Unilateral vs. bilateral squat training for strength, sprints and agility in academy rugby players

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Title. Unilateral vs Bilateral Squat training for Strength, Sprints and Agility in Academy Rugby Players

Brief Running Head. Unilateral squat training

Key words: Single-leg, speed, change of direction, power

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ABSTRACT

The purpose of this study was to investigate the effects of a five-week lower limb unilateral or bilateral strength programme on measures of strength, sprinting and change of direction speed.

Eighteen academy rugby players (18.1 ± 0.5 years, 97.4 ± 11.3 kg, 183.7 ± 11.3 cm) were randomly assigned to either a unilateral (UNI) or bilateral (BI) group. The UNI group squatted exclusively with the rear elevated split squat (RESS), whereas the BI group trained only with the bilateral back squat (BS). Both groups trained at a relative percentage of the respective one repetition max (1RM) twice weekly over a five-week period. Subjects were assessed at baseline and post-intervention for 1RM BS, 1RM RESS, 10 m sprint, 40 m sprint and Pro agility.

There was a significant main effect of time for 1RM BS ($F_{(1,16)} = 86.5$, $p < 0.001$), ES (0.84< Cohen *d*< 0.92), 1RM RESS ($F_{(1,16)} = 133.0$, $p < 0.001$) ES (0.89< Cohen d <0.94). 40m sprint ($F_{(1,16)} = 14.4$, $p = 0.002$) ES (0.47<Cohen d<0.67) and Pro-Agility ($F_{(1,16)} = 55.9$, $p < 0.001$), ES (0.77<Cohen d< 0.89), but not 10m sprints ($F_{(1,16)} = 2.69$, $p = 0.121$), ES (0.14<Cohen d <0.38). No significant interactions between group and time were observed for any of the dependant variables. This is the first study to suggest that BI and UNI training interventions may be equally efficacious in improving measures of lower body strength, 40m speed, and change of direction in academy level rugby players.

Keywords: Single-leg, speed, change of direction, power

INTRODUCTION

In recent years the use of unilateral (UNI) exercises such as the lunge, step-up, split squat and rear elevated split squat (RESS) have become popular in strength and conditioning practice[21]. UNI exercises are regularly included within strength programmes as assistance exercises to bilateral exercises (BI) such as the back squat (BS), typically implemented to increase volume load or provide variation. There are many examples of UNI exercises[31] being utilised in strength and conditioning programmes yet there is little evidence of their efficacy with trained individuals.

Improvements in strength and power through the use of BI exercises such as the BS are well established[6, 8], and are often selected as the primary exercise for this purpose. For example, one study reported significant improvements in 40 m running velocity, countermovement and squat jump performance in junior level footballers after 8 weeks of twice-weekly BS[6]. Similarly, Comfort Haigh, and Matthews (2012)[8] reported concomitant improvements in BS strength and sprint performance over 5 and 10 m, following 8 weeks of resistance training in professional rugby league players. One study has also suggested that long-term strength training with the BS or front squat may improve change of direction performance in junior footballers[17].

The BS is performed with a two-leg support, but many athletic skills such as sprinting, jumping and changing direction are performed either unilaterally, or with weight transferred to one leg at a time. It could be speculated that UNI exercises are preferable in improving some aspects of physical performance compared to the BS due to greater specificity, which refers to the degree of similarity between training exercises and athletic performance.

Specificity is an important principle in training programme design, with both researchers and practitioners attempting to maximize transfer between training and competitive performance[33].It is also considered that greater similarities between training exercises and physical performance variables are more likely to maximize transfer effects[3.] This idea is consistent with previous research, for example one study found that 8 weeks of plyometric training including unilateral exercises induced significant improvements to 10m time[24]. Furthermore a 9-week sprint and plyometric program including both unilateral and horizontal exercises improve sprint performance over 10m significantly more than sprinting alone[11]

Practitioners often include UNI exercises as part of a comprehensive strength programme based on this rationale, however such a contention is purely speculative. Research to date investigating UNI training interventions on measures of strength and power demonstrate tenuous external validity, primarily due to the use of untrained individuals[22]. For example one study compared the effects of an 8-week RESS and BS protocol on several aspects of strength and power in untrained individuals and reported significant improvements in lower limb strength with little difference between groups[22]. Although it was suggested that UNI and BI training were equally effective in improving lower body strength, practitioners should be cautious in applying these findings to trained populations. Previous studies investigating the acute responses to UNI exercises in trained individuals suggest comparable muscle activity and hormonal fluctuations between BI and UNI exericses[16], reduced torso angle and greater activation of the gluteus medius[23] in UNI compared to BI exercises, however the practical implications of these findings are not clear.

Further theory supporting unilateral training may be explained by the Bilateral deficit (BLD), which states that simultaneous BI contractions produces lesser force compared to the

summed identical UNI contractions[25].The BLD has been observed in jumping activities[4], and the leg extension[9]. Authors cite a reduced neural drive as the mechanism. This early research may suggest that performing exercises unilaterally could produce favorable adaptations to unilateral strength as more force may be produced unilateral, which may impact unilateral activities. A previous study found that training with UNI exercises may be more effective than BI exercises for improving unilateral vertical jumping performance[22,] however this has not yet been investigated in trained athletes

In order for practitioners to consider UNI exercises as a viable option for developing lower body strength in trained athletes, more longitudinal data are required investigating the responses of trained individuals to UNI versus BI training interventions. Due to the aforementioned limitations in the existing literature, the purpose of this study was to compare the effects of BI and UNI training on lower body strength, sprinting and change of direction speed (COD) in trained rugby union players. It was hypothesized that the effects of UNI and BI training would be similar in improving lower body strength compared to pre-training. It was also hypothesized that UNI training would be more effective than BI training in improving 10 m, 40 m and change of direction speed.

METHODS

Experimental approach to the problem

To test the main hypothesis, that UNI training would significantly increase lower limb strength as much as BI training, a 2 x 2 mixed design was used. The within subject factor was time at two levels (pre and post) and the between subject factor was grouped at two levels;

unilateral (UNI), and bilateral (BI). The UNI group squatted exclusively with the RESS, while the BI group squatted exclusively with the BS twice weekly for a period of five weeks. Participants were tested before and after the 5-week intervention period to determine any changes in the dependent variables, including 10 and 40 m sprint, Pro-agility, one repetition max (1RM) max BS and 1RM RESS squat.

Subjects

Eighteen healthy academy rugby players (18.1 ± 0.5 years, 97.4 ± 11.3 kg, 183.7 ± 11.3 cm), with at least one year of resistance training experience volunteered to participate in this study. All participants were engaged in a structured strength and conditioning programme and were familiar with the RESS and BS. Prior to any data collection, all participants provided written informed consent, which was reviewed by the Edinburgh University Ethics Committee, and participants under the age of 18 were also required to obtain parental consent. Criteria for exclusion consisted of; participants with less than one year resistance training experience, evidence of orthopedic or lower limb injuries, or heart/circulatory conditions. Participants were randomly assigned to an experimental (UNI) or control (BI) group (Table 1). Subjects in the UNI group were not significantly different to the BI group in terms of age, height, weight, relative strength ratio or training history ($p > 0.05$), and there was 93% training attendance in the UNI group and 92% in the BI group.

****Insert Table 1 about here****

Experimental Procedures

Testing

Prior to baseline testing, participants were given a three-week instructional period, consisting of 6 sessions to learn correct technique in the RESS and BS. Participants were encouraged to increase the load on a weekly basis using an auto-regulatory progressive pattern[19.] Familiarisation of 10m, 40m, and Pro-agility tests were well established, as participants undertake these tests as part of routine performance testing at least four times per year.

****Insert Table 2 about here****

Testing Protocol

Upon completion of familiarisation, participants were required to attend two testing sessions separated by three days. During the first session, information on stature (Leicester stadiometer, Invicta Plastics Ltd, U.K.) and bodyweight was obtained (Avery Berkel 33/448, W & T Ltd., U.K.). Participants completed a ten minute standardized warm-up consisting of dynamic bodyweight exercises, gradually increasing in intensity. Participants then performed two 40 m sprints, where the best 10m and 40m split times were obtained (Brower Timing Systems, Draper, UT), which have been reported as reliable and valid measures of speed[32].

In order to train at a relative percentage of maximum values for RESS, participants completed a 3RM RESS on both legs, with self-selected dominant leg used for statistical analysis[21]. RESS were performed within a power rack with safety pins set at hip height to allow participants to fail safely within the rack by dropping the weight on the pins. While performing the RESS, the foot of the non-exercising leg was placed on a 40 cm support box to ensure the exercising leg was independently performing the movement. RESS and BS depth were standardized to an angle of 100° between femur and tibia[26].Previous research has found that the UNI squat can be measured with high reliability[21.] Subjects were tested twice, separated by 48 hours to determine 3RM as seen in previous research[21] Intraclass correlation coefficients were recorded. Differences between pre- and post-test measures were determined by the paired-sample t-test. The 3RM test was found to be reliable, ICC=0.98, there was no difference between the first and second trial (p=0.17).

Three days later participants completed three repetitions of the Pro-agility test following the standardised warm up. The Pro-agility has shown high test-retest reliability as a measure of change of direction speed (CODS) in active individuals[32]. Markers were placed at 0, 5 and 10 yards with timing gates on the 5-yard line, to indicate where participants start and finish. Participants began in a neutral 3-point position with feet either side of the midline,

participants then turned and ran five yards to the right side and touched the line with the right hand, and then ran 10 yards to the left, touched the line with their left hand the ran back through the start line to the finish. The trial was then completed in the other direction, with a 3rd trial completed off the preferred foot. The fastest trial was recorded.

Thirty minutes later, a 3RM test on the BS was performed, where depth was standardized to a degree of 100° between femur and tibia in accordance with recommended full squat guidelines outlined in previous studies[26]. For both lifts, depth was assessed using a video camera (Sony HDR-AS100VR Action Camera, UK) placed side-on to the participant. BS depth was judged retrospectively, and if participants failed to achieve the correct depth, testing was repeated 48 hours later. Prior to the 3RM testing in both groups, sets of 5-10 repetitions with a self-selected weight on the first set with a 1-minute recovery period was completed, followed by one set of 5 repetitions having increased the load by 10-20% as seen in previous studies[22]. Three minute recovery periods were allocated between each successive set. Participants had a limit of 5 trials (including the warm-up sets) to attain the 3RM, as prescribed in previous research[22.] The 1RM was then extrapolated using a prediction formula, which is a commonly used method to determine 1RM[5.] This testing protocol was subsequently replicated post intervention on the 6th week.

Testing Conditions

The testing environment remained consistent from pre to post test, as did the order of testing, warm up procedures and participant's footwear. Procedures were also completed at the same time of day to avoid circadian fluctuations, and adequate recovery from any previous training and/or competition was allowed. There was a three day rest period between

initial testing and the intervention and a three day rest period between the end of the training intervention and post testing.

Training Intervention

Participants completed a five-week strength training intervention, consisting of two fully supervised training sessions per week, with BS and RESS depth standardised to the testing conditions. In the UNI group, researchers observed the lead leg and the barbell for correct technique. If posterior displacement of the barbell occurred on descent with no anterior movement of the knee joint, the lift was deemed unsuccessful due to weight distribution in the non-exercising leg[21] .Subjects repeated the missed rep but were only given one additional attempt to complete repetition correctly. Intensity was standardised across groups using the same relative intensity at a percentage of 1RM in each exercise[22] and the UNI group trained both legs at a percentage of 1RM. Participants followed the same prescribed loading pattern over the five-week period. The highest prescribed volume and lowest intensity occurred during week 1, whereas the lowest prescribed volume and highest intensity occurred during week 5 (Table 2). Tempo was also standardised across groups by encouraging the use of a 2-0-1, whereby the concentric and eccentric phases are completed in one and two seconds respectively, with no pause between phases[26.] This tempo rather than a fast concentric phase was chosen to reduce shear and compressive related forces[26] Three minutes of rest was allocated between each set, and training days were separated by 72 hours to ensure sufficient recovery between sessions. No additional lower limb strength exercises were performed during the intervention period. Both the control and experimental group participated in two skills sessions, two rugby sessions and one game per week.

*** Insert Table 3 about here***

Statistical Analysis

Data are presented as mean (M) ± standard deviation (SD) and were screened for normality and homogeneity of variance using the Wilks-Shapiro and Levene's test respectively. Two-way analysis of variance (ANOVA) with mixed design were used to examine any differences in each performance variables, within and between groups, before and after the training period. Significant effects for time and interaction effects (condition x time) were measured using the Wilks Lambda test. Significance was accepted at $p<0.05$, and Effect sizes were assessed using partial eta squared (partial η^2) values which were square-rooted to give correlation coefficients that were compared with the effect sizes given by Hopkins; 0.1-0.3 as small, 0.3-0.5 as moderate, 0.5-0.7 as large and 0.7-0.9 as very large[8]

RESULTS

There was a significant main effect of time for 1RM BS ($F_{(1,16)}$ = 86.5, p < 0.001), ES (0.84< Cohen *d*< 0.92). 1RM RESS ($F_{(1,16)}$ = 133.0, p < 0.001) ES (0.89< Cohen d <0.94); 40 m sprint ($F_{(1,16)}$ = 14.4, p = 0.002) ES (0.47<Cohen d<0.67); and pro-agility ($F_{(1,16)}$ = 55.9, p < 0.001), ES (0.77<Cohen d< 0.89), but not 10m sprints ($F_{(1,16)}$ = 2.69, p = 0.121), ES (0.14<Cohen d <0.38). Differences in 1RM BS pre- to post-intervention are shown in Figure 1.0 and differences in 10m, 40m, pro-agility and 1RM RESS squat (pre-post) are shown in Table 3. No significant interactions were observed between any of the dependant variables.

Insert figure 1.0 about here

Insert Table 3 about here

DISCUSSION

The primary finding of the current study was that UNI and BI training were equally effective in improving lower body strength. There was a large effect size reported for Back Squat ES (0.84< Cohen *d*< 0.92). Similar Improvements were also observed in 40m between groups ES (0.47< Cohen d < 0.68) and Pro-Agility ES (0.78< Cohen d < 0.88). This is in contrast to the hypothesis that UNI training would be more effective in enhancing 10m, 40m and change of direction speed.

Lower body strength

The data in the current study suggests that BI and UNI training exert reciprocal benefits to UNI and BI strength, with increases of 5.7 ± 3.8 % and 5.0 ±3.7 % in BS 1RM in the UNI and BI groups respectively. RESS 1RM strength also improved by 9.2 ± 2.1% and 10.5 ± 3.2% in the UNI and BI groups. These findings are in agreement with our hypothesis that UNI and BI training would be equally effective for improving lower body strength, and somewhat in agreement with previous literature[22.] McCurdy et al. (2005) reported similar improvements in BI and UNI strength, in untrained individuals. The present study suggests this may also be the case in academy level rugby players, indicating some degree of external validity in applying these results to athletic groups.

At this stage we cannot draw any conclusions regarding the physiological mechanism that would explain the findings in the present study. Previous research has found that muscle activity is comparable between the RESS and BS when relative intensities are matched[16], specifically in the lower back, hamstring, gluteals and quadriceps which may indicate that the amount of neuromuscular activity required for both exercises is the same and therefore strength adaptations are similar. However, research by Mccurdy et al (2010) reported increased EMG activity in gluteus medius and hamstring during the RESS, but increased quadriceps activity in the BS[23]. The authors attributed these findings to the relative instability of the RESS in comparison to the BS, however the subjects were female so results may differ with male athletes, the subjects in this study also had less experience using the RESS and the discrepancies in muscle activity may be due to the novelty of the exercise. Antagonist activity is known to increase when new tasks are introduced[12] in order to improve stability and safeguard against excessive forces [34]. In the present study, this was addressed with a longer familiarisation period, however EMG recording was not available during this study therefore we may only speculate based on findings from previous research. Furthermore, as BI training improved UNI strength, this explanation seems unlikely, whereas the compatibility in muscle involvement may be responsible for the similarities in strength development between groups.

Previous research has also found that both the UNI and BS produce similar post exercise testosterone[16,] which is a significant finding as an elevation in testosterone can have a positive effect on muscular strength development by increasing protein synthesis, lean body mass, and aiding in exercise recovery[35], however it is unlikely that 5 weeks would have been a long enough time period for hypertrophy to occur.

10m

No significant main effect for time in 10 m speed was observed, however there was a small effect size ES (0.14<Cohen d <0.38). This was surprising, as a previous study have demonstrated increases in maximal squat strength are associated with improvements in 10 m sprint time[8]. Furthermore, a recent meta-analysis, which included 510 subjects, 85 effect sizes and 15 studies investigated the relationship between increases in lower body strength and transfer to sprint performance, and reported a significant correlation in lower body strength and sprint performance over short distances (< 20 m) [27]. It is well established that peak ground reaction forces and impulse are strong determinants of sprint performance[15], and based on this it was expected that an increase in force production would contribute to improved 10 m sprint times.

The lack of a main effect may be explained by the short study period. Five weeks is a short duration to expect any substantial changes in sprinting performance. Practitioners maintain that athletes require a certain amount of time to be able to "use" new levels of strength and express them in a specific context [33]. It is also possible that the lack of effect may be due to lag time. Lag time refers to the period of time in which a specific adaptation manifests itself, or the duration in which an athlete learns how to optimally express force[1]. It is possible that different training methods can produce lag times varying in duration, sometimes extending over months at a time [33]. Furthermore, central to the concept of transfer

of training is specificity, which states that the adaptations are specific to the nature of the training[37], therefore a concurrent sprint training programme may have elicited further changes in 10m time. A speed programme was not provided during this time due to the stage of the season players were in and to isolate the effects of the resistance training programme on the performance variables. However, this is in contrast to 40m data below. Finally, it is possible that statistical power was insufficient to show this difference, resulting in a Type II statistical error.

40m

Moderate effect size was found for 40m time ES (0.47< Cohen d < 0.68), with no significant interaction between groups. This is in contrast to the hypothesis that UNI would be more effective in improving 40 m sprinting time compared to BI training. Data from this study are consistent with previous research, suggesting that improvements in lower limb strength transfers to enhanced sprinting performance[8, 27].

The current data also provides new information for practitioners regarding the effectiveness of UNI training and its transference to improved sprint performance. Based on the concept of specificity, it was hypothesized that training with the RESS would result in more pronounced improvements in sprinting performance compared to the BS. However, specificity is a complex concept that is determined by overload in specific criteria[33.]

Siff and Verkoshansy (1998) suggest that the magnitude of training transfer depends on dynamic correspondence, whereby basic mechanics rather than outward appearances of

training movements must replicate athletic skills. Additionally, for exercises to transfer successfully to athletic performance, exercises must overload specific parameters including the type of muscular action, force magnitude and direction, dynamics of effort and rate of force development (RFD) [30,33,37]. Sprinting is a complex athletic activity, requiring high levels of force, the ability to produce force during quick contact times, and exert force in the appropriate direction[18,36]. As improvements were observed in UNI and BI strength in both groups, it is likely that participants were able to exert greater peak ground reaction force (pGRF), impulse and RFD as a result of both training methods, however these parameters were not measured in this study.

Pro - Agility

This is the first study to compare the effects of UNI and BI training on measures of change of direction speed (CODS). In the pro-agility test, there was a large main effect size (0.78< Cohen d < 0.88). Participants improved by 1.74% ± 1.0% s and 1.9% ± 0.8% in the UNI and BI groups respectively.

These results demonstrate that strength training is an appropriate means to improve CODS in a five-week period in trained rugby players. There is currently some disparity in the literature with regard to the effects of strength training on measures of CODS, partly as a result of different test designs and different strength-speed parameters. For example, a previous study reported significant improvements in sprint times and change of direction in the T test following 8 weeks of squat jump training with 30% and 80% of 1RM[20]. It has also been reported that strength training with either the front squat or BS over a period of two years significantly improves CODS performance of CODS in junior footballer players[17].

However, it should be noted that although the Pro-agility has reported high test-retest reliability [32] direct transfer into improved athletic performance cannot be assumed, as research has demonstrated that agility is a product of both physical and cognitive factors, including perceptual skills, decision making skills and pattern recognition [29]. The ability of team sport athletes to "read and react" to game specific stimuli is an important variable associated with improved agility[29]. This study utilised a pre-planned change of direction test, creating some difficulty in deducing what the performance implications may be, but collectively, research suggests that aspects of improved strength and power may positively influence the physical factors associated with change of direction speed.

Limitations

In attempt to evenly match the total work, each group trained at a relative percentage of their respective 1RM, following the same sets and repetition scheme. A limitation of standardising the groups using intensity was that workload was difficult to evenly match between groups, as it would be assumed that load would be equally distributed between legs during the BS. It would also be assumed that 100% of the total load during the RESS is placed on the front foot. Through the use of EMG, UNI training may incur a higher relative workload compared to BI training; with previous data suggesting 85.1% of the total load is placed on the front foot during the RESS[23]. Inequalities in net joint torques between the right and left sides during the BS have also been demonstrated[13]. It was therefore difficult to accurately match total work due to biomechanical differences between the exercises.

The intervention may have also been limited by the concurrent nature of training necessary for the participants involved, which included lower and upper-body resistance

training. Participants were required to gain weight during this time, and reported average increases in bodyweight of 2.21kg ±0.49kg and 2.35kg ±0.80kg in the UNI and BI groups respectively. This may have confounded the results by negatively affecting 10 m speed, as acceleration is a product of force divided by mass[18]. Furthermore, the participants in this study were engaged in at least three rugby training sessions per week. Current evidence suggests that this approach may attenuate gains in muscle strength and power[14], but the randomised design in the current study should have controlled for this as both groups participated in equal number of rugby sessions.

Furthermore, improvements over a 5-week period may be indicative of early strength improvements, which are primarily a result of neural adaptations associated with skill learning, rather than changes in muscle cross sectional area [25], although we did observe some increases in body mass also. 5 weeks was the maximum study length that was permitted due to the player's involvement in international competitions.

A longer study length is required to clarify any chronic adaptations and longer-term benefits associated with UNI training. Future studies should attempt to investigate any chronic adaptations or long-term benefits associated with unilateral training, such as transferability to athletic skills, as well as the implications in preventing and/or managing injury. EMG and hormonal data would also provide valuable information on the physiological responses to each exercise modality. Further research could explore exercises other than the squat.

Conclusion

Unilateral and bilateral training modalities appear equally effective in improving lower body strength, sprint, and CODS following 5 weeks of strength training with the RESS or BS in trained academy level rugby players who have initial strength levels comparable with other professional rugby union teams[2]

Practical Applications

This study was the first to compare the effects of UNI and BI training modalities on aspects of strength and power in Academy rugby players. From a practical perspective, these findings provide strength and conditioning practitioners with evidence that UNI squatting may be considered an effective alternative to BI methods during the initial stages of training. It could also offer additional benefits for non-assessed variables, including injury prevention given the prevalence of UNI movements during sport. Future work should explore the mechanisms and other UNI and BI exercises beyond squats.

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Table 1: Participant characteristics. Values are mean (standard deviation). Relative strength ratio was 1RM Squat (kg divided by body mass (kg).

Characteristics	**UNI**	**BI**
Age (yrs)	18.1 (0.5)	18.1(0.5)
Bodyweight (kg)	96.7 (9.3)	98.1(13.4)
Resistance training experience (y)	1.62 (0.18)	1.65 (0.18)
Body height (cm)	1.83 (3.4)	1.85(8.9)
Relative strength ratio	1.60 (0.11)	1.57 (0.20)

Table 2: Outline of the three week familiarization resistance training protocol

Set	Protocol
1	Warm up
2	10 reps at 50% of 6RM
3	6 reps at 75% 6RM
4	Reps to failure at previous session 6 RM
5	Reps to failure with adjusted 6RM

Table 3: Outline of 5 week UNI and BI training intervention

Week	Reps	Sets	Percentage of 1RM
Week 1	6	4	75%
Week 2	6	4	80%
Week 3	5	4	85%
Week 4	4	4	90%
Week 5	3	4	92%

Table 4: Pre and post changes for 10m sprint, 40m sprint, Pro-agility and 1RM RESS. Data are presented as mean (SD). *denotes significant difference from pre values.

Variable	Pre	Post
10m (s)		
Uni	1.73 (0.09)	1.70(0.05
40m (s)		
Uni	5.35 (0.15)	5.26 (0.16)*
Bi	5.40(0.26)	5.34(0.23)*
Pro Agility (s)		
Uni	4.61(0.11)	4.53 (0.07)*
Bi	4.71(0.15	4.64(0.14)*
1RM RESS (kg)		
Uni	76(6.1)	83(5.1)*
Bi	75(4.5)	81(4.3)*

Figure Legends

Figure 1. Squat 1RM (pre and post)

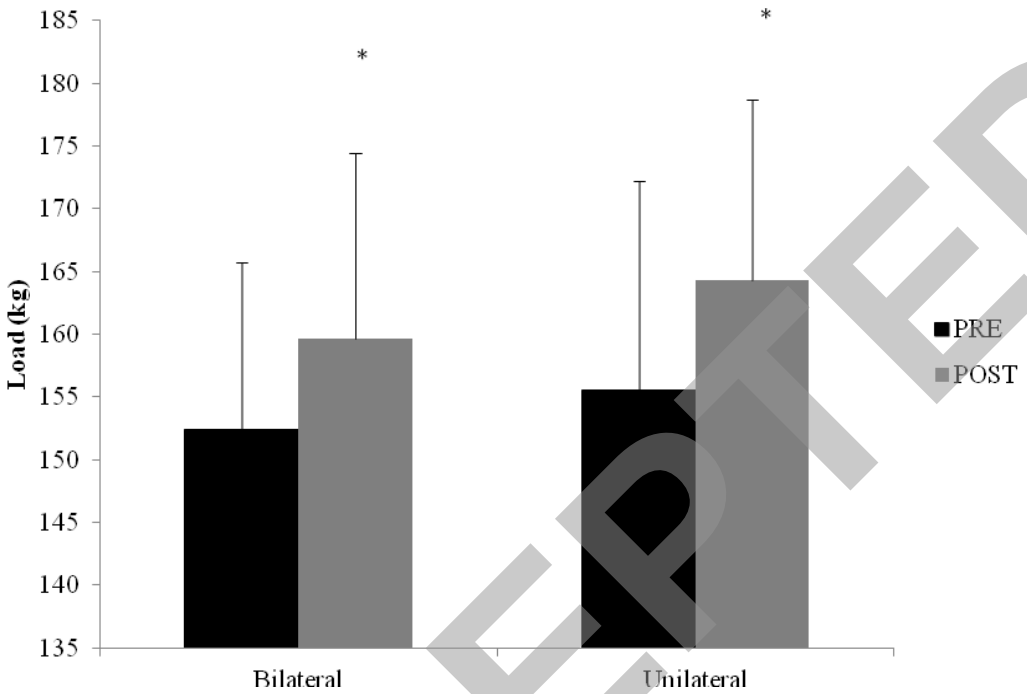

Figure 1.0. Mean (SD) Back Squat 1RM before and after a 5-week BI or UNI training intervention

*Denotes significant difference pre-post within groups ($p < 0.05$)