean values of muscle strength of the RM (95% CI, −7.15 to −3.79), SA (95% CI, −6.40 to −3.82), MT (95% CI, −7.18 to −5.03), and LT (95% CI, −9.35 to −6.52) compared with the baseline. However, significant increases in muscle strength were observed in the RM (95% CI, −4.16 to −0.44), SA (95% CI, −5.32 to −1.74), MT (95% CI, −5.42 to −1.83), and LT (95% CI, −7.3521 to −3.47) in the SE group (Figure 2A–D). In addition, the BFR+SE group showed greater improvements in the muscle strength of the RM (*d* = 1.49; 95% CI, −4.49 to −1.36), SA (*d* = 1.03; 95% CI, −3.63 to −0.46), MT (*d* = 0.96; 95% CI, −4.91 to −0.48), and LT (*d* = 0.91; 95% CI, −4.95 to −0.36) compared with the SE group (Figure 2A–D).

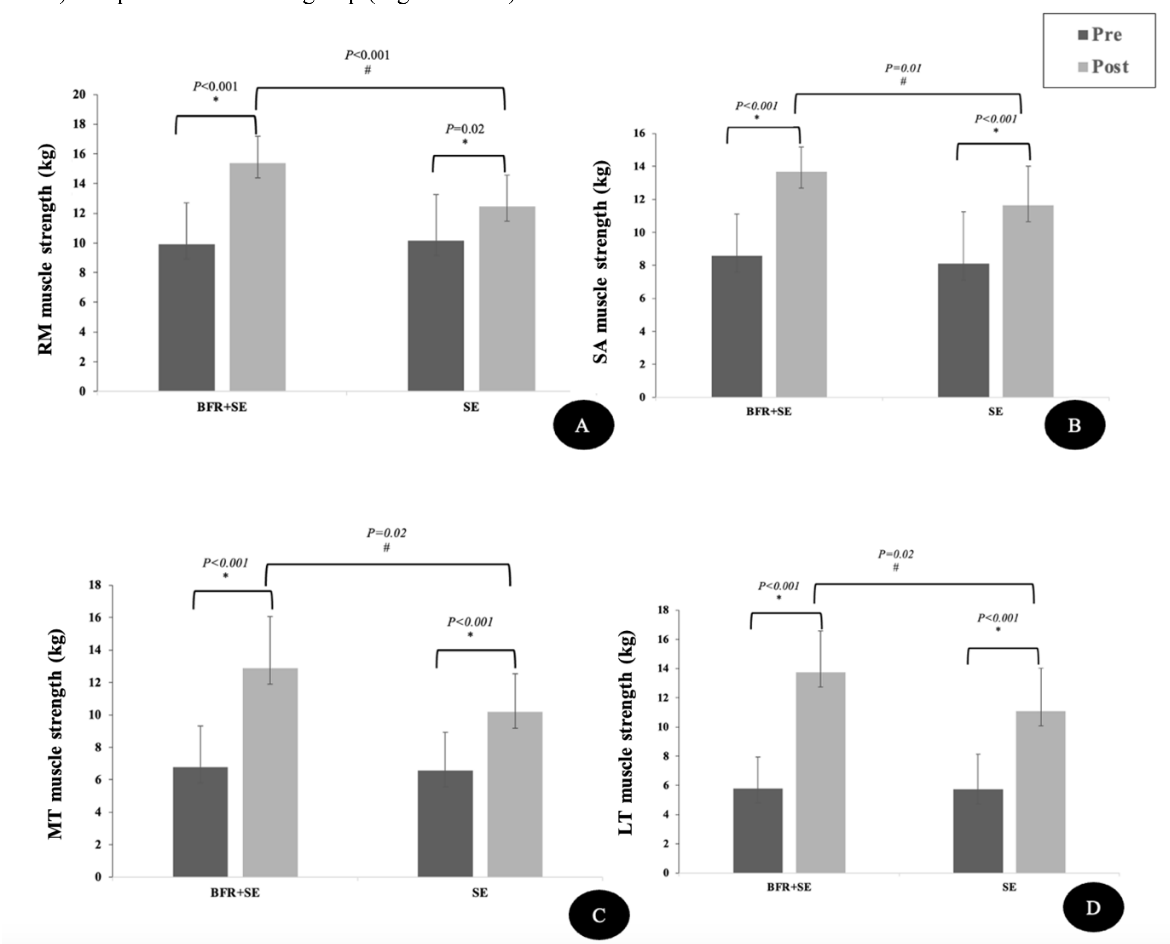

Figure 2A–D. Mean and standard deviation of the muscle strength of the rhomboid major (RM), serratus anterior (SA), middle trapezius (MT), and lower trapezius (LT). BFR, blow flow restriction; SE, strengthening exercise.
* Significantly different between pre- and post-intervention, $P < 0.05$.
# Significantly different from the SE group, $P < 0.05$.

Muscle thickness

As shown in Table 2, the mean value of the muscle thickness of the LT and SA were significantly increased following an intervention in the BFR+SE group compared with baseline (all P <0.01) and the SE group (P = 0.04 and P = 0.01, respectively).

RSP

Both groups exhibited significant improvements in RSP after 4 weeks of intervention (all P < 0.05). A significant improvement in RSP was noted in the BFR+SE group when compared with the SE group (P < 0.001) (Table 2).

TSD

Following a 4-week intervention, both groups displayed significant improvement in the mean value of the TSD compared with baseline (all P <0.05). However, compared with the SE group, the BFR+SE group showed greater improvements in TSD (P = 0.03) (Table 2).

Table 2. Mean (standard deviation) values and mean difference (95% CI) of outcome measures pre- and post-intervention among the groups.

Variable	BFR+SE group (n = 14)			SE group (n = 14)			Difference among groups (95% CI)	*d*
	Pre	Post	Difference (95% CI)	Pre	Post	Difference (95% CI)		
Thickness (mm^2)								
LT	9.48 ± 3.32	11.57 ± 1.82*	−2.01 (−3.31 to −0.72)	9.44 ± 2.80	9.88 ± 2.24	−0.45 (−2.43 to 1.54)	−1.68† (−3.31 to −0.06)	0.83
SA	9.69 ± 1.19	11.95 ± 1.72*	−2.26 (−3.68 to −0.83)	9.52 ± 3.44	10.08 ± 1.54	−0.55 (−2.95 to 1.84)	−1.87† (−3.16 to −3.17)	1.14
RSP (cm^2)	5.56 ± 0.99	3.21 ± 0.56*	2.35 (1.69 to 3.02)	5.02 ± 0.72	4.06 ± 0.57*	0.96 (0.67 to 1.26)	0.85† (0.39 to 1.29)	1.50
TSD (inch)	5.58 ± 0.51	4.30 ± 0.46*	1.28 (0.95 to 1.60)	5.41 ± 0.74	4.73 ± 0.74*	0.68 (0.36 to 0.99)	0.43† (0.04 to 0.82)	0.70

Values were expressed as mean and standard deviation.
Abbreviations: BFR, blood flow restriction; LT, lower trapezius; mm, millimeters; RSP, round shoulder posture; SA, serratus anterior; SE, strengthening exercise; TSD, total scapular distance; cm, centimeters.
* Significantly different from pre-intervention, P <0.05.
† Significantly different from the SE group, P<0.05.

Discussion

This study was the first to examine the effectiveness of BFR training combined with an SE program on muscle strength, muscle thickness, RSP, and TSD in participants with RSP. We found that the BFR+SE program increases the muscle strength of the RM, SA, MT, and LT, enhances muscle thickness of the LT and SA, and improves the RSP and TSD compared with the SE program alone. In this study, BFR training and SE (including stabilization exercise and stretching) were selected because of their effectiveness in correcting RSP and preventing shoulder pain caused by altered scapular kinematics compared with a single exercise (Fathollahnejad et al., 2019). Our finding that the muscle strength of the RM, SA, MT, and LT was considerably increased in the BFR+SE group than in the SE group supported our hypothesis, which was consistent with the findings of previous reports. For example, a recent study and systematic review indicated that SE with BFR is effective in increasing strength in participants with musculoskeletal disorders (i.e., anterior cruciate ligament reconstruction, knee osteoarthritis, chronic ankle instability, tennis elbow, and older adults with sarcopenia) compared with traditional SE alone (Pitsillides et al., 2021; Werasirirat &Yimlamai, 2022b). Recently, Green et al. (2020) examined the effects of BFR at 20%1RM for 4 weeks on the proximal musculature of the upper extremity in healthy men and demonstrated greater strength of the SA, external rotators, RM, LT, MT, and pectoralis major than those of controls. In addition, Jales et al. (2022) showed that with an 8-week intervention, 60% BFR with low load resistance resulted in significant improvements in the strength of the SA, LT, shoulder abductor, shoulder external rotator, and elbow flexor, arm circumference and muscle excitation in healthy participants 4 weeks after the intervention. These differences in results may be attributed to the differences in participants (RSP vs. healthy participants) and exercise protocols (elastic band vs. load resistance) employed among studies. The most likely mechanism is the reduction in oxygen delivery to the muscle tissue under greater metabolic stress, which increases the production of proteins and hormones that help in muscle growth

(Brandner et al., 2015; Yasuda et al, 2010). In addition, the cortical excitability at the primary control site for the lower limb as a result of lower-body BFR training may have spilled over to the proximal control site for arms and recruited agonist in the arm training from the influencing motor unit with an increased circulating concentration of anabolic stimuli (e.g., growth hormone and noradrenaline), along with the recruitment of a greater muscle mass. Furthermore, distal occlusion (proximal arm) may result in muscle fatigue below the cuff and recruitment of synergistic proximal muscles above the occlusion area (scapulothoracic muscles) (Madarame et al., 2008; May et al., 2018).

Whether this greater improvement in muscle strength after BFR training was primarily due to muscular thickness must be further determined. However, in the present study, only SA and LT muscles were selected for thickness measurement because these muscles have been shown to reduce muscle imbalance and improve posture in participants with shoulder pathologies and stabilized scapula (Park & Lee, 2020). As expected, the BFR+SE group elicited a greater thickness of the SA and LT than the SE alone. These results are in agreement with those of many other studies showing hypertrophic adaptation in low-intensity vascular occlusion training. Werasirirat & Yimlamai (2022a) determined the effects of a rehabilitation program with or without BFR on athletes with chronic ankle instability and found that the BFR rehabilitation program was more effective in improving muscle strength of the ankle plantarflexor and evertor and hypertrophy of fibularis longus than the traditional rehabilitation program. Tennent et al. (2017) demonstrated greater quadriceps muscle strength, thigh girth, and functional return to activities in participants with knee arthroscopy following the BFR rehabilitation program. Moreover, Ramis et al. (2020) showed that BFR training resulted in low-intensity improvement in quadriceps and bicep muscle strength and thickness in healthy participants. Taken together, these findings suggest that the BFR+SE increases muscle strength, at least in part, by enhancing muscle thickness. Various molecular and metabolic mechanisms for strength and thickness adaptations may explain the results of low-intensity and BFR training. BFR could potentiate thickness during low-intensity exercise, as a result of the hypoxic environment which may lead to increased recruitment of fast-twitch muscle fibers, increased inflammatory and endocrine response, and elevated intramuscular inorganic phosphates (Takada et al., 2012). Neutrophils and macrophages can release growth factors such as insulin-like growth factor, basic fibroblast growth factor, transforming growth factor, and mechano growth factor, and this may facilitate muscle regeneration and hypertrophic response by activating satellite cells and the mTORC1 signaling pathway (Gundermann et al., 2014; Rossi et al., 2018; Ruaro et al., 2019).

The degree of RSP and TSD were significantly less in the BFR+SE group than in the SE group, decreasing by 2.35 cm and 1.28 inch, respectively. Decreasing RSP and TSD indicated less internal rotation of the scapula in the transverse plane, suggesting the beneficial effect of BFR and the stretching effect of the tight PM muscle on participants with RSP. This finding was consistent with those of previous studies. For example, Lee et al. (2015) showed that PM stretching with scapular posterior tilting exercise resulted in significant improvements in RSP and PM index in participants with RSP. Moreover, stabilization exercises and manual therapy for 8 weeks were significantly effective in reducing neck pain and improving function and posture in participants with neck pain and forward head posture (Fathollahnejad et al., 2019). In addition, the reason for the lack of additive effect is currently unknown; however, it may imply that the muscle strength of the RM, SA, MT, and LT increases, which were associated with great muscle thickness of the LT and SA. The LT and SA as upward rotators of the scapula are important for the normal shoulder joint and the MT helps control scapular abduction during upward rotation. Therefore, the BFR+SE program can improve the control of the RM, SA, MT, and LT muscles and pull the scapula and thoracoscapula closer to the normal position from RSP (Sheikhhoseini et al., 2018).

Limitations

This study has several limitations. First, although this study determines the additional benefits of BFR+SE versus SE alone, it did not include a BFR group, a control group, and a cross-over design. Thus, their synergistic effects were not investigated. Second, the age of the participants ranges from 18 to 25 years. Although the age range appeared to be narrow, this may not influence the outcomes of this study. Third, a follow-up design was not employed; therefore, the long-term benefits of BFR+SE in participants with RSP remain unknown.

Conclusions

The participant with RSP demonstrated decreased muscle weakness and thickness and increased TSD. The results of this study revealed that the addition of BFR to a traditional SE program over 4 weeks was effective in improving the strength of RM, SA, MT, and LT, muscle thickness, RSP, and TSD in participants with RSP. Therefore, this information may help physical therapists or practitioners design SE programs, which have to be modified to decrease stress and tension around the shoulder for improving RSP.

Conflicts of interest

The authors declare no conflict of interest.

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