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Short-Term Effects of Eccentric Overload Versus Traditional Back Squat Training on Strength and Power

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ABSTRACT

Background of Study: Benefits of training with eccentric overload (EO) include increased concentric strength, eccentric strength, explosiveness, and muscle adaptation. There is a lack of practical strength training protocols that compare traditional methods and EO. **Purpose:** Compare effects of eccentric overload versus traditional training on strength and performance. Method: Thirty-three trained males (age: 21.4 ± 2.7 years) were divided into three groups: Traditional (TRAD, N =12), EO, (N =11), and Control (CTRL, N =10). Back squat training lasted five weeks. The average intensity (%1RM) for each repetition and the volume was the same between groups. **Results:** Multiple 3x2 (Group x Time) Analyses of Variance (ANOVAs) were performed on the following: 1RM, eccentric 1RM (Ecc1RM), countermovement jump height (CMJ), and 20-meter sprint times. A significant Group x Time interaction (p =.001) was observed for Ecc1RM. The source was a significant increase in Ecc1RM strength from pre to post-test for the EO group (+16.9 kg) and TRAD group (+12.7 kg). A significant Group x Time interaction (p =.026) was observed for CMJ. The source was a significant increase in CMJ height from pre to post-test for the EO group (+3.8 cm) and TRAD group (+2.9 cm). **Conclusions:** Using EO and TRAD during a short-term back squat training protocol enhanced vertical jump explosiveness and eccentric strength. Athletes aiming to enhance lower body explosiveness and eccentric strength are likely benefit from EO. Athletes looking to enhance concentric strength should adhere to methods whereby paired concentric-eccentric actions are the primary focus.

Key words: Back Muscles, Progressive overload, Resistance Training, explosiveness, Athletic Performance

INTRODUCTION

Resistance training (RT) is used to increase muscle size (Norrbrand et al., 2008), strength (Brandenburg and Doherty, 2002; Wirth et al., 2015; Yarrow et al., 2008), and explosiveness (Bosco et al., 1981; Doan et al., 2002; Hortobágyi at al., 2001; Sheppard and Young, 2010) for sport and competition. Aside from exercise selection, the two primary factors that are used to prescribe RT are volume and intensity. Volume is prescribed in sets, repetitions, and intensity. Each repetition can be broken down into two phases: concentric and eccentric. The concentric phase of an exercise is when the total length of a muscle is shortening under the tension of a load. The eccentric phase of an exercise is when the total length of a muscle is lengthening under the tension of a load.

Traditionally, intensity has been prescribed relative to concentric capability, usually in the form of 1-repetition maximums (1RMs). However, evidence shows that force production during eccentric muscle actions can reach intensities of 120-190% of maximal concentric capabilities depending on exercise selection (Friedmann-Bette et al., 2010; Munger et al., 2017). Eccentric overload (EO) is the loading technique where loads greater than 1RM are applied to the eccentric phase (Munger et al., 2017). Traditional prescription of exercise does not account for eccentric capabilities; thus it may be limiting potential performance, strength muscle gain. Therefore, direct comparisons between traditional training (where the load remains constant; TRAD), and EO are needed.

Specialized exercise and lab equipment such as flywheel machines and isokinetic dynamometers are commonly used

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to apply EO (Norrbrand et al., 2008; Baroni et al., 2011) and compare it to TRAD, however, one shortcoming in the research is that most studies do not equate for volume when comparing the two types of training. Baroni and colleagues (2001) confirmed this when they examined differences between maximal isokinetic eccentric versus concentric training of the knee extensors. Both exercise groups performed ten sets of ten repetitions. The results showed that the eccentric group produced greater mean and peak torque (53-133% and 54-121% greater, respectively) intensities than the concentric group. Despite sets and repetitions being equal between groups, the eccentric group produced more work, thus more volume since intensity is accounted for in volume. This is common in isokinetic studies unless sets and repetitions between groups are augmented to standardize volume. Volume may be a confounding variable when it remains uncontrolled in EO versus TRAD comparisons. Norrbrand and colleagues (2009) also examined the effects of EO versus TRAD using flywheels (EO) and a weight stack machine (TRAD) during knee extensions. The flywheel allows for variable resistance. That is, resistance is not constant throughout the entire range motion. In contrast, the resistance of the weight stack machine is isoinertial. There was an 8.7% increase in average work performed by the EO group versus the TRAD group, therefore volume was not the same even though sets and repetitions were equal among groups. The EO group experienced muscle hypertrophy of all quadriceps muscles and strength gain at several angles during maximal voluntary contraction. The TRAD group gained more strength during a dynamic strength test and hypertrophy of one quadricep muscle. Study designs need to be implemented that can definitively attribute training effects to EO rather than a combination of training mode and volume.

Eccentric hooks are a simple solution since they allow for equated volume by using average load per repetition. They can also be used in large, dynamic movements such as back squat, front squat, and bench press. Therefore, the purpose of the study was to compare the effects of EO and TRAD back squat training on strength and performance using eccentric hooks to equate volume between the two types of training. It was hypothesized that EO training would enhance explosive performance in the vertical jump, sprint split times, and would result in an increase both concentric and eccentric strength.

METHODS

Participants and Study Design

Forty-two resistance trained males were recruited for this quasi-experimental study design. G*Power 3.1 was used to conduct an A-priori power analysis to determine that a sample size of forty-two subjects would be needed for the investigation (Effect size f:.25, α error probability:.05, power:.80, groups: 3, number of measurements: 2, correlation among represented measures: 0.5, nonsphericity correction: 1). There was a 21% attrition rate. Nine subjects did not complete the study. Four subjects broke contact and quit for reasons undisclosed to the research team. Four subjects did not meet the minimum strength requirement. One subject sustained an injury unrelated to the investigation. Thirty-three resistance trained males (age: 23.4 ± 2.7 years, height: 174.9 ± 10.6 cm, mass: 78.3 ± 10.6 kg) completed the investigation before its end. Subjects were strategically placed into one of three groups once 1RMs were obtained. The mean 1RMs of the groups were continuously monitored as subjects were placed into groups and was primary means to counterbalance the groups. This method was used to prevent strength differences at baseline between groups. The three groups are as follows: 1) a traditional group where the load of a repetition remained constant (TRAD, n=12), 2) an eccentric overload group (EO, n=11) and 3) a control group (CTRL, n=10). To participate in the study, subjects had to meet the following criteria; 1) be free of musculoskeletal injury in the lower extremity within the past year, 2) be able to back squat their bodyweight to a depth whereby the thigh is parallel to the ground, 3) had routinely performed lower body RT two times per week on average for one year prior to the study, and 4) were between the age of 18 and 30 years old. Subjects were excluded from the study if they did not meet any one of the criteria listed. The dependent variables that were measured and analyzed were back squat 1RM, eccentric-only back squat 1RM (Ecc1RM), countermovement jump (CMJ) height, and sprint split time from 0-5 meters, 5-10 meters, 10-20 meters, and 0-20 meters. Training group (EO, TRAD, and CNTRL) served as the independent variables.

Pretest Day One

This session took approximately 70 minutes to complete. Upon arriving to the lab, subjects read and signed an informed consent document approved by the University's Institutional Review Board (IRB). Then subjects read and completed the Physical Activity Readiness Questionnaire (PARQ). The PARQ is a screening document that requires participants to indicate if they have symptoms or a history of cardiovascular disease, musculoskeletal injury, if they are taking any medications, and if they know of any reason they should not be participating in physical activity. Answering 'Yes' to any of the questions precluded subjects' participation in the study. Next, subjects' height and body mass were recorded. A stadiometer was used to record height in centimeters of subjects, whereas a bodyweight measurement was collected in kilograms using a calibrated scale. Then subjects were guided in a general warm-up prior to performing the following tests in order: 1) A back squat 1RM, and 2) an Ecc1RM.

The EO group was familiarized with eccentric hooks (Fatgripz, Toronto, ON, Canada) as the final task on *Pretest Day One* since they were the only group to use them for training. For practice, the EO group completed 10 repetitions using an empty 20kg barbell and the eccentric hooks. Then they completed 5 repetitions with 80% of 1RM during the eccentric phase and 50% of 1RM during the concentric phase. Maximal back squat testing was performed on *Pretest Day One* to preclude subjects from any undue testing if they did not meet the minimum strength requirement. Testing procedures on *Pretest Day One* were ordered in a manner that would allow loads to be lifted from light to heavy throughout the session.

Pretest Day Two

This session required approximately 30 minutes to complete and was scheduled 2 to 4 days after the *Pretest Day One.* Upon returning to the lab, subjects performed the same general warm-up as *Pretest Day One*, followed by a maximal countermovement jump (CMJ) and 20-meter sprint assessments. Assessments on this day were performed in order from least-fatiguing to most-fatiguing to minimize accumulated fatigue from test-to-test.

Post-Testing

All subjects performed the first of two post-testing sessions within 4 to 7 days after the last training session. Most participants attended testing and training sessions on the same two days of each week at the same time, unless they had scheduling conflict. They completed the same tests in the same manner *Pretest Day One* and *Pretest Day Two*.

General Warm-Up

The general warm-up was performed on testing and training days. It consisted of 18 meters of the following five exercises in order: 1) Alternating straight leg kicks (Kicking outward with a straight leg during alternating strides) 2) Walking knee tucks (grabbing the foot and knee to stretch the glutes while performing alternating strides), 3) Walking lunges, 4) High knees (flexing at the hips to bring the thigh parallel to the ground during alternating strides), and 5) karaokes (a lateral movement involving crossovers in front of and behind the lead leg during alternating strides). Each warm-up exercise was demonstrated for the subjects. Similar warm-ups are often used in performance-related studies (Bartolini et al., 2011; Nealer et al., 2017).

Back Squat Warm-Up

The warm-up sets were relative to the subjects' predicted 1RM, which was verbally supplied by subjects and based off recent lifting experience. and the same loads were used for pretesting and post-testing. They started submaximal testing by doing a 10-repetition warm-up set with a standard 20kg barbell only. Then they did 7 back squats at 60%, 4 at 70%, 2 at 80%, and 1 at 90% of their predicted 1RM. Three minutes of rest was taken between each set.

Concentric 1RM

Testing of subjects' 1RM ensued immediately after the *Back Squat Warm-Up*. The first 1RM attempt was equal to the subjects' predicted 1RM. If successful, subjects had 4 more attempts to attain their actual 1RM with three minutes of rest between each attempt. Load was increased until subjects failed a lift. Squats that were not performed to a depth of thigh parallel to the ground were deemed a failed lift. Subjects were excluded from the study if they were unable to squat their own bodyweight because eccentric overload is considered an advanced lifting technique.

Eccentric 1RM

Once subjects' 1RM was established, Ecc1RMs were conducted. Safety bars within the squat rack were adjusted so that the barbell sat on the safety bars when the subject reached a squat depth of thigh parallel to the ground. Subjects performed a warm-up of 4 eccentric-only back squats at 60%, 3 at 80%, 2 at 90%, and 1 at 100% of 1RM by lowering the bar to the safeties. A spotter assisted the lifter by actively moving the bar upward during the concentric portion of all repetitions of submaximal sets to minimize accumulated fatigue. The commands were communicated to participants at a cadence of 60 beeps per minute, which was ensured by a metronome. The commands were "Squat…one…two…three…up." Then, subjects had 4 attempts to attain their Ecc1RM after completing the warm-up. A spotter was not used during these repetitions as lifters could safely lower the loaded barbell onto the safety bars in the power rack. Three minutes of rest was given between each attempt and is consistently used in large, dynamic movements involving heavy loads (Archer et al., 2016; Maulit et al., 2017). Lowering the bar to the safeties prior to the lapsing of 3 seconds resulted in a failed attempt. Only successful repetitions were used for analysis of Ecc1RM. Three seconds during the eccentric muscle action is a time constraint consistently used during eccentric overload repetitions of multi-joint exercises (Kelly et al., 2015; Meneghel et al., 2014; Wirth et al., 2015).

Countermovement Jump (CMJ)

This test was used to assess muscular explosiveness. High performance in this test was characterized by high displacement off the ground. Performance of a countermovement jump was explained and demonstrated by an investigator to standardize the procedure. The investigator ensured that the subjects' feet were placed between hip and shoulder width, and that subjects initiated the movement by using a forceful downward arm swing. The external coaching cue and statement used were "During your jump you should reach for, and tap, the highest vane on the vertical jump device (Vertec, Knoxville, TN)." Three warm-up jumps were performed prior to testing at 50%, 75%, and 90% of maximal effort. Thirty seconds of rest was given between each jump. Next, they performed max effort jumps with 30 seconds of rest between jumps until there was not an increase in jump height. Thirty seconds of rest between jumps does not negatively affect jump performance (Pinto et al; 2014). The highest max-effort vertical jump was recorded.

Twenty-Meter Sprints

Twenty-meter sprints are a test of horizontal power. The subjects must produce rapid succession of strides with high force to propel themselves forward. High performance in this test is characterized by low times at several different intervals of the sprint. Sprinting took place on a flat concrete run using an electronic laser timing device (Brower Timing Systems, Draper, UT). The laser timing devices were set at a height of 1 meter off the ground except for the first laser, which was set at foot height and caught the initial movement of the foot. All sprints were performed in sneakers using a staggered two-point stance. Subjects were instructed to perform two warm-up sprints at 75% and a 90% of their perceived maximal effort. One minute of rest was given between warm-up trials. Next, 2 maximal effort sprints were performed with two minutes of rest between each trial. Two minutes of rest between max effort sprints has been used in previous research (Nealer et al., 2017). Split times from 0-5 meters, 5-10 meters, and 10-20 meters were recorded. The total time of the sprint (0-20 meters) was also used for analysis. Split times from the fastest overall sprint were used in data analysis.

Training

Training sessions took approximately 30 minutes to complete. Subjects trained twice a week over five weeks. This protocol was used to be consistent with other short-term training studies (Norrbrand et al., 2008; Friedmann-Bette et al., 2010). Subjects were instructed to maintain habitual lower body training frequency, but to replace two of their leg training days with the exercise prescribed during the study. The purpose of this instruction was to attenuate the effects that could potentially be caused by changes in habitual frequency. All prescribed training sessions were preceded by at least 48 hours of rest for the lower body. Volume and intensity changed twice throughout the five-week training cycle for experimental protocol groups (EO and TRAD). Volume was reduced, and intensity was increased as training progressed. Volume and intensity were equated for the training groups. The average relative load per repetition was equal between groups. For example, the EO group performed squats at 105% of 1RM during the eccentric phase, and 55% of 1RM during the concentric phase, which is an average of 80% of 1RM per repetition therefore, the TRAD group performed squats at 80% of 1RM. Eccentric hooks, capable of temporarily overloading the eccentric phase of back squats, were used by the EO group (Figure 1). All eccentric overload repetitions were supervised and controlled by two investigators that manually replaced the eccentric hooks on the bar after each repetition. The eccentric hook height was preset to unhinge from the bar at a squat depth where the thigh was parallel to the ground.

The eccentric phases of all back squats for the EO group were performed to a 3-second cadence, which was ensured by a metronome and commanded by an investigator. Subjects were instructed to complete the concentric action as fast as possible upon hearing the word "Up." Prior to each training session, all subjects completed the *General Warm-Up* followed by a squat-specific warm-up throughout the training. The training warm-up consisted of 10 back squat repetitions with a 20kg barbell only, then 7 at 60%, 4 at 70%, and 2 at 75% of their 1RM.

Figure 2 outlines the testing and periodized training procedures for each group. The first training block lasted two weeks

Figure 1. 1) Starting position of squat with eccentric hooks loaded onto the bar prior to eccentric phase. 2) Bottom of squat where loaded eccentric hooks have released from bar. 3) End position after explosive concentric phase with less load then eccentric

and the EO group performed 4x5 repetitions at 105% of 1RM eccentrically, and 55% of 1RM concentrically. The TRAD group performed 4x5 at 80% of 1RM. The second training block lasted another two weeks and the EO group performed 3x4 at 110% of 1RM eccentrically, and 60% of 1RM concentrically. The TRAD group performed 3x4 at 85% of 1RM. The last raining block lasted one week and the EO group performed 3x2 at 115% of 1RM eccentrically, and 65% 1RM concentrically. The TRAD group performed 3x2 at 90% of 1RM.

The CTRL group attended training sessions of equal time commitment to the training groups. Instead of squatting, they did self-selected upper body resistance exercise. They were encouraged to maintain their regular lower body training regimen to prevent lower body strength loss.

Statistical Analysis

Multiple one-way Analyses of Variance (ANOVAs) were used to detect differences at baseline between the groups for all dependent variables. Multiple 3x2 (Group x Time) ANOVAs were performed on the following dependent variables; 1RM, Ecc1RM, CMJ. A 3x2x4 (Group x Time x Split) ANOVA was performed on sprint split times (0-5, 5-10, 10-20, 0-20 meters). Alpha level was set to 0.05 and International Business Machines' Statistical Package for the Social Sciences (SPSS), version 26, was used for all statistical procedures.

RESULTS

Baseline Data

There were no statistical differences between groups at baseline for all dependent variables (Table 1).

1RM

The 3x2 ANOVA did not reveal a Group by Time interaction [F(2, 30) =.047, p =.093). A main effect of Time [F(1, 30) = 41.84, p <.001] was observed where post-test (129.3 ± 31.3 kg) was greater than pretest (120.8 ± 31.4 kg). There was no effect of Group (p =.865).

Table 1. Baseline Values by Group [Countermovement (CMJ), 1-Repetition Maximum (1RM), Eccentric 1-Repetition Maximum (Ecc1RM)]

Variable (M±SD)	Group			*p*-value
	EO (n = 11)	TRAD (n = 12)	CNTRL (n = 10)	
Age (years)	21.09±3.239	21.58±3.029	21.50±1.90	0.907
Height (cm)	177.86±7.07	172.98±8.42	173.93±4.52	0.232
Mass (kg)	76.80±10.83	80.53±11.37	77.29±9.85	0.668
CMJ (cm)	62.00±8.27	59.37±9.82	62.48±11.80	0.730
0-5 meters (s)	1.57±0.18	1,65±0.17	1.52±0.18	0.263
5-10 meter (s)	0.80±0.16	0.75±0.07	0.78±0.03	0.500
10-20 meters (s)	1.29±0.17	1.35±0.09	1.31±0.05	0.457
0-20 meters (s)	3.66±0.21	3.75±0.25	3.61±0.19	0.372
1RM (kg)	119.58±32.93	123.04±35.02	119.30±28.23	0.954
Ecc1RM (kg)	141.23±40.36	145.15±35.77	144.70±35.10	0.964

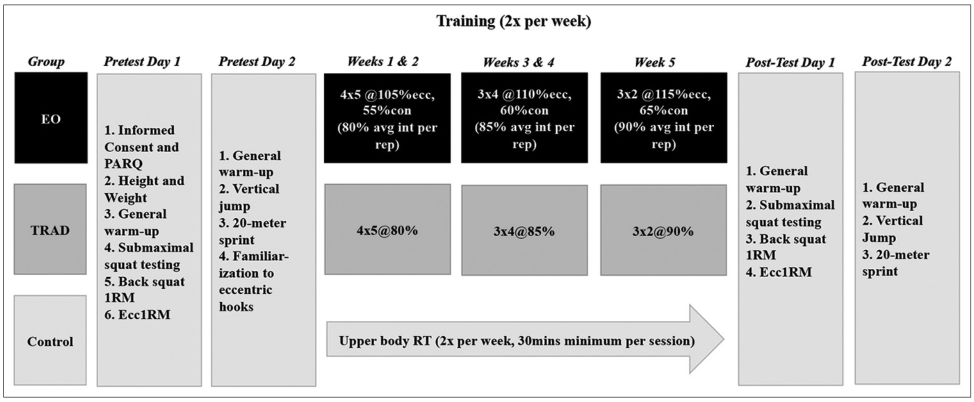

Figure 2. General layout of testing and training procedures

Ecc1RM

A significant Group x Time interaction [*F*(2, 30) = 9.39, *p* =.001] was observed as group differences emerged from the pre-test to post-test. The interaction was due to a significant increase in mean Ecc1RM strength from pre to post-test for the EO group (+16.9 kg) and TRAD group (+12.7 kg). The CNTRL group (+2.0 kg) showed no differences from the pre to post-test (Figure 3).

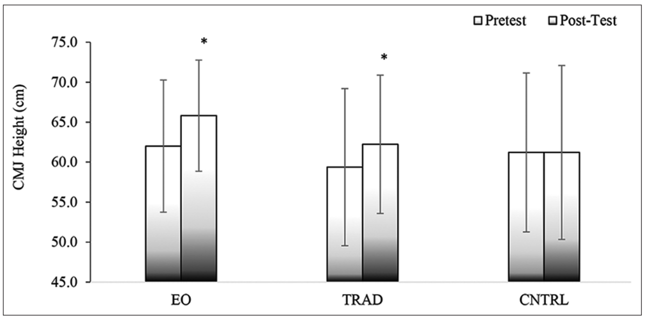

Figure 3. Ecc1rm strength by group at pre and post-test
*Significantly greater than pretest

CMJ Height

A significant Group x Time interaction [*F*(2, 30) = 4.12, *p* =.026] was observed for CMJ from the pretest to post-test. The source of the interaction was related to a significant increase in mean CMJ height from pre to post-test for the EO group (+3.8 cm) and TRAD group (+2.9 cm). The CNTRL group (+0.0 cm) showed no differences from the pre to post-test (Figure 4).

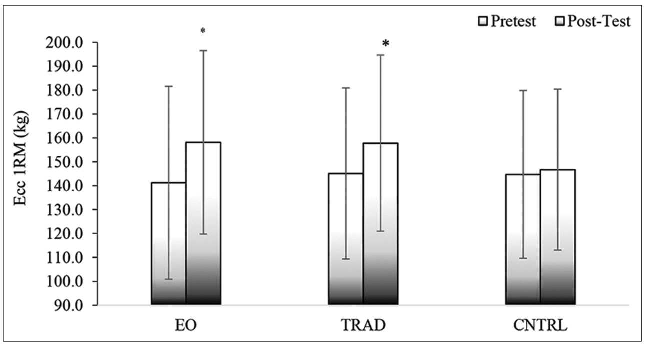

Figure 4. Cmj height by group at pre and post-test
*Significantly greater than pretest

Twenty-meter sprints

The 3x2x4 ANOVA did not reveal a 3-way interaction [F(6, 26) = 1.192, *p* =.318].

The 3x2x4 ANOVA revealed a 2-way significant Time by Split interaction [F(3, 29) = 4.758, *p* =.027]. The source of the interaction was related to a decrease in time during sprints from pretest (1.837 seconds) to post-test (1.800 seconds) and between splits (0-5 meters = 1.535 seconds; 5-10 meters = 0.782 seconds; 10-20 meters = 1.321 seconds; 0-20 meters = 3.638 seconds). There was no main effect of group [F(2, 30) = 0.777, p =.469].

DISCUSSION

The purpose of the study was to compare the effects of EO and TRAD back squat training on strength and performance using eccentric hooks. The findings were that EO and TRAD resulted in significantly greater Ecc1RMs and greater CMJ height over the control group. The mean change in eccentric strength and CMJ height was greater for the EO group than the TRAD group, however it was not statistically different. The results suggest that there may be concurrent overlap and specificity between the training types. The reasons for overlap in this study may be twofold.

First is that adaptation is not exclusive to action type used in training. For example, eccentric strength may be gained when training focuses on concentric actions (Colliander and Tesch, 1990) and concentric strength may be gained when training focuses on eccentric actions (Fernandez-Gonazalo et al., 2014; Vikne et al., 2006). This interplay between eccentric and concentric training was examined by Colliander and Tesch (1990) when they compared concentric-only and concentric-plus-eccentric isokinetic training of the quadriceps over a 12-week period. Males in both experimental groups increased eccentric and concentric peak torque. This has been further demonstrated by Fernandez-Gonzalo and colleagues (2014) when using flywheel squat training to overload eccentric muscle actions. Groups of men and women increased concentric 1RM, squat jump height, drop jump height, and power production during submaximal loads in the back squat. It has also been supported by Vikne and colleagues (2006) when they trained the elbow flexors of 22 men with maximal eccentric-only and concentric-only exercise. The eccentric and concentric groups gained similar amounts 1RM strength of the elbow flexors. Second, the TRAD group, which used the isoinertial (constant load) method of training, still performed a substantial amount of eccentric work in their lifting protocol even though it was not ‘overload.’ This factor likely contributed to development of eccentric strength for the TRAD group.

Specificity, as it relates to muscle action type and kinetic factors, may be a reason for greater eccentric strength gain and CMJ height for the experimental groups. Although they were not statistically different, the mean differences at pre and post-testing between TRAD and EO trend towards the idea that training is specific to action type and kinetic specificity. One factor associated with back squats is a vertical ground reaction force vector. EO and TRAD back squats both yield vertical ground reaction force vectors. EO exhibits a greater magnitude of forces during eccentric phase relative to the concentric phase, which is similar to how the countermovement jump exhibits greater ground reaction forces during the eccentric phase by use of a forceful arm swing. In contrast to EO and TRAD back squatting, sprints yield a ground reaction force vector direction that is angled in the forward direction rather than vertically. The difference between force vector directions between sprinting and squatting may be the reason for lack of carryover into sprinting.

One limitation of the current study is that physiological mechanisms were not tied into the performance results. Areas that should be further explored to explain the mechanisms behind eccentric training include the role of titin in skeletal muscle contraction, tissue dynamics, and neuromuscular behavior. The evidence seems to suggest that concentric actions should be paired with eccentric actions in most scenarios since eccentric training provides many physiological benefits. For instance, eccentric overload with flywheels results in greater muscle hypertrophy than TRAD (Norrbrand et al., 2008) in both men and women (Fernandez-Gonzalo et al., 2014). Type II muscle fibers are more susceptible to mechanical stress than Type I fibers during heavily-loaded eccentric muscle actions. In turn, Type II fibers also seem to experience more muscle hypertrophy than Type I fibers (Hortobágyi et al., 1996; Vikne et al., 2006). Adaptation is detectable in as little as six weeks at the single-fiber level using eccentric-focused exercise (Friedmann-Bette et al., 2010). Last, there may be a gradual shift in fiber type towards the type II phenotype (Hakkinen & Komi, 1983; Vikne et al., 2006). These findings are particularly useful in the development of strength and explosive athletes.

This study contributes to an area within the human performance literature that is needed. There are still many questions about the implementation of EO in training programs. The role of this study was to make a comparison between EO and TRAD while controlling for volume. In doing so, a substantial amount of eccentric work was assigned to both groups. This is a limitation that future research endeavors may want to consider when implementing a comparative study design.

Several studies have examined the effects of EO acutely (Bosco at al., 1981; Doan et al., 2002; Drury et al., 2006; Munger et al., 2017, Sheppard and Young, 2010;). and over the short-term (Brandenburg and Doherty, 2002; Friedmann-Bette at al., 2010; Higbie et al., 1996; Hortobágyi,et al., 2001; Norrbrand et al., 2008; Nosaka and Newton, 2002; Vikne et al., 2006; Wirth et al., 2015; Yarrow et al., 2008). Future studies should investigate the long-term effects to add to the chronological knowledge of EO.

CONCLUSION

The practical implications are that use of a short-term eccentric overload program is beneficial to athletic performance when vertical explosiveness and eccentric strength is important, however similar results can be obtained by implementing TRAD training. Therefore, athletes that perform explosive movements and experience heavy eccentric loading, such as jumps, jump-landings, negative accelerations, and changes in direction, may benefit from eccentric overload. However, if concentric strength is the primary factor in competitive events, such as strongman or powerlifting, athletes should consider TRAD and other paired concentric-eccentric training. Coaches and athletes should consider the principles of *action-type specificity* and *kinetic specificity* when designing an RT program.

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