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A Comparison of Back Squat & Safety Squat Bar on Measures of Strength, Speed, and Power in NCAA Division I Baseball Players

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Abstract Squat exercise variations are considered a cornerstone of resistance training (RT) programs. Understanding the effectiveness of differing squat exercise variations is important for coaches and athletes in order to optimizing the effectiveness of a RT program. **Purpose:** The current investigation examined a comparison of the standard Olympic barbell loaded back squat (BS) with a squat performed with the safety squat bar (SSB). **Methods:** Twenty eight Division I male baseball players (19.2±1.1 years, 182.5±5.6 cm, 87.6±5.1 kg) participated in a RT program comprised of two workout sessions a week for nine weeks, performing either a BS or SSB utilizing an autoregulatory progressive resistance periodization, concurrent with their existing, season-specific, resistance training program. Pitchers (n=14) utilized the SSB bar with the goal of minimizing stress on the shoulder and elbow joints during the execution of the squat. The non-pitchers (n=14) performed the Olympic barbell BS. Lower body strength (estimated 1RM squat), sprint speed (54.86 m sprint), and vertical jump (VJ cms) were assessed prior to and following the RT training period. **Results:** Both the VJ and estimated 1RMs had a significant positive improvement from pre-training to post-training for both the BS and SSB groups ($p<0.05$). When comparing gain scores between each group there were no significant differences between the BS and SSB groups for either 54.86 m sprint or VJ ($p>0.05$). However, the 1RM squat gain score for the SSB was significantly greater than the BS group ($p<0.05$) noting that the effect size of change from pre to post RT was 2.69 and 2.71 standard deviations for the BS and SSB groups respectively. **Discussion:** Given that both squat modalities yielded approximately equal improvements in VJ and lower body strength, coaches and athletes can consider the SSB variation of the squat as a viable option for developing lower body strength and power when an Olympic barbell may be contraindicated because of an upper body injury.

Keywords Resistance training, Autoregulatory, Squat variations

1. Introduction

Resistance training (RT) is a valuable tool for decreasing risk of injury as well as increasing athletic performance through increasing muscular strength and skeletal muscle mass [1, 19]. Resistance training also improves the rate of force development, by increasing the synchronization and recruitment of additional muscle fibers, increased central motor drive, elevated motor neuron excitability, and reduced presynaptic inhibition [2, 36]. Resistance & neuromuscular training produces increases in bone density, muscle growth, increases in strength of tendons and ligaments, as well as strengthening the osteotendinous and osteoligamentous junctions [19]. Because most athletic movements require the coordinated contraction of the hips, quadriceps, hamstrings, and lower legs, squatting is one of the few exercises that is able to recruit multiple muscle groups in a single movement [12, 18, 31]. The squat is a multi-joint movement that develops the musculature surrounding and controlling the knees and hips and has been one of the most predominately used exercises for developing lower body strength and power [16, 20, 37, 39]. Many of the same muscle groups and movement patterns for sprinting and jumping are utilized during squatting [10, 30, 44]. The most common squat variation employed by coaches is the barbell back squat (BS) [20].

There are, however, some contraindications for performing the BS with certain populations. This is because the BS can put the shoulder complex into a compromising position [15], via external rotation and abduction which could cause the biceps tendon to pull on the superior labrum. This problem is intensified when overhead athletes exhibit glenohumeral internal rotation deficit (GIRD), which is

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very common with baseball athletes [5, 15, 42, 43]. To alleviate the additional stress on the shoulder, utilization of specialty barbells can be implemented. There are several specialty barbells on the market, with the most common being a Safety Squat Bar (SSB). The SSB features two handles that extend forward from the barbell, surrounded by three pads, in addition to a slight forward cambered end on each side (Figure 1). This eliminates the externally rotated and abducted shoulder position by allowing the hands to be forward of the barbell during the squat. There is however, insufficient research into the effectiveness of utilizing the SSB variation with regard to increasing performance measures such as jumping, sprinting, and maximal leg strength.

Figure 1. Safety Squat Bar (SSB) placement, start position and bottom position

Figure 2. Back Squat (BS) barbell placement, start position, and bottom position

Linear periodization (LP) is form of RT where volume and intensity is prescribed in a predetermined, incremental fashion. LP RT programs usually begin at a lower intensity and larger volume, and over the course of the predetermined period, intensity increases while volume decreases in a linear routine [7, 21]. Likewise, non-LP RT also implements planned adjustments of intensity and volume over time but does not follow the same linear progression of intensity & volume, but rather an undulating progression [4]. The rationale behind undulating periodization (UP) RT is to train across multiple intensity/volume zones simultaneously to develop multiple qualities within a microcycle [32]. Within the UP RT program, the changes in intensity and volume happen between sessions within the same microcycle, usually in a high intensity & low volume, low intensity & high volume, and medium intensity & volume progression. These progressions can be daily (DUP), or weekly (WUP) [9]. Several studies compared the effects of LP versus DUP RT programs while using a non-periodized RT program as a control and found that UP either performed as well or better than LP models [4, 33, 35].

Another form of UP RT is known as Progressive Resistance Exercise (PRE) [13, 14]. The basic principles of PRE are the performance of 10 repetitions for two sets, followed by repetitions to failure for a third set, increasing weight each set. The third set of repetitions would determine the following session's prescribed weights. Based on the previous session's third set total repetitions, weight would increase if more than 10 reps were performed, and respectively decrease if fewer reps were performed [13, 14]. The current study also investigates the use of Autoregulatory Progressive Resistance Exercise (APRE) protocol and its effects on performance measures. Mel Siff's book "Supertraining" [38] introduced APRE. The protocol for APRE includes a 10RM microcycle for developing muscular endurance & hypertrophy, a 6RM microcycle for developing strength & hypertrophy, and a 3RM microcycle for developing maximal strength & power.

There is only one study that investigated the capabilities of APRE as a valid means of producing strength gains in a short-term protocol and found that the APRE protocol produced greater strength gains than a LP RT protocol among collegiate football players [28]. To our knowledge, the current investigation will be the first study to utilize collegiate baseball athletes to investigate the effectiveness of the APRE protocol in producing strength & performance gains in the short term. The information garnered from this experiment can contribute to the paucity of research concerning utilizing APRE.

In an effort to provide coaches with an alternative squat variation for athletes with increased risk of shoulder or elbow injury, the purpose of this article is 2-fold, first, to determine if performance gains of performing RT with the use of Safety Squat Bar variation is comparable to the performance gains with a traditional barbell BS. The second purpose is to investigate the effectiveness of the APRE protocol that was implemented during the strength and conditioning program with regards to increasing muscular strength, muscular power, and sprint speed performance.

2. Methods

2.1. Participants

The data presented in this manuscript was a retrospective examination of previously collected training data. The data was collected as a result of a mandatory strength and conditioning program of NCAA Division I baseball players at West Point Military Academy. The results of the strength and conditioning program were presented in this manuscript in order to provide an understanding of the efficacy of the strength and conditioning program. Prior to examining the data collected as a result of the strength and conditioning program, the University IRB committee was contacted seeking an "exempt status". This study was approved as an exempt status examination of existing data that was not collected for the purpose of research by the Institutional Review Board of Southern Utah University (SUU IRB APPROVAL # *08-062018a*). As such, retroactive informed consent was not required of the athletes.

2.2. Procedures

All participants engaged in RT twice a week, with the prescribed squat variation on Day 1. The second day (Day 2) of RT for the nine week intervention consisted of either a Romanian Deadlift (RDL) or a hexagonal bar deadlift (HBDL). The groups performed an RDL for the APRE 10RM block and then a HBDL for the APRE 6RM and APRE 3RM blocks. All training was performed in the same training facilities, under the instruction and supervision of a National Strength and Conditioning Association (NSCA) Certified Strength & Conditioning Specialist (CSCS). All warm up, supplemental, and accessory exercises were identical in volume and intensity for both groups. Anthropometric, VJ, 54.86 m sprint, and 3-5 RM data was collected the week before (0 week) and at the conclusion of the 9-week training period. Training sessions lasted between 45 minutes to 1 hour. Each session began with a 10-15 minute dynamic warm up consisting of a series of hip flexor stretches, 20 band resisted terminal knee extensions on each leg, 20 spider lunge and hamstring stretch on each leg drills, and 15 thoracic spine extensions from a quadruped position; followed by performance of either the BS or SSB in accordance with the respective protocols. The training protocol for the nine-week period consisted of three weeks of each Autoregulatory Progressive Resistance Exercise (APRE) protocol outlined by Siff [38] and performed in a previous study conducted by Dr. Mann (Tables 1 & 2) [28, 38]. All subjects performed 3 weeks of the 10RM protocol, 3 weeks of the 6RM protocol, and 3 weeks of the 3RM protocol. At the end of each 3 week iteration, the athletes estimated 1RM was calculated using the Brzycki formula, which was then used in conjunction with the NSCA chart for calculating the 6RM or 3RM for the first week of each subsequent 3 week protocol [8, 21]. All subjects performed accessory exercises at intensity ranges from 65% to 85% (Table 3).

Table 1. APRE Repetition Maximum Protocols

	APRE routines		
Set	3RM routine	6RM routine	10RM routine
0	Warm up	Warm up	Warm up
1	6 reps at 50% 3RM	10 reps at 50% 6RM	12 Reps at 50% 10RM
2	3 reps at 75% 3RM	6 reps at 75% 6RM	10 reps at 75% 10RM
3	Reps to failure at 3RM	Reps to failure at 6RM	Reps to failure at 10RM
4	Adjusted reps to failure	Adjusted reps to failure	Adjusted reps to failure

[1] Reps-repetitions. [2] RM-repetitions maximum.

Table 2. APRE Load Adjustment Protocols

3RM routine		6RM routine		10RM routine	
Repetitions	Set 4	Repetitions	Set 4	Repetitions	Set 4
1–2	Decrease 5–10 lbs.	0–2	Decrease 5–10 lbs.	4–6	Decrease 5–10 lbs.
3–4	Same	3–4	Decrease 0–5 lbs.	7–8	Decrease 0–5 lbs.
5–6	Increase + 5–10 lbs.	5–7	Same	9–11	Same
7+	Increase +10–15 lbs.	8–12	Increase 5–10 lbs.	12–16	Increase 5–10 lbs.
		13+	Increase 10–15 lbs.	17+	Increase 10–15 lbs.

Table 3. Accessory Exercises

Weeks 1-3		Weeks 4-6		Weeks 7-9	
Squat Day	HBDL day	Squat Day	HBDL day	Squat Day	HBDL day
TRX Push Ups 3x8, 3x10, 3x12	Single Leg RDLs 3x8, 3x10, 3x12	Landmine Press 4x6	Reverse Lunge 4x8	Split Stance Landmine Press 4x6	Reverse Lunge 4x5
Scapular Retracts 3x20, 3x25, 3x30	TRX Fall Outs 3x10, 3x12, 3x15	Single Leg Glute Bridge 4x8	Isometric Pallof Press 4x15 seconds	Cable Chops 4x8	Partner Assisted Isometric Pallof Press 4x15 sec
Glute Bridge 3x8, 3x10, 3x12	Landmine Press 3x8, 3x10, 3x12	Turkish Get Up 4x6	Weighted TRX Push Up 4x8	Single Leg TRX Squat 4x6	Weighted TRX Push Up 4x5
Pallof Press 3x10, 3x12, 3x14	Band Y T Is 3x10, 3x12, 3x15	Chest Supported Row 4x8	Face Pulls 4x12	Single Arm Dumbbell Row 4x6	Rotational Cable Lift 4x12
Leg Curls 3x8, 3x10, 3x12	Lateral Med Ball Toss 3x10, 3x12, 3x15	Leg Curls 4x8	Back Extensions 4x10	Sandbag Carry 4x30 yards	Lateral Lunge 4x6
Hammer Machine Rows 3x8, 3x10, 3x12	Inverted TRX Rows 3x10, 3x12, 3x15	Farmer's Walk 4x30 yards	Weighted Pull Ups 4x6	Leg Curls 4x10	Chin Ups 4x6

2.3. Assessment and Reliability

Prior to and following the 9-week RT intervention period the participants were assessed for VJ height, 54.86 m sprint time, and an estimated 1RM squat. All testing was proceeded by the team's standard dynamic warm up conducted before practice (and as described in the preceding paragraph). After familiarization training, athletes tested both power and speed characteristics via a counter movement vertical jump for VJ height and 54.86 m (60-yards) sprint speed. Athletes were given three attempts at establishing a maximal VJ height with 45 – 60 sec. rest between attempts, and their best attempt being recorded via a Just Jump System (reliability $r \geq 0.97$) (Probotics Inc., Huntsville, AL, USA) [27]. Immediately following a 60 sec minimum rest after VJ testing, 54.86 m sprint times were recorded. Sprint testing was conducted on an artificial turf indoors, with markers at 9.14 m intervals from start line to finish line. Athletes started in a 2-point stance and time started on the athlete's initial movement. All athletes were given two attempts with 2-3 mins rest between attempts, with their fastest time recorded via stopwatch (reliability ICC ≥ 0.99) [22, 40].

Two days following the speed and power tests, the two groups performed a 3-5 repetition maximum squat with their respective group implement. The NSCA recognizes 1-RM measures as a reliable assessment of muscular strength [21]. Reported reliability coefficients of $r \geq 0.90$ and ICC ≥ 0.90 suggest that 3-RMs are reliable measures of lower body muscular strength [29]. Prior to squat testing, athletes performed the same dynamic warm up as performed before their training sessions. Repetitions were counted as valid when the athlete's femur was parallel to the floor which were supervised and counted by a NSCA CSCS. An estimated 1RM for both back squat (BS) and safety squat bar (SSB) were calculated using the Brzycki formula (ICC ≥ 0.89) [8, 41]. The implements that were utilized were a standard Olympic barbell weighing 20 kg, and a specialty barbell known as a Safety Squat Bar, weighing 23 kg. All recordings were performed by a NSCA CSCS.

2.4. Design and Analysis

The dependent variables (DVs) in this study were counter movement VJ height, 54.86 m sprints, and estimated squat 1RMs. Descriptive statistics (mean ± SD) were calculated for each DV during review of the previously collected data. With-in each group, dependent-samples t-tests were used to determine any significant differences between pre-training and post-training for each DV. Independent-samples t-tests were used to determine any significant differences between each group's gain scores for each DV. The alpha criterion for significance was set at $\alpha \leq 0.05$. Given the growing concern of relying solely upon p-values as a method of establishing a valid research outcome [3], effect size (ES) calculations were also carried out for each DV. Statistical analysis was conducted with MS Excel 2013.

3. Results

Twenty-eight male athletes participated in the pre-season strength and conditioning training period where progress was assessed by recording counter movement VJ height, 54.86 m sprints, and estimated squat 1RMs prior to and following the training period. Table 4 provides the participant descriptive information. Results indicated a significant improvement in both VJ height and estimated 1RM squats ($p<0.005$) for both the BS and SSB groups (Table 4). However, there was no significant change in 54.86 m sprint times for either group ($p>0.05$). When comparing gain scores between groups, there was no significant difference between the BS and SSB groups for either VJ height ($p=0.37$) or 54.86 m sprint ($p=0.42$), the SSB group's estimated 1RM gain score however, was significantly greater than the BS group ($p<0.05$).

Table 4. Participant Descriptive Information

	N	Age (years)	Height (cms)	Mass (kgs)
BS	14	18.7 ± 0.9	180.9 ± 6.1	86.7 ± 4.6
SSB	14	19.8 ± 1.1	184.0 ± 4.4	88.2 ± 5.4

[1] Participant means and standard deviations for descriptive information.

The pre to post ES was calculated for all of the DVs (see Table 5). The BS and SSB group's estimated 1RM squats both exhibited a very large effect size and were virtually identical (2.69, 2.71 respectfully). The ES for VJ height were trivial for the BS (0.22), and small for the SSB (0.38). The ES for 54.86 m sprint were trivial (-0.22) for the BS group and small (-0.44) for the SBS group [6, 34].

Table 5. Participant vertical jump, 54.86 meter sprint, and estimated 1RM leg strength

	VJ (cms)			54.86 Meter Sprint (seconds)			Estimated 1RM (kgs)		
	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES
BS	74.6 ± 8.1	76.5 ± 8.0*	0.23	7.12 ± 0.33	7.05 ± 0.26	-0.22	136.2 ± 11.0	166.1 ± 23.7*	2.69
SSB	72.4 ± 7.6	75.3 ± 8.3*	0.38	7.27 ± 0.17	7.19± 0.20	-0.44	112.3 ± 14.9	152.6 ± 22.0*	2.71

[1] Participant means and standard deviations for dependent variables. [2] ES-effect size in standard deviations.
* Significant improvement pre to post RT intervention $p<0.05$.

4. Discussion

The primary purpose of this study was to examine the previously recorded data of RT of 24 NCAA division I baseball athletes using either the SSB or BS and APRE periodization on improving maximal strength, power, and speed characteristics. The saliency of the study was twofold. First, because the BS puts the shoulder complex into a compromising position of external rotation combined with horizontal abduction [15], certain populations that present shoulder pain or excessive joint laxity and instability may benefit from the use of the SSB. The SSB attempts to alleviate the additional stress on the shoulder by holding the barbell via forward handles, which eliminates the compromised shoulder position. A direct comparison of individuals engaged in identical RT programs with only the squat modality differing may provide evidence that the SSB modality would provide similar positive adaptations as the BS variation of the squat. Secondly, the two different groups also lent the opportunity to examine the effectiveness of the APRE protocol across similar exercises. To the author's knowledge, this is the only study to directly compare performance of the SSB and BS, and only the second study to investigate the use of APRE as a means to enhance performance.

The original hypothesis was that all DVs would improve at similar rates from pre to post RT, and that the APRE protocol would be successful in producing a significant effect on the DVs. Both squat variations had similar, significant effects on improving the VJ and estimated 1RM squat. Although neither group significantly improved 54.86 m sprint times, there was an average decrease of 1% between pre and post RT intervention for the 54.86 m sprint times. The data collected supports the studies original hypothesis for both VJ and estimated 1RM squats, but not for 54.86 m sprint times. A possible explanation for the minimal improvement in sprint times could have been due to the loading pattern of squatting which is an axial load vector whereas sprinting is primarily an anteroposterior movement [11]. As such, it's likely that the axial strength and power gains as a result of the APRE RT protocols were not transferable to the participant's anteroposterior sprint speed.

The current Autoregulatory Progressive Resistance Exercise (APRE) protocol [28, 38] evolved from DeLorme's Progressive Resistance Exercise method (PRE) [14] protocol that was prescribed for RT following femoral fractures. DeLorme found that soldiers with femoral fractures were able to return to active duty quicker and with fewer difficulties while utilizing a PRE protocol as compared to those following a more conservative physical therapeutic rehabilitation protocol [13]. Kenneth Knight modified the original PRE for rehabilitation following knee surgery, adjusted the protocol to a 6RM and renamed the protocol the Daily Adjustable Progressive Resistance Exercise (DARPE) protocol [25, 26]. Along with an additional 4th set, Knight introduced prescribed reps and intensities for the first two sets as a percentage of the load of the third set. The third set performance would dictate the load of the subsequent fourth set, which would then dictate the load for the following session [26]. Mel Siff's book "Supertraining" [38] introduced APRE. Siff continued Knight's DAPRE protocols and set increases while adding a 3RM protocol. The protocols for APRE were now an APRE 10RM protocol for developing muscular endurance & hypertrophy, an APRE 6RM protocol for developing strength & hypertrophy, and an APRE 3RM protocol for developing maximal strength & power.

In the only other study on the effects of APRE, Mann et al. purported that APRE was more effective at improving squatting and pressing maximal strength in NCAA Division I football players over a 6 week period when compared to a similar 6 week period of LP the year prior [28]. Mann et al. only utilized the APRE 6 protocol, as strength and hypertrophy were deemed the most desirable traits to develop for the sport (which the current authors disagree with). The APRE year performed significantly better in the 1RM squat than the LP year. The current study supports Mann et al. findings of APRE being an effective means of increasing squat strength. Although the increase from pre to post testing of the 1-RM in the APRE year was significant ($p<0.05$), the percent increase was only 5% [28]. The percent increase in the current study for the BS and SSB estimated

1RM squats were 22% and 36% respectively. The much larger increases in the 1RM squat variations in the current are likely due to the APRE including a 3RM microcycle for developing maximal strength & power.

When compared to normative data of collegiate baseball players from Hoffman [23], the BS group's squat mean estimated 1RM was in the 90th percentile, and the SSB group's squat mean estimated 1RM was in the 80th [23]. Both the BS & SSB groups outperformed normative data for VJ height (71.9 cm) of professional Major League baseball players [24]. The BS group improved to matching the normative data for 54.8m sprint times of NCAA Division I baseball players, while the SSB group's mean fell in the 98th percentile of 54.86 m times [23].

Although there is only one previous study into the effects of APRE, there have been several studies in comparison of UP RT versus classical LP RT, where UP produced comparable increases in maximal strength as LP [4, 33, 35]. One such study conducted by Baker, Wilson, and Carlyon found that, when compared to 12 weeks of LP, 12 weeks of UP produced statistically similar increases in 1RM squat and VJ scores [4]. Another study investigated the effect of 12 weeks of DUP and LP and found that DUP resulted in a higher percent increase in 1RM leg press than that of the LP [33]. In the first study to directly compare LP and DUP models, Rhea et al [35] examined 20 male subjects with minimum of 2 years of training experience. Both groups significantly increased their 1RM leg press after RT interventions, but the DUP had significantly greater percent increases in 1RM leg press from both beginning to mid-point testing, as well as pre to post RT intervention [35]. Based on the results of the aforementioned studies, UP is an effective means of producing improvements in desirable athletic qualities, sometimes more so than the LP model across the same amount of time.

While there is no current research specifically on the use of a SSB, there is a comparison of front squat and back squat barbell placement effects on squat mechanics [20]. Gullett et al. [20] found that bar position did not affect muscle activity during squatting in healthy trained men and women. The SSB is similar to both the front and back barbell squat variations. The SSB rests in the same position across the shoulders as the barbell does for the BS. The forward curve design feature of the SSB moves the load slightly forward of a standard barbell placement, which could mimic the angle of trunk inclination typically found during FS. Further research into the specific biomechanics of utilizing the SSB is warranted.

A strength of the current study was that it was a retrospective analysis of data collected during a real RT intervention period for a Division I NCAA baseball team that lends credibility of external validity. However there were several limitations to the study. The athletes had required activity courses such as boxing or survival swim that were physically demanding as well as skills practice for their sport, which presumably would interfere with the true interactions of the RT protocols on the DVs. Likewise, the athlete's class and practice schedules were also an unforeseen difficulty, as some RT sessions had to take place post practice and late in the evening. While these aforementioned limitations may have impacted internal validity, it could be argued that the limitations are potential realities that strength and conditioning coaches and athletes may contend with, and as such add to the robustness of the credibility of the results of the study. Future research might investigate a direct comparison of an APRE protocol to other periodization protocols, such as LP, UP, or block periodization. Research examining the effectiveness of APRE on performance measures among additional populations (youth, female, and recreationally active populations) would also be noteworthy. Finally, studies examining the effectiveness of the SSB should include EMG muscle activity so as to provide a further understanding as to the effectiveness of the SSB in regards to reducing the stress on the shoulder while performing the squat.

5. Practical Applications

This retroactive analysis of APRE RT data from a NCAA Division I men's baseball team supports that the SSB and Olympic barbell as similar, valid modalities for coaches to utilize for the purpose of squatting when designing RT blocks for increasing strength & power qualities. The SSB provides coaches a programmatic design variable that allows the athlete to perform the squat exercise without putting additional stress on the shoulder complex. Because no significant difference was found when comparing the BS and SSB groups in terms of VJ, estimated 1RM squat strength, and sprint speed, either squat variation may be used interchangeably in the training program of baseball athletes. Developing a proper training program that addresses both injury prevention/rehabilitation as well as increasing performance qualities requires professionals be up to date on current research and protocols that can be best implemented for their periodization plans; also known as "Evidence Based" strength and conditioning [17]. Finally, the difficulty of training individuals within a team setting is that there can be a loss of focus in regards to addressing the individual needs for a given athlete. As such, the APRE periodization model allows for adjustments of the training session based on the athlete's acute physical state providing a mechanism for tailoring the training session to the individual state of the athlete.

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