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The Effects of Practical Blood Flow Restriction Training on Adolescent Lower Body Strength

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Abstract

The purpose of this study was to examine the effects of a practical blood flow restriction (BFR) training program on lower-body strength of high school weightlifters. Twenty-five students were divided into three groups. For six weeks, each group completed the same resistance training program with the exception of the parallel back squat exercise (2 days/week), which was different for each group. One group (HI) completed a traditional high load (≥65% 1RM) back squat protocol with three sets of low repetitions (≤10). The LO group completed the squat exercise using a relatively light load (≤30% 1RM) for one set of 30 repetitions and three sets of 15 with 30 seconds of rest between sets. The LO+BFR group followed the same protocol as LO, but did so with blood flow restricted. 1RM back squat tests were conducted prior to the start of the program and again upon conclusion, the values of which were used as the dependent measure. A 3 x 2 (group x time) repeated measures ANOVA revealed a significant interaction (p=.043). Follow-up tests were conducted to explore the interaction. Paired-sample t-tests for each group indicated a significant increase in leg strength for the LO+BFR group (p=.005), but not for the HI (p=.142) or LO groups (p=1.00). This suggests that a practical BFR training program may be effective in increasing 1RM squat performance of high school students.

Keywords: KAATSU, occlusion, youth, high school, squat, 1RM

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INTRODUCTION

Resistance training is commonly used for increasing muscular strength. Progressive weight training programs are recommended for all ages by many professional organizations, such as the American College of Sports Medicine (ACSM) and the National Strength and Conditioning Association (NSCA) (1, 12, 29). Similar to adult guidelines (1), relatively heavy loads coupled with low repetitions are recommended for developing muscular strength in adolescents. Specifically, the NSCA suggests using 60-70% 1RM for 3-6 repetitions and 70-80% 1RM for 1-6 repetitions for intermediate and advanced adolescent lifters respectively (8).

In recent years, there has been an increase in research utilizing relatively low loads (≤ 30% 1RM) and high repetitions (sets of 15-30) in conjunction with blood flow restriction (BFR). These studies have demonstrated that this methodology can also result in improved strength. These observations have been noted across various populations, including untrained younger (33, 38) and older adults (37, 39), as well as recreationally (34) and athletically trained adults (18, 35).

Blood flow restriction training is the act of reducing the amount of arterial blood flow to the working muscles while occluding venous return (7). This is done by placing a wrapping device around the proximal end of the muscles in which restriction is desired. The resultant decreased delivery and cessation of return is believed to be responsible for many of the proposed mechanisms for the efficacy of BFR training, including metabolite accumulation (30), increased recruitment of Type II muscle fibers (31, 32), and cell swelling (15).

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To achieve restriction of blood flow, most investigations have utilized pneumatic wrapping cuffs, which precisely control the applied pressure. However, these can be impractical for use outside of a laboratory setting. In 2009, Loenneke and Pujol proposed the use of elastic knee wraps for BFR training (16), which would make the method feasible among the general public (i.e., practical BFR). Unlike pneumatic cuffs, precise quantification of the pressure exerted by elastic wraps is problematic. However, applying the wraps with a moderate perceptive pressure (e.g., a seven on a scale of zero to ten) has been shown to be effective in providing adequate compression (34).

Practical BFR has been shown to be successful in increasing strength in non-laboratory settings. Yamanaka et al. (35) and Luebbers et al. (18) both utilized practical BFR in established strength and conditioning programs of National Collegiate Athletic Association (NCAA) Division I and Division II American football organizations, respectively. In each investigation, those who trained with practical BFR experienced greater increases in 1RM squat strength relative to those who did not train with BFR. This indicates that utilizing elastic wraps for blood flow restriction can be viable for training in real-world situations.

Although BFR training has been investigated across a wide range of adult populations, there appears to be an absence of research on BFR training among adolescents, despite accounts that indicate BFR is likely being used with this age group. In 2006, Nakijima et al. surveyed 105 facilities in Japan that utilized BFR. Of the 12,642 respondents, 17.8% were aged 19 years or younger (23). More recently, Patterson and Brander (2017) surveyed 115 BFR practitioners in 20 countries. Approximately 20.5% of these trainers used BFR with clients aged 20 years or

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younger (25). While neither of these papers reported the exact ages of participants, it seems reasonable to assume that at least some were of high school age. To the best of the authors' knowledge, to date, no scientific investigation has examined the efficacy of BFR training in an adolescent population.

The purpose of this study was to examine the effects of a practical blood flow restriction training intervention on lower body strength in high school weightlifters, as measured by a maximal parallel back squat exercise test. It was hypothesized that those training for leg strength with a low load in combination with practical BFR would experience similar increases in strength as those training with a traditional high load back squat.

METHODS

Experimental Approach to the Problem

The current investigation utilized a pre-test post-test mixed model design with a training intervention. Participants were high school students enrolled in a weight training class, out of which, three groups were created. For six weeks during the final quarter of the academic year, all students completed the same strength training program, with the exception of the back squat exercise, which was different for each group. Prior to the start of the program, and again upon conclusion, leg strength for each student was measured via a one-repetition maximum (1RM) back squat exercise test.

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Subjects

Twenty-seven high school students volunteered to participate in this study. All students were members of the same weightlifting class in a large high school (>1100 students) in the midwest United States. The course was a non-specialized physical education elective course, open to all high school students, and was comprised of students from grades 9 (n= 9), 10 (n=10), 11 (n=3), and 12 (n=5). The class was one semester in length (approximately 19 weeks), and occurred during the final two quarters of the academic year. All participants had a minimum of ten weeks of weightlifting experience prior to the initiation of the study. This investigation was approved by the university's Institutional Review Board and permission to conduct the study at the high school was granted by the school district's Board of Education and the high school principal. All participants and their legal guardians signed an Informed Consent document.

Training Groups

The participants were divided into three training groups of nine (HI, LO, and LO+BFR), which were created via matched randomization. Students were rank ordered based on their weightlifting experience. This order was then separated into thirds. Students from the top third of the rank were then randomly assigned among the three training groups. This procedure was followed for the middle third and the lower third of the rank order, whereas all three training groups had an equal number of participants from each of the three ranked levels. The three female participants were semi-randomized so that one was in each training group.

The study began with 27 participants. Due to a non-training-related injury, one male participant in the LO group was unable to complete the post-test 1RM back squat. One male participant in the LO+BFR group was ill during the final week when 1RM testing occurred and

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was removed from study. Therefore, complete data was analyzed for 25 participants (Table 1). Analyses of variance (ANOVAs) were conducted to examine the three groups (both before and after the removal of the two aforementioned participants) on training age, 1RM squat, grade level, body mass, and height prior to the initiation of the training program. Results indicated that there were no differences among the groups ($p > .05$) on any of these variables (Table 2).

(Table 1 about here)

(Table 2 about here)

Weightlifting Program

The weight training program used in the class was designed by two members of the high school physical education staff. Both were state-certified physical education teachers, and each also held master's degrees. One was the instructor of record for the participating class and had over 15 years of experience teaching physical education and coaching high school athletics. The class met for three sessions each week, on Monday, Wednesday, and Friday. The high school followed a block schedule which allowed for 45 minute sessions on Mondays, and 90 minute sessions on Wednesdays and Fridays. In brief, each session consisted of a full-body workout in which all major muscle groups were exercised. Mondays and Fridays were designated as "strength" training days, and Wednesday was a "power" training day. The parallel back squat was only performed twice a week, on strength training days. Table 3 provides an overview of the training program.

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(Table 3 about here)

One-repetition Maximum Back Squat

All students in this investigation had experience with 1RM parallel back squat tests prior to the initiation of this study. The pre-test back squat 1RMs were completed during the final week of the first half of the semester, just prior to a week-long break. The resistance training program began on the day classes resumed and continued for six weeks. The post-test 1RMs were completed on the Wednesday in the week immediately following the conclusion of the program.

The procedures used for the 1RM back squat tests were as follows. Students completed two warm-up sets: ten repetitions utilizing approximately 40% of their estimated 1RM followed by five repetitions utilizing approximately 60% of their estimated 1RM. The load was then increased to approximately 80-85% of the estimated 1RM, and following adequate rest, one repetition was performed. Additional weight was then added for each subsequent one-repetition set, until the student was no longer able complete a repetition correctly. The 1RM was determined as the last weight utilized in which the student successfully completed the lift with proper form through the entire range of motion (20).

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Exercise Intervention

For six weeks, all students completed identical workouts each training session, with the exception of the parallel back squat, which was different for each training group. The squat exercise was the first exercise performed for each workout, after a total body warm-up. Below is a description of the back squat exercise protocol for each group. A summary overview is available in Table 4.

(Table 4 about here)

HI: These participants completed the parallel back squat exercise following a progressive overload protocol that had been utilized since the beginning of the semester. On Mondays, they completed 3 sets of 10 repetitions with a load calculated as a percentage of their pre-test 1RM. The weight of the first set was approximately 65% of their 1RM, with the following two sets at 70% and 75% respectively (3 x 10 @ 65/70/75% 1RM). On Friday, they completed 3 sets of 3 repetitions beginning with approximately 80% of their 1RM, and increased the percentage to 85% and 90% for the final two sets (3 x 3 @ 80/85/90% 1RM). Rest periods between sets were approximately 3-5 minutes. The eccentric and concentric motions for each phase were not paced, but the students were instructed to perform slow, controlled movements.

Progression: The 1RM value that was used as the basis for load percentages would be adjusted upward 5% when a student was able to complete all repetitions for all three sets of the exercise at the required weight. For example, if a student with an initial 1RM of 220 lb (100 kg) was able to complete all three sets of 10 repetitions at 145, 155, and 165 lb (65, 70, and 75%),

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then the 1RM would be increased by 5% for the following week to a theoretical 1RM of 230 lbs. The approximate loads for the 3 x 10 workout based off of the predicted 1RM would then be 150, 160, and 170 lb. These weights would remain constant for all subsequent 3 x 10 sessions until the student was able to once again complete all repetitions for all three sets. The 1RM would then again be adjusted upward by 5% to a new theoretical 1RM, and the percentage loads weights would increase accordingly. This process was also used for the 3 x 3 workout sessions. These participants progressed as individuals, not as a group.

LO: The participants in this group completed the parallel back squat with the same series of sets and repetitions on both Mondays and Fridays. The protocol was 1 set of 30 repetitions followed by 3 sets of 15 repetitions with a load of approximately 20% of their 1RM (1 x 30, 3 x 15 @ 20% 1RM). The rest periods between each set were 30 seconds in length. A pace of 1.5:1.5 seconds for the concentric and eccentric phases for each repetition was guided by a series of repeating ascending and descending tones which were played over a stereo system from a pre-recorded .mp3 file.

Progression: For the first two weeks, the load remained at 20% of the pre-program 1RM value. This was adjusted upward to 25% of the 1RM for the second two-week period, and then to 30% 1RM for the final two weeks of the six week program. All participants progressed bi-weekly, as a group.

LO+BFR: This group completed the same low-load parallel back squat protocol and progression as the LO group. The only difference being that this group performed the squat

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exercise with blood flow restricted.

Practical Blood Flow Restriction: Restriction of blood flow was achieved with the use of elastic powerlifting knee wraps with hook-and-loop closure (Grizzly Fitness, Kitchener, Ontario, Canada). The wraps measured 7.6 x 167.6 cm (3.0 x 66.0 in) and had been marked with short, silver-colored lines, perpendicular to the edge at 1.3 cm (0.5 in) intervals. In preparation for the squat session, the wraps were applied (overlapping so as to limit the covered area to 7.6 cm in width) around the proximal end of the lower extremities (at the top of thigh, near the inguinal crease), and secured without tension. Then, following the protocol utilized by Luebbers et al. (2014), just prior to the beginning of the lifting session, pressure to the muscles was applied by pulling the wraps to a 7.6 cm (3.0 in) overlap, as measured by the silver markings, and re-secured. They remained in place for the duration of the squat exercise session, including the rest periods, and were removed immediately upon its conclusion.

Participants in each group were instructed not to perform any weightlifting exercises outside of the class for the duration of the six week program. A volume-load comparison for each group can be reviewed in Table 5.

(Table 5 about here)

Familiarization with practical Blood Flow Restriction

This study was conducted during the final half of the second semester of the academic year. In anticipation of this investigation, practical blood flow restriction was incorporated into

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the course during the first half of the semester. This allowed students to become familiar with using elastic knee wraps for BFR as well as practice the repetition cadence that would be used during the forthcoming program. Blood flow restriction was used only for low-load back squat exercises, and was done during four separate training sessions across five weeks.

Loaded Walkouts

In an effort to help the members of the low-load groups remain acclimated to supporting and balancing a high relative weight on their backs, loaded walkouts were incorporated into the final sessions each week. This exercise was done by participants positioning themselves underneath a barbell loaded with a weight equivalent to their pre-test 1RM and then un-racking it in the same manner as used for the back squat. They would then slowly walk back 2-4 steps and then stop with their feet directly underneath them, shoulder-width apart. This position was then held for approximately 30 seconds, after which they would then slowly walk forward and re-rack the barbell. An actual squat was never performed. In brief, participants simply held a loaded barbell in the starting position of a parallel back squat for 30 seconds. Participants in all three groups did this exercise every Friday during the six-week program.

Statistical Analysis

A 3 x 2 mixed model ANOVA with the training groups as the between factor and the 1RM pre- and post-test results as the within factor was performed using IBM SPSS Statistics 24 (SPSS Inc., Chicago, Illinois, USA). Significant effects were explored with one-way ANOVAs and paired-samples t-tests. The level of significance was set at .05 for all analyses.

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RESULTS

The parallel back squat 1RM means and standard deviations as well as change scores for each group are denoted in Table 6. Individual participant 1RM test scores for each group are presented in Figures 1-3.

The ANOVA revealed a significant Time x Group interaction, $F(2, 22) = 3.646$, $p = .043$, $n_p^2 = .249$. The interaction is represented in Figure 4.

To help interpret the interaction, the data was examined in three ways. One-way ANOVAs were computed across groups on the pre-test and post-test 1RMs, and paired-samples t-tests for each group were conducted. The one-way ANOVA on the pre-test 1RM scores revealed no group differences ($F(2, 22) = .159$, $p = .854$). Likewise, the one-way ANOVA on the post-test values indicated no differences among the groups ($F(2, 22) = .186$, $p = .832$). However, paired samples t-tests for each group indicated a significant increase for the LO+BFR group, $t(7) = 3.959$, $p = .005$, but no significant change for either the HI group, $t(8) = 1.627$, $p = .142$, or the LO group, $t(7) = .000$, $p = 1.000$.

(Table 6 about here)

(Figure 1 about here)

(Figure 2 about here)

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(Figure 4 about here)

DISCUSSION

The purpose of this study was to examine the effects of a practical blood flow restriction training intervention on the lower body strength of high school weightlifters. It was hypothesized that the LO+BFR group would experience similar increases in leg strength as the HI group. The hypothesis was only partially supported in that while the LO+BFR group did increase in strength, the change in strength observed in the HI group did not reach significance. The significant interaction revealed by the repeated measures ANOVA indicated a difference among the groups' pre- and post-test 1RM scores. When the groups' performances were examined individually via the paired-samples t-tests, it was revealed that the LO+BFR group experienced an increase in 1RM squat performance and the HI group did not (p=.005 vs. p=.142 respectively).

The primary finding of this study is that low-load BFR training is effective in increasing lower-body strength in adolescent weightlifters. While the efficacy of BFR resistance training has been demonstrated previously in adult populations (18, 33-35, 37-39), this investigation is the first to examine this modality in an adolescent population. Collectively, the participants in this study, although young, were not unfamiliar with resistance training. The NSCA defines a novice as those with limited experience with strength training (≤ 2 to 3 months). Intermediate and advanced weightlifters are as those with 3-12 months and greater than 12 months of experience, respectively (8). Of the 25 participants in this study, only 6 had not been a part of a weightlifting class previous to enrolling in the current course. However, the investigation was

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conducted during the second half of the 19 week class, ensuring that all participants had at a minimum ten weeks of strength training experience prior to the start of this investigation, although most had several more (Table 2).

Novice weightlifters typically respond positively to the initiation of weight training, even when frequency and volume are relatively low. This is thought to primarily be due to neuromuscular adaptations rather than morphological changes in the skeletal muscle (2, 21, 24). That is, when an individual is learning a new motor skill (e.g., parallel back squat), the body adapts rapidly in terms of motor unit recruitment and synchronicity. In weightlifting, this increased efficiency of movement can lead to increases in strength that are apparent soon after the onset of training. However, as the proficiency of the movements reach their limit, further increases in strength are thought to typically require muscle hypertrophy (6, 21, 28), although not all research is in agreement (3, 4, 19). Regardless, as lifters gain experience, resistance training programs generally incorporate a progressive increase in volume-load (the number of repetitions x external mass), which has been shown to be effective in promoting muscle size (11) and strength (10). However, if the progression is insufficient in providing an adequate stimulus for continued adaptations, strength may be maintained, but will likely not improve (9). This appeared to be evident in the present study. The total volume-loads for both the LO and LO+BFR groups were equal (Table 5). The LO group, unlike the LO+BFR group, did not experience an increase in 1RM squat performance, despite the equal total volume-load. Rather, the LO group simply maintained their pretest strength levels across the six week period. For the adolescents in the present study, this indicates that the restriction of blood flow to the exercised muscles may have provided a stimulus for increasing strength beyond the exercise load and the

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set and repetition protocol. This is similar to research in young adults that compared volume-load equivalent practical BFR and non-BFR resistance training programs (35). For the HI group, the increase in strength was less than the LO+BFR group and was non-significant. As is evident in Figure 1, the HI program was not effective for all members of the group. Since these participants progressed through their program individually and not as a group as did those in LO and LO+BFR groups, it is difficult to make direct comparisons. However, it is possible that the progression method utilized in the HI protocol was not sufficient to provide the stimulus needed to elicit strength adaptations for some participants. This may also help explain the lack of significance observed with the post-test one-way ANOVA.

Whether the numerous potential mechanisms for the efficacy of BFR training for adults (13, 26) are the same for adolescents is beyond the scope of the current investigation, and requires further examination. Of particular interest may be motor unit recruitment (22, 36), which as Dotan et al. have noted, appears to account for differing rates of strength development between youth and adults (5). Future investigations of BFR training with this age group should consider methodologies – such as electromyogram (EMG) – that could provide insight regarding muscle activation and recruitment order. Additionally, the volume-load of the BFR protocol used for adolescents should be considered. As demonstrated by the present study, the strength increase experienced by the restriction of blood flow does appear to be independent of the volume-load of the protocol (LO+BFR vs. LO). The HI group, despite utilizing a lower volume-load, experienced a non-significant increase in 1RM strength of approximately 6 kg. However, it should be noted that not all members of the group increased in strength; some participants experienced a decrease in squat performance (Table 6 & Figure 1). Yet, given that the lower-

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volume HI protocol was effective for some members, exploring set and repetition BFR training protocols that result in a lower volume-load than that of the present study, could help establish a minimum threshold needed for BFR to be effective with this age group. If a reduced volume-load could still be efficacious at increasing strength, it may make BFR even more appealing for use with adolescents.

This study is not without limitations. Due to being conducted within a single ongoing high school class, the number of students available from which to create the three groups was limited. The small number of participants in each group does necessitate that the results be cautiously interpreted. Also, the students were fairly diverse in regard to experience with resistance training and with age. Although the groups were match randomized by training experience, having groups that are more homogeneous may have allowed for results that were more conclusive. However, it should be considered that this class was likely representative of the student composition of many high school weightlifting classes in the United States. Finally, the pressure exerted by the elastic knee wraps utilized by the LO+BFR group for restriction of blood flow was standardized. Research has indicated that the pressure needed to cause adequate blood flow restriction varies among individuals, based primarily on limb circumference (14). Since this variability was not considered in this study, it is possible that the pressure exerted was not optimal for each participant.

PRACTICAL APPLICATIONS

While both high-load traditional resistance training and low-load practical BFR resistance training can potentially increase muscular strength in adolescents, BFR may offer unique

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elements that could be appealing to teachers and coaches of this age group. High-load training typically induces some degree of muscle damage, which may cause short term muscular soreness (both acute and delayed) as well as diminished performance and function (27). Conversely, low-load BFR has been demonstrated to increase muscular strength without causing muscle damage. While there have been reports of delayed onset muscle soreness (DOMS), the use of low-load BFR has not been show to induce clinical markers of muscle damage to any level of significance (17). This could have important implications for the high school physical education programs and athletic teams. Being able to strategically incorporate low-load BFR into a resistance training program may increase the rate at which students advance through the program. Additionally, the use of a low relative load may be appealing to students who have difficulty performing and/or recovering from high-load resistance training. This could increase the number of adolescents who pursue resistance training as a mode of exercise.

Conclusion

The present study is the first to indicate that low-load, practical BFR resistance training may also be an effective means for increasing muscular strength in adolescents. The use of elastic knee wraps makes the inclusion of practical BFR resistance training into a high school program a cost-effective, feasible option for school districts, physical educators, and coaches of these students.

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Figure Legends

Figure 1. HI group (n=9) parallel back squat one-repetition maximum (1RM) test values

Figure 2. LO group (n=8) parallel back squat one-repetition maximum (1RM) test values

Figure 3. LO+BFR group (n=8) parallel back squat one-repetition maximum (1RM) test values

Figure 4. Group x time interaction for parallel back squat one-repetition maximum (1RM)

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Table 1: Participant Demographics

	Age (years)	Body Mass (kg)	Height (cm)
Boys (n=22)	15.8 ± 1.2	77.4 ± 17.7	179.4 ± 8.9
Girls (n=3)	16.6 ± 1.2	64.8 ± 15.1	160.8 ± 2.9

Mean ± Standard Deviation

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Table 2: Training Groups

	Training Experience (years)	Squat 1RM (kg)	Grade Level	Body Mass (kg)	Height (cm)
HI (n=9)	1.8 ± 1.1	92.7 ± 22.5	9.7 ± 1.0	77.5 ± 23.0	177.9 ± 9.2
LO (n=8)	2.2 ± 1.3	94.8 ± 30.2	10.1 ± 0.9	75.1 ± 16.4	174.2 ± 11.6
LO+BFR (n=8)	1.9 ± 1.8	88 .0 ± 20.6	10.3 ± 1.3	74.8 ± 13.4	179.5 ± 10.9

Mean ± Standard Deviation [No differences among the groups for any variable ($p > .05$)]

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Table 3. Representative Training Sessions

Mondays (Strength)			Wednesdays (Power)		Fridays (Strength)		
Primary Exercise	Sets x Reps	% 1RM	Primary Exercise	Sets x Reps	Primary Exercise	Sets x Reps	% 1RM
Back Squat	(See Table 4)		Hang Cleans	3 x 5	Back Squat	(See Table 4)	
Bench Press	3 x 10	65/70/75	Push Press	3 x 5	Bench Press	3 x 3	80/85/90
			Clean and Jerk	2 x 5	Deadlift	3 x 3	80/85/90
					Decline Press	3 x 3	80/85/90
Auxiliary Exercise			Auxiliary Exercise		Auxiliary Exercise		
Pull-ups			Dumbbell reverse flys		Loaded walkouts		
Dumbbell curls			Triceps press		Dumbbell rows		
Medicine Ball twists			Planks		Dumbbell curls		
			Calf raises		Crunches		

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Table 4. Parallel Back Squat Exercise Protocols

HI Group			LO Group			LO+BFR Group		
Day	Sets x Reps	% 1RM*	Day	Sets x Reps	% 1RM*	Day	Sets x Reps	% 1RM*
Monday	3 x 10	65%	Monday	1 x 30, 3 x 15	20%	Monday	1 x 30, 3 x 15	20%
Friday	3 x 3	80%	Friday	1 x 30, 3 x 15	20%	Friday	1 x 30, 3 x 15	20%

*see text for descriptions of load progression

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Table 5: Volume-load (kg) comparisons for hypothetical participants with an initial 1RM of 100 kg. For the HI participant, the example is at an optimal rate of progression (i.e., increasing 5% every week), to show maximal potential volume-load.

Week 1	**Monday**			**Volume-load (kg)**			**Friday**			**Volume-load (kg)**		
1RM=100 kg	**Set**	**Reps**	**%**	**HI**	**LO**	**LO+BFR**	**Set**	**Reps**	**%**	**HI**	**LO**	**LO+BFR**
	1	10	65	650			1	3	80	240		
	1	10	75	700			1	3	85	255		
	1	10	80	800			1	3	90	270		
1RM=100 kg	1	30	20		600	600	1	30	20		600	600
	1	15	20		300	300	1	15	20		300	300
	1	15	20		300	300	1	15	20		300	300
	1	15	20		300	300	1	15	20		300	300
	Day Total Volume-load:			**2150**	**1500**	**1500**	**Day Total Volume-load:**			**765**	**1500**	**1500**
	Week Total Volume-load:			**2915**	**3000**	**3000**						

Week 2	**Monday**			**Volume-load (kg)**			**Friday**			**Volume-load (kg)**		
1RM=105 kg	**Set**	**Reps**	**%**	**HI**	**LO**	**LO+BFR**	**Set**	**Reps**	**%**	**HI**	**LO**	**LO+BFR**
	1	10	65	685			1	3	80	255		
	1	10	75	735			1	3	85	270		
	1	10	80	840			1	3	90	285		
1RM=100 kg	1	30	20		600	600	1	30	20		600	600
	1	15	20		300	300	1	15	20		300	300
	1	15	20		300	300	1	15	20		300	300
	1	15	20		300	300	1	15	20		300	300
	Day Total Volume-load:			**2260**	**1500**	**1500**	**Day Total Volume-load:**			**810**	**1500**	**1500**
	Week Total Volume-load:			**3070**	**3000**	**3000**						

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Week 3	Monday			Volume-load (kg)		
1RM=110 kg	**Set**	**Reps**	**%**	**HI**	**LO**	**LO+BFR**
	1	10	65	715		
	1	10	75	770		
	1	10	80	880		
1RM=100 kg	1	30	25		750	750
	1	15	25		375	375
	1	15	25		375	375
	1	15	25		375	375
	Day Total Volume-load:			**2365**	**1875**	**1875**
	Week Total Volume-load:			**3185**	**3750**	**3750**

Friday			Volume-load (kg)		
Set	**Reps**	**%**	**HI**	**LO**	**LO+BFR**
1	3	80	265		
1	3	85	270		
1	3	90	285		
1	30	25		750	750
1	15	25		375	375
1	15	25		375	375
1	15	25		375	375
Day Total Volume-load:			**820**	**1875**	**1875**

Week 4	Monday			Volume-load (kg)		
1RM=115 kg	**Set**	**Reps**	**%**	**HI**	**LO**	**LO+BFR**
	1	10	65	750		
	1	10	75	805		
	1	10	80	920		
1RM=100 kg	1	30	25		750	750
	1	15	25		375	375
	1	15	25		375	375
	1	15	25		375	375
	Day Total Volume-load:			**2475**	**1875**	**1875**
	Week Total Volume-load:			**3355**	**3750**	**3750**

Friday			Volume-load (kg)		
Set	**Reps**	**%**	**HI**	**LO**	**LO+BFR**
1	3	80	275		
1	3	85	295		
1	3	90	310		
1	30	25		750	750
1	15	25		375	375
1	15	25		375	375
1	15	25		375	375
Day Total Volume-load:			**880**	**1875**	**1875**

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Week 5	Monday			Volume-load (kg)		
1RM=120 kg	Set	Reps	%	HI	LO	LO+BFR
	1	10	65	780		
	1	10	75	840		
	1	10	80	960		
1RM=100 kg	1	30	30		900	900
	1	15	30		450	450
	1	15	30		450	450
	1	15	30		450	450
	Day Total Volume-load:			**2580**	**2250**	**2250**
	Week Total Volume-load:			**3500**	**4500**	**4500**

Friday			Volume-load (kg)		
Set	Reps	%	HI	LO	LO+BFR
1	3	80	290		
1	3	85	305		
1	3	90	325		
1	30	30		900	900
1	15	30		450	450
1	15	30		450	450
1	15	30		450	450
Day Total Volume-load:			**920**	**2250**	**2250**

Week 6	Monday			Volume-load (kg)		
1RM=125 kg	Set	Reps	%	HI	LO	LO+BFR
	1	10	65	815		
	1	10	75	875		
	1	10	80	1000		
1RM=100 kg	1	30	30		900	900
	1	15	30		450	450
	1	15	30		450	450
	1	15	30		450	450
	Day Total Volume-load:			**2960**	**2250**	**2250**
	Week Total Volume-load:			**3650**	**4500**	**4500**
	Program Total Volume-load:			**19,675**	**22,500**	**22,500**

Friday			Volume-load (kg)		
Set	Reps	%	HI	LO	LO+BFR
1	3	80	300		
1	3	85	320		
1	3	90	340		
1	30	30		900	900
1	15	30		450	450
1	15	30		450	450
1	15	30		450	450
Day Total Volume-load:			**960**	**2250**	**2250**

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Table 6: Parallel Back Squat One-repetition Maximum (1RM) Results and Change Scores

	Pre-test (kg)	Post-test (kg)	Change (kg)
HI (n=9)	92.7 ± 22.5	99.2 ± 20.7	6.6 ± 12.1
LO (n=8)	94.8 ± 30.2	94.8 ± 30.0	0.0 ± 8.8
LO+BFR (n=8)	88 .0 ± 20.6	102.3 ± 21.7	14.2 ± 10.1

Mean ± Standard Deviation

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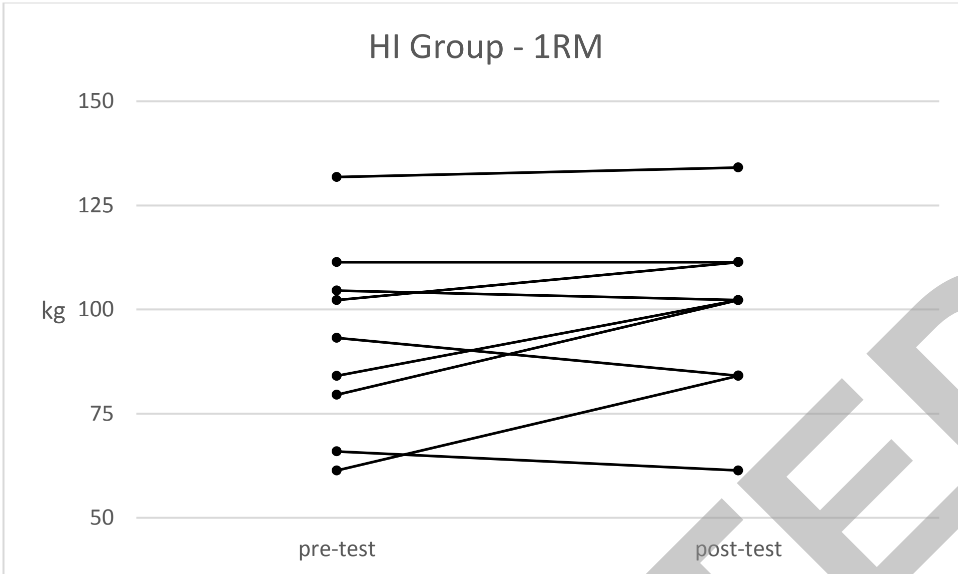

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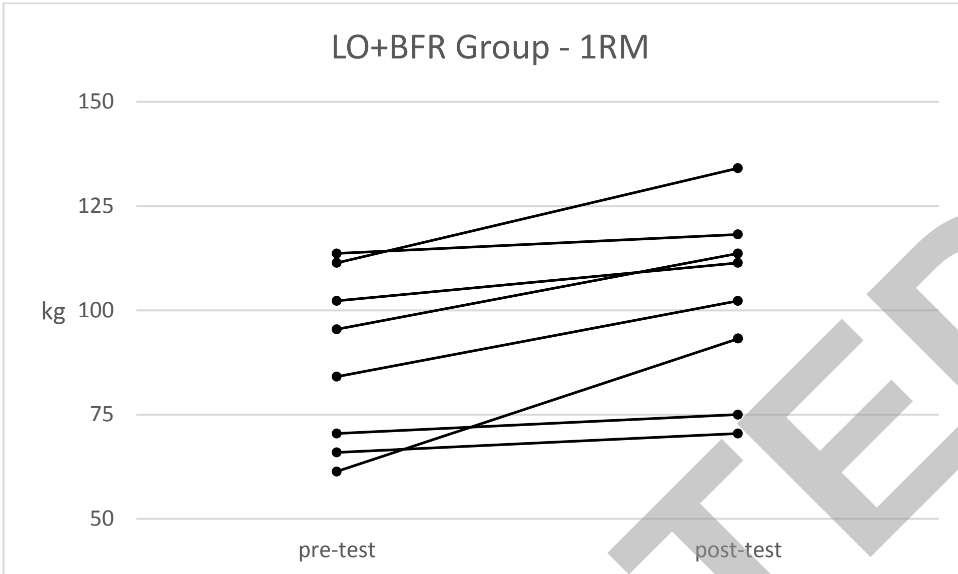

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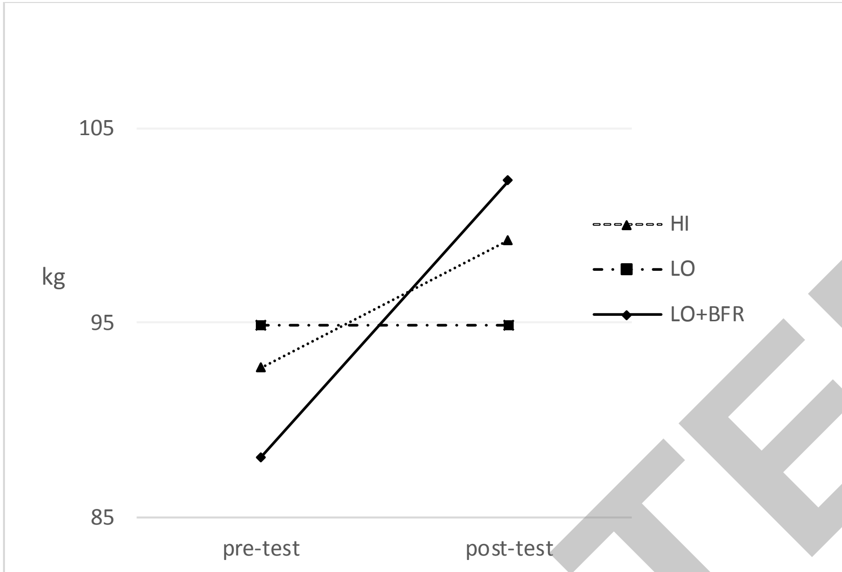

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