SHORT COMMUNICATION

An integrated application of practical blood flow restriction in resistance trained individuals

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Practical blood flow restriction (PBFR) training has been used as a training technique to induce muscular strength and hypertrophy gains while utilizing lighter loads [≤ 40% one repetition maximum (1RM)]. It is unclear if PBFR can be incorporated into traditional training programs to alleviate some exposure to heavy loads.

Objective: Compare the impact of a traditional resistance training with the addition of PBFR (TRAD + PBFR) to traditional resistance training without PBFR (TRAD) on maximal bench press and leg press strength.

Design and Methods: Participants performed full body training for 4 weeks (2-3x/week). PBFR group performed 62% of sets blood flow restricted at 30% 1RM while the TRAD group performed all sets at an intensity of >70% 1RM.

Results: Twenty-one resistance trained individuals (≥ 1 year resistance training) completed the study. For bench press strength, there was no group (TRAD + PBFR vs. TRAD) by time (pre vs. post) interaction (BF10 = 0.32). However, there was a main effect for time (BF10 = 24.04). The TRAD + PBFR group increased strength from 99 ± 29 to 106 ± 23 kg and the traditional training condition increased from 111 ± 27 to 117 ± 24kg. For leg press strength, there was no interaction (BF10 = 0.83). However, there was a main effect for time, with both conditions increasing strength. For the PBFR group strength increased from 372 ± 61 to 423 ± 76 kg and the TRAD group increased strength from 354 ± 87 to 434 ± 96kg.

Conclusion: TRAD + PBFR elicited similar strength adaptations compared to TRAD. PBFR may provide a means to exposing the muscle and connective tissue to less overall mechanical stress when incorporated into a traditional heavy resistance training program.

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Key words: practical blood flow restriction ■ resistance training ■ low load training

INTRODUCTION

In the past it was often suggested that training loads of at least 70% of 1RM must be lifted in order to achieve increases in skeletal muscle size and strength.[1] However, the high mechanical stress of these prescribed loads may be too demanding for some individuals (i.e., injured, elderly). Blood flow restriction training (BFR) has been demonstrated to provide a low intensity lifting alternative effective for stimulating muscular strength and hypertrophic gains.[2-4] BFR typically involves the application of a pressurized cuff, which is applied to the proximal portion of either the arms or legs with the intention of decreasing arterial blood flow to a working muscle, while largely restricting venous return.[5] Although blood flow restriction has been studied extensively, less is known regarding practical blood flow restriction (PBFR). PBFR involves, amongst others, the use of elastic bands as a wrapping device which applies pressure to the limb, resulting in a similar stimulus as more sophisticated pneumatic devices.[6]

Loenneke et al.[7] examined the repetitions performed to failure, rating of perceived exertion and blood lactate responses to knee extension exercise performed at 30% one repetition-maximum (1RM) with and without PBFR (knee wraps). Authors found that PBFR resulted in fewer repetitions performed to failure, while resulting in a similar lactate response and similar ratings of perceived exertion.[7] Thus, practical BFR may be a useful tool for decreasing the volume of exercise necessary at a given training load. Lowery et al.[6] performed a training study implementing practical BFR, demonstrating similar changes in biceps brachii muscle thickness when comparing PBFR and traditional high load training protocols over an 8-week training period. Thus, PBFR appears to be a useful tool for an individual engaging in resistance training who is looking to decrease their exposure to heavy loads over the course of a training period. Although PBFR has been studied, little research has applied PBFR in a way that may be considered ecologically valid. Meaning, an individual interested in increasing strength may incorporate PBFR as a way to reduce their overall exposure to heavy loads in their training program without completely removing the heavy mechanical stimulus (i.e., still perform some heavy sets >70%1RM within a program). The purpose of this study was to compare strength adaptations following 4 weeks of high-load bench press and leg press training to a resistance training program comprised of a mixture of high-load and low-load training with PBFR.

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METHODS

Participants

A total of twenty-six resistance trained males were recruited for the present study. Participants were excluded from the study if they were determined to be higher than "low risk" based on their completion of the pre-activity screening questionnaire (PASQ).[8] Participants were determined to be low risk if they were not diagnosed with cardiovascular, pulmonary, and/or metabolic disease and had no more than one cardiovascular disease risk factor. One individual did not meet inclusion criteria and four individuals were unable to complete the study due to reasons unrelated to the study (In the TRAD + PBFR group two individuals were lost to non-related illness and one individual failed to return; In the TRAD group one person dropped out due to a non-related injury), leaving a final sample of 10 participants in the PBFR group and 11 participants in the TRAD group. All participants were screened to ensure they met the criteria for qualifying as resistance trained (resistance trained for at least one year, at least two times per week). Participants completed an informed consent. Each participant was informed of the potential benefits and risks of participation prior to preliminary testing. Participants were informed of withdrawal criteria, which included having extreme muscle soreness and/or intolerable joint pain, as well as the desire to voluntarily exit the study at any time. The study received approval from the university's Institutional Review Board.

Study Design

During the first visit, baseline measures of one repetition maximum (1RM) strength were performed in both the leg press and bench press exercise. All strength testing procedures were administered according the National Strength and Conditioning Association's protocol for 1RM testing.[9] Verbal encouragement was provided. Leg press strength was assessed followed by bench press strength. Additional strength assessments were also performed for the bent over row, barbell biceps curl and lying triceps extension in order to set training loads. A minimum of 5 minutes rest was allowed between strength assessments. Following strength testing, participants were randomly assigned (coin flip) to either a resistance training group with practical blood flow restriction (TRAD + PBFR) or a heavy resistance training (TRAD) group without PBFR. Participants randomized into the TRAD + PBFR condition were also familiarized with PBFR during their first visit. In addition, both groups were familiarized with the exercises utilized in the training program. Three days following the first visit, participants began a 4-week training program. The training program consisted of 11 training sessions dispersed over 4 weeks (2x/week for first week and 3x/week for weeks 2-4). Following the 4 weeks of training, participants from both groups completed post 1RM strength testing for leg press and bench press. Post testing occurred 48 hours following the last training session and occurred within ± 2 hours the time that pre-testing took place. All pre and post testing was conducted by a researcher who was blinded to the resistance-training groups. Participants were asked to maintain their regular diet for the duration of the study, but were provided 25 grams of whey isolate protein (Dymatize® Nutrition, Inc., North Carolina, United States) on training days. In addition, participants were asked to refrain from outside training for the duration of the study period.

Training Protocol

Participants in each group underwent a 4-week resistance training program for all major muscle groups (See Table 1). Participants warmed up prior to resistance training with a dynamic warm-up involving muscle groups that were trained in that day's training session. Training occurred on 2 non-consecutive days a week during the first week of training and 3 non-consecutive days a week for the remaining three weeks of the study. Volume-load (repetitions x sets x %1RM) was approximately equal between groups, with the TRAD + PBRF group performing more sets per exercise to achieve a similar volume-load compared to the TRAD group (see Table 1). The exercises were exactly the same for both groups and both groups performed a goal number of repetitions for each set (Table 1). However, the PBFR group performed 62% of all sets using blood flow restriction in combination with loads of 30% of 1RM, while the TRAD group performed all sets at an intensity of > 70% 1RM (Full program provided in Table 1). The perceived pressure for blood flow restriction in the PBFR group for the arms and legs was set at 7 out of 10.[10] Pressure was applied using elastic knee wraps (Harbinger, 76mm width). The protocol for blood flow restriction training followed previous research,[11] which consisted of 30% of 1RM for 3-5 sets ranging from 15-30 repetitions. During the first set of each exercise in the PBFR condition, 30 repetitions were performed. For the additional three sets, 15 repetitions were performed.[10]

The non-blood flow restriction group completed the same amount of sets as the PBFR condition at the recommended repetition range (alternating 12 repetitions at 70% 1RM and 7 repetitions at 80% 1RM for different training days for the primary lifts of leg press and barbell bench press). The resistance load for each exercise was determined for each participant prior to beginning the training program. Rest times between sets was limited to 30-60 seconds for both groups and for all exercises except bench press and leg press exercises, which utilized a recovery of 2-3 minutes. In both groups, resistance loads were lowered if participants were unable to complete the prescribed repetitions. All training was monitored by study staff with a ratio of one supervisor to every 4 participants to ensure proper instruction and execution of technique.

Statistical Analysis

Demographics data were analyzed using SPSS 26.0 (SPSS Inc., Chicago, IL, USA). Bayesian analysis was conducted using JASP version 0.14.1. A Bayesian condition (PBFR + TRAD vs. TRAD) x time (pre vs. post) repeated measures analysis of variance (RMANOVA) with an uninformed prior of 0.5 for the fixed effect was used to examine changes in strength between conditions over time. Thresholds of Bayes

Table 1 Training Program

Week	Day	Exercise	Condition	Set 1 Reps	Set 1 % 1RM	Set 2 Reps	Set 2 % 1RM	Set 3 Reps	Set 3 % 1RM	Set 4 Reps	Set 4 % 1RM	Set 5 Reps	Set 5 % 1RM	Set 6 Reps	Set 6 % 1RM	Volume-load
Week 1	Day 1	45 Degree Leg Press	TRAD	12	70	12	70	12	70	12	70					3360
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		Lying Leg Curl	TRAD	12	70	12	70	12	70	12	70					3360
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		BB Bench Press	TRAD	12	70	12	70	12	70	12	70					3360
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		BB Curl	TRAD	12	70	12	70	12	70	12	70					3360
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		Lying Triceps Extension	TRAD	12	70	12	70	12	70	12	70					3360
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
	Day 2	BB Bench Press	TRAD	7	80	7	80	7	80	7	80	7	80	7	80	3360
			TRAD + PBFR	7	80	7	80	30	30	15	30	15	30	15	30	3370
		BB Bent Over Row	TRAD	6	80	6	80	6	80	6	80					1920
			TRAD + PBFR	6	80	6	80	6	80	6	80					1920
		45 Degree Leg Press	TRAD	7	80	7	80	7	80	7	80	7	80	7	80	3360
			TRAD + PBFR	7	80	7	80	30	30	15	30	15	30	15	30	3370
Week 2 - 4	Day 1	45 Degree Leg Press	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		Lying Leg Curl	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		BB Bench Press	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		BB Biceps Curl	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		Lying Triceps Extension	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
	Day 2	BB Bench Press	TRAD	7	80	7	80	7	80	7	80					2240
			TRAD + PBFR	30	30	15	30	15	30	15	30					2250
		BB Bent Over Row	TRAD	6	80	6	80	6	80	6	80					1920
			TRAD + PBFR	6	80	6	80	6	80	6	80					1920
		45 Degree Leg Press	TRAD	7	80	7	80	7	80	7	80					2240
			TRAD + PBFR	30	30	15	30	15	30	15	30					2250
	Day 3	Bent Over Row	TRAD	12	70	12	70	12	70	12	70					3360
			TRAD + PBFR	12	70	12	70	12	70	12	70					3360
		BB Biceps Curl	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		45 Degree Leg Press	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		Lying Leg Curl	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		BB Bench Press	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930
		Lying Triceps Extension	TRAD	12	70	12	70	12	70	12	70	12	70			4200
			TRAD + PBFR	12	70	12	70	30	30	15	30	15	30	15	30	3930

Training program for the traditional training condition (TRAD) and traditional training with practical blood flow restriction (TRAD+PBFR). Percentage of one-repetition maximum (%1RM) and repetitions (reps) are displayed across exercise sets. Highlighted sets and reps utilized PBFR. Barbell = BB

Factor (BF_{10}) 3 or 0.33 were used as evidence for the alternative (TRAD + PBFR ≠ TRAD) and null (TRAD + PBFR = TRAD) hypothesis respectively.[12] Accordingly, a BF_{10} of 3-10 was considered moderate evidence for the alternative, whereas a $BF_{10} > 10$ was considered strong evidence for the alternative hypothesis. Conversely, a BF10 of 0.33-0.1 was considered moderate evidence for the null hypothesis, whereas $BF_{10} < 0.033$ was considered strong evidence for the null hypothesis.[12] Levene's test for equality of variances was used to assess homogeneity of variance between groups and Kolmogorov-Smirnov test was used to test normality of distribution. Independent samples T-tests were used to compare demographics information between conditions. Significance was set at $p < 0.05$ for demographics information, and Levene's and Kolmogorov-Smirnov tests.

RESULTS

Demographics

Data are presented as means (standard deviation). Age [TRAD + PBFR: 21.3 (1.88) vs. TRAD: 21.7 (1.19) years] height [TRAD + PBFR: 175.5 (5.9) vs. TRAD: 179.8 (8.0) cm], body mass [TRAD + PBFR: 83.7 (11.0) vs. TRAD: 83.5 (12.1) kg], and body fat [TRAD + PBFR: 13.8 (5.94) vs. TRAD: 12.0 (4.75) percent]. There were no significant differences between groups for any baseline values ($p > 0.05$)

Strength

Data were normally distributed and Levene's test indicated equal variances between conditions ($p > 0.05$). For bench press strength, there was no group (TRAD + PBFR vs. TRAD) by time (pre vs. post) interaction ($BF_{10} = 0.32$). In addition, there was no main effect for condition ($BF_{10} = 0.75$). However, there was a main effect for time ($BF_{10} = 24.04$). For the TRAD + PBFR group, strength increased from 99 ± 29 to 106 ± 23 kg and the TRAD condition increased from 111 ± 27 to 117 ± 24 kg. For the leg press strength, there was no group (TRAD + PBFR vs. TRAD) by time (pre vs. post) interaction ($BF_{10} = 0.83$). In addition, there was no main effect for group ($BF_{10} = 0.49$) However, there was a main effect for time ($BF_{10} = 1.35e + 6$), with both conditions increasing their maximal strength. For the TRAD + PBFR group strength increased from 372 ± 61 to 423 ± 76 kg and the TRAD group increased strength from 354 ± 87 to 434 ± 96 kg. Individual data for changes in strength are provided in Figure 1.

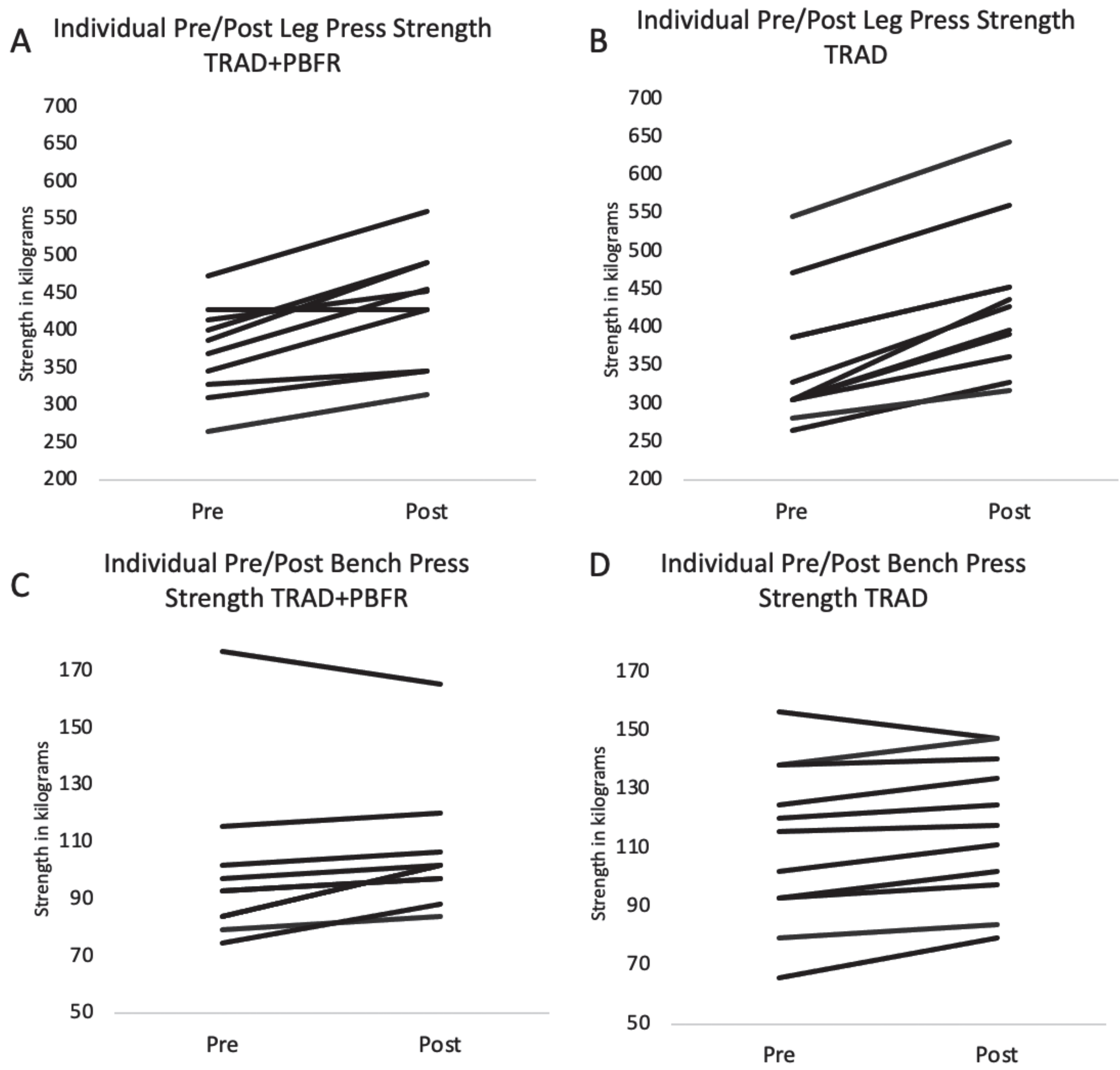

Figure 1 displays individual strength data for the traditional training condition combined with practical blood flow restriction (TRAD + PBFR) and the traditional resistance training condition (TRAD) for both the leg press (A,B) and bench press (C,D) exercises.

DISCUSSION

The purpose of this study was to investigate strength adaptations between a group performing only high load resistance training (TRAD) to a condition where some of the high load training is substituted with PBFR (TRAD + PBFR). The primary findings of this study suggest that both TRAD + PBFR and TRAD result in increases in muscular strength. For the bench press, our analysis indicated that there was evidence that the changes were not different between conditions (interaction $BF_{10} = 0.32$). However, for the leg press we were unable to determine if the changes were different between conditions (interaction $BF_{10} = 0.83$). In the present study the TRAD + PBFR group performed 62% of all sets utilizing 30% of 1RM, as compared to the TRAD group who performed all sets > 70% of 1RM. It has been demonstrated that low-load exercise can lead to similar changes in muscle size compared to traditional high-load exercise with and without blood flow restriction; however, low load training typically underperforms high load training alternatives when examining strength outcomes.[13-15] For example, Lixandrao[15] observed increases in knee extension 1RM strength following 12 weeks of lower body resistance exercise at 20% 1RM and various restrictive pressures; however, strength increases were greater in a group training with 80% 1RM. These differences are likely driven by specificity, as 1RM strength and maximal voluntary contraction appear to increase the most when training is performed with higher loads.[16] In addition, Morton et al.[17] demonstrated that multiple exposures to a 1RM during a low load resistance training program can largely negate the differences in 1RM strength observed between high load and low load training modalities. Thus, it appears that strength can be increased with low volumes of exposure to lifting heavy loads. The results of the present study extend the findings of Morton et al.[17], suggesting that a low load training program using PBFR, with a reduced amount of high load training (38% of exercise sets) can result in similar strength gains in the bench press exercise. In addition, TRAD + PBFR led to increased leg press strength; however, we were unable to determine if this increase was different than that of the TRAD condition.

The present findings are in somewhat contrast to those of Yamanaka et al.[18] who examined adaptations when blood flow restricted exercise was performed in addition to a regular strength training program. Yamanaka et al.[18] had individuals perform an additional 3 sets of bench press and squat exercise at 20% 1RM with and without BFR following their regular training program. Authors observed a 9.3% and 14.0% change in strength for the bench press and squat exercise respectively, compared to the non-BFR condition which observed changes of 3.2% and 4.9%. The present study induced increases in bench press and leg press strength of 5% and 16%, respectively for the TRAD + PBFR condition and 4.8 and 22% for the non-BFR condition over the 4 weeks of training. The differences between these studies may be due to the overall robustness of the exercise stimuli. Meaning, the traditional training program by Yamanaka et al.[18] (off-season football strength training program), may have been insufficient for maximizing changes in strength. In contrast, the present study may have included enough exposure to heavy training loads in both conditions to facilitate strength increases. However, difference in the study populations may also contribute to these differences (Division 1A football players vs. resistance trained individuals). More studies incorporating practical BFR into existing resistance training programs are necessary to better understand the utility of this stimulus.

The present study is not without limitation. For example, it is possible that the use of PBFR led to a high level of variation in the actual applied restriction pressure. However, it has been demonstrated that individuals identify a 7/10 on the perceived tightness scale as a sub-occlusive pressure,[19] and that adaptations are similar between high and low sub-occlusive restrictive pressures.[20] In addition, the sample size in the present study may have limited our ability to detect differences and/or similarities between groups. However, we did observe robust increases in all strength measures in both conditions. Another limitation of the present study is the use of a set load and rep range for the duration of the study. Although this approach may be typical within a given training block, it is possible that progressing weight over the 4 week time period may have resulted in differential strength adaptations. This approach may also represent an ecologically valid example of how PBFR may be incorporated into a training programs. In addition, the present study only included male participants. Thus, generalizability may be limited to males only. Finally, the present study was limited in duration (4 weeks). It is possible that these training programs would result in different adaptations over a longer period of time.

CONCLUSION

Results of the present study demonstrate that strength changes can be achieved over a short-term period (4 weeks), when performing a strict high load resistance training program or a heavy resistance training program incorporating low load PBFR to alleviate some of the exposure to heavy training loads. Although we were unable to detect differences in the leg press, our data suggest no differences in bench press strength across time. Future studies with larger sample sizes are necessary to better understand the efficacy of this approach. PBFR + TRAD may provide a means to increase strength, while exposing the muscle and connective tissue to overall less high load mechanical stress.

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None

Conflict of Interest

The authors report no relationships that could be construed as a conflict of interest.

REFERENCES

1. American College of Sports M. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 2009;41;3:687-708.
2. Kim D, Loenneke JP, Ye X et al. Low-load resistance training with low relative pressure produces muscular changes similar to high-load

resistance training. *Muscle Nerve* 2017;56:E126-E133.

3. Jessee MB, Buckner SL, Mouser JG et al. Muscle adaptations to high-load training and very low-load training with and without blood flow restriction. *Front Physiol* 2018;9:1448.
4. Shinohara M, Kouzaki M, Yoshihisa T et al. Efficacy of tourniquet ischemia for strength training with low resistance. *Eur J Appl Physiol Occup Physiol* 1998;77:189-191.
5. Jessee MB, Mattocks KT, Buckner SL et al. Mechanisms of blood flow restriction: the new testament. *Tech Orthop* 2018;33;2:72-79.
6. Lowery RP, Joy JM, Loenneke JP et al. Practical blood flow restriction training increases muscle hypertrophy during a periodized resistance training programme. *Clin Physiol Funct Imaging* 2014;34:317-321.
7. Loenneke JP, Kearney ML, Thrower AD et al. The acute response of practical occlusion in the knee extensors. *J Strength Cond Res* 2010;24: 2831-2834.
8. Eickhoff-Shemek JM, Craig AC. Putting the New ACSM's Pre-Activity Health Screening Guidelines Into Practice. *ACSM Health Fit J* 2017;21:11-21.
9. Haff GG, Triplett NT. Essentials of strength training and conditioning 4th edition: *Human kinetics*; 2015.
10. Wilson JM, Lowery RP, Joy JM et al. Practical blood flow restriction training increases acute determinants of hypertrophy without increasing indices of muscle damage. *J Strength Cond Res* 2013;27:3068-3075.
11. Loenneke JP, Pujol TJ. The use of occlusion training to produce muscle hypertrophy. *Strength Cond J* 2009;31:77-84.
12. Van Doorn J, van den Bergh D, Böhm U et al. The JASP guidelines for conducting and reporting a Bayesian analysis. *Psychon Bull Rev* 2021;28: 813-826.
13. Mitchell CJ, Churchward-Venne TA, West DW et al. Resistance exercise load does not determine training-mediated hypertrophic gains in young men. *J Appl Physiol* 2012;113:71-77.
14. Ogasawara R, Loenneke JP, Thiebaud RS et al. Low-load bench press training to fatigue results in muscle hypertrophy similar to high-load bench press training. *Int J Clin Med* 2013;4:114-121.
15. Lixandrao ME, Ugrinowitsch C, Laurentino G et al. Effects of exercise intensity and occlusion pressure after 12 weeks of resistance training with blood-flow restriction. *Eur J Appl Physiol* 2015;115:2471-2480.
16. Buckner SL, Jessee MB, Mattocks KT et al. Determining Strength: A Case for Multiple Methods of Measurement. Sports Med 2017;47:193-195.
17. Morton RW, Oikawa SY, Wavell CG et al. Neither load nor systemic hormones determine resistance training-mediated hypertrophy or strength gains in resistance-trained young men. *J Appl Physiol* 2016;121:121-138.
18. Yamanaka T, Farley RS, Caputo JL. Occlusion training increases muscular strength in division IA football players. *J Strength Cond Res* 2012;26: 2523-2529.
19. Bell ZW, Dankel SJ, Mattocks KT et al. An investigation into setting the blood flow restriction pressure based on perception of tightness. *Physiol Meas* 2018;39:105006.
20. Counts BR, Dankel SJ, Barnett BE et al. Influence of relative blood flow restriction pressure on muscle activation and muscle adaptation. *Muscle Nerve* 2016;53:438-445.