THE JOURNAL OF SPORTS MEDICINE AND PHYSICAL FITNESS
EDIZIONI MINERVA MEDICA

Strength, body composition, and functional outcomes in the squat versus leg press exercises

Fabrício Eduardo ROSSI, Brad J SCHOENFELD, Skyler OCETNIK, Jonathan YOUNG, Andrew D VIGOTSKY, Bret CONTRERAS, James KRIEGER, Michael MILLER, Jason CHOLEWA

J Sports Med Phys Fitness 2016 Oct 13 [Epub ahead of print]

THE JOURNAL OF SPORTS MEDICINE AND PHYSICAL FITNESS
Rivista di Medicina, Traumatologia e Psicologia dello Sport
pISSN 0022-4707 - eISSN 1827-1928
Article type: Original Article

The online version of this article is located at http://www.minervamedica.it

Running Head: Squat versus Leg Press

Strength, body composition, and functional outcomes in the squat versus leg press exercises

Fabrício E. Rossi[1,2]

Brad J. Schoenfeld[3]

Skyler Ocetnik[1],

Jonathan Young[1]

Andrew Vigotsky[4]

Bret Contreras[5]

James W. Krieger[6]

Michael G. Miller[7]

*Jason Cholewa[2]

1. Institute of Bioscience, Department of Physical Education Univ. Estadual Paulista, Rio Claro, São Paulo, Brazil.
2. Department of Kinesiology, Recreation, and Sport Studies, Coastal Carolina University, Conway, SC, USA
3. Department of Health Sciences, CUNY Lehman College, Bronx, NY
4. Kinesiology Program, Arizona State University , Phoenix, AZ , USA
5. Sport Performance Research Institute, AUT University, Auckland, New Zealand
6. Weightology, LLC, Issaquah, WA, USA
7. Department of Human Performance and Health Education, Western Michigan University, Kalamazoo, MI

*Corresponding author:
Jason Cholewa, PhD
Coastal Carolina University
PO Box 261954
Conway, SC 29528
P: 843-349-2041
F: 843-349-2875
jcholewa@coastal.edu

Word Count: 3864

Abstract

BACKGROUND: The purpose of this study was to compare strength, body composition, and functional outcome measures following performance of the back squat, leg press, or a combination of the two exercises. METHODS: Subjects were pair-matched based on initial strength levels and then randomly assigned to 1 of 3 groups: A squat-only group (SQ) that solely performed squats for the lower body; a leg press-only group (LP) that solely performed leg presses for the lower body, or; a combined squat and leg press group (SQ-LP) that performed both squats and leg presses for the lower body. All other RT variables were held constant. The study period lasted 10 weeks with subjects performing 2 lower body workouts per week comprising 6 sets per session at loads corresponding to 8-12 RM with 90 to 120 second rest intervals. RESULTS: Results showed that SQ had greater transfer to maximal squat strength compared to the leg press. Effect sizes favored SQ and SQ-LP versus LP with respect to countermovement jump while greater effect sizes for dynamic balance were noted for SQ-LP and LP compared to SQ, although no statistical differences were noted between conditions. CONCLUSIONS: These findings suggest that both free weights and machines can improve functional outcomes, and that the extent of transfer may be specific to the given task.

KEYWORDS: Functional fitness; specificity of training; exercise machines; free weights

Introduction

Resistance training (RT) can be carried out using a variety of implements. Two of the most commonly used types of implements are free weights and machines. Machines can be operationally defined as devices that contain cables, pin-loaded weight stacks, or fixed lever arms, while free weights refer to dumbbells and plates that are loaded onto the ends of a barbell (1). Generally, but not always, machines move in a fixed plane of motion while free weight exercise is carried out in three-dimensional space.

It is widely believed that free weight exercise promotes better transfer to sports specific and functional skills compared to machine-based exercises. This purported superiority has been attributed to mechanical specificity, whereby free weights more closely replicate movement patterns, force application, and velocities of movement during functional tasks (2). Free weight squats have also been suggested to activate more muscles in the lower limbs than smith machine squats (3) and induce a greater acute hormonal response than the leg press (4). Despite a sound logical basis, however, there is a paucity of controlled research that lends support to this hypothesis. Recently, Wirth et al. (5) randomized recreationally trained university students to perform lower body exercise consisting of either the squat or leg press. Both groups performed 5 sets of 6-10 repetition maximum (RM) for 8 weeks. Results showed statistically greater increases in both countermovement and squat jump performance for those performing the squat versus the leg press. These finding suggest that free weight exercise promotes greater transfer to vertical jump performance compared to machine-based exercise.

It should be noted that there are many components of functionality – in particular, components of dynamic balance – that have not been studied with respect to the influence of different training modalities. Moreover, to the authors' knowledge, no studies to date have investigated the effects of combining free weight and machine-based exercises compared to performing either type of modality alone. The purpose of this study therefore was to compare strength, body composition, and functional outcome measures following performance of the back squat, leg press, or a combination of the two exercises over an 8-week study period.

Methods

Experimental Approach to the Problem

Subjects were pair-matched based on initial strength levels and then randomly assigned to 1 of 3 groups: A squat-only group (SQ) that solely performed squats for the lower body; a leg press-only group (LP) that solely performed leg presses (Prestige Strength VRS, Cybex International, Inc . Medway, MA,USA) for the lower body, or; a combined squat and leg press group (SQ-LP) that performed both squats and leg presses for the lower body. All other RT variables were held constant. The study period lasted 10 weeks with subjects performing 2 lower body workouts per week comprising 6 sets per session at loads corresponding to 8-12 RM with 90 to 120 second rest intervals. Total training volume (reps × sets) was equated between groups. Testing was carried out pre- and post-study for indices of muscle strength, body composition, and functional performance.

Subjects

Subjects were a convenience sample of 26 male volunteers recruited from a university population (age = 22.0±3.9 years; height = 175.4±7.7 cm; body mass = 80.7±17 kg). Subjects were reported to be without any existing musculoskeletal disorders, free from consumption of anabolic steroids or any other illegal agents known to increase muscle size for the previous year, and had not performed any regimented resistance training for the past 6 months. Subjects were instructed to avoid taking any performance-enhancing supplements during the study period.

Participants were pair-matched according to baseline strength and then randomly assigned to 1 of 3 groups: A squat-only group (SQ) that solely performed squats for the lower body (n = 8); a leg press-only group (LP) that solely performed leg presses (n = 9); or a combined squat and leg press group (SQ-LP) that performed both squats and leg presses (n = 9). Approval for the study was obtained from the university's Institutional Review Board (IRB). Informed consent was obtained from all participants.

Resistance Training Procedures

The per-session RT protocol consisted of 6 sets of squats for the SQ group, 6 sets of leg presses for the LP group, and 3 sets of squats and 3 sets of leg presses for the SQ-LP group. Training for each protocol consisted of 2 weekly sessions performed on non-consecutive days for 10 weeks. All groups had a target of 8-12 repetitions per set. The first 2 weeks of training consisted of an acclimation phase, whereby sets were terminated 1 or 2 repetitions short of failure. Thereafter, sets were carried out to the point of momentary concentric muscular failure—the inability to perform another concentric repetition while maintaining proper form—for the final 8 weeks of the study. Cadence of repetitions were carried out in a controlled fashion, with a concentric action of approximately one second and an eccentric action of approximately two seconds. Subjects were afforded 90 to 120 seconds of rest between sets. The load was adjusted for each exercise as needed on successive sets to ensure that subjects achieved failure in the target repetition range. All sessions were directly supervised by the research team to ensure proper performance of the respective routines. Attempts were made to progressively increase the loads lifted each week within the confines of maintaining the target repetition range. Initial loads for each exercise were based on 80% of subjects' 1RM, as determined during initial testing, consistent with recognized guidelines established by the National Strength and Conditioning Association (6).

Dietary Adherence

To avoid potential dietary confounding of results, subjects were advised to maintain their customary nutritional regimen. Attempts to monitor adherence to these instructions were unsuccessful due to poor subject compliance in filling out and submitting food journals.

Measurements

Pre intervention body composition was assessed prior to the strength training familiarization sessions. At least 72 hours following familiarization, balance and jump testing was assessed on day one, and 48 hours later strength testing was assessed on day two. Post testing body composition was assessed at least 24 hours following the completion of all resistance training on a Friday. Subjects then reported to the lab on the following Monday for balance and jump testing, and then 48 hours later for strength testing.

Muscle Strength: Lower body strength was assessed by 1RM testing in the parallel back squat ($1RM_{SQUAT}$) and the leg press ($1RM_{LEGPRESS}$) exercises, in that order. Subjects reported to the lab having refrained from any exercise other than activities of daily living for at least 48 hours prior to baseline testing and at least 48 hours prior to testing at the conclusion of the study. RM testing was consistent with recognized guidelines established by the National Strength and Conditioning Association (6). Two familiarization sessions separated by at least 48 hours were performed prior to 1 RM testing. Subjects performed a general warm-up prior to testing that consisted of light cardiovascular exercise lasting approximately 5-10 minutes. A specific warm-up set of the given exercise of 5 repetitions was performed at ~50% 1RM followed by one to two sets of 2-3 repetitions at a load corresponding to ~60-80% 1RM. Subjects then performed sets of

1 repetition of increasing weight for 1RM determination. Three to 5 minutes of rest was provided between each successive attempt. All 1RM determinations were made within 5 attempts. Subjects were required to reach parallel in the $1RM_{SQUAT}$ for the attempt to be considered successful as determined by the research team. For the $1RM_{LEGPRESS}$ a goniometer was used to ensure that all subjects began the movement with a 90-degree angle at the knee and a 60-degree angle at the hip. The attempt was deemed successful when subjects were able to fully extend at the knee while maintaining contact between the hips and the seat. Two members of the research team supervised all testing sessions and an attempt was only deemed successful when a consensus was reached between the two. Based on results of a small pilot study (n=5), the test-retest intraclass correlation coefficient (ICC) from our lab for the $1RM_{LEGPRESS}$ and $1RM_{SQUAT}$ was 0.961 and 0.969, respectively.

Dynamic Balance: The Star Excursion Balance Test (SEBT) was used to assess changes in dynamic balance. The SEBT was selected because of its high reliability and validity as a non-instrumented dynamic balance test for physically active people (7, 8). Testing was carried out as follows: The floor was marked with a star pattern in 8 directions, 45° apart from each other: anterior, posterior, medial, lateral, posterolateral, posteromedial, anterolateral, and anteromedial. Subjects placed one foot in the center of the star pattern and then reached as far as possible with the other foot in clockwise fashion in all eight directions. The subject lightly tapped the floor, and then returned the leg to the center of the star after each tap. The trial was repeated if the subject made any of the following errors: rested his foot on the ground, tapped the floor heavily, lost balance, or was unable to return to the starting position in a controlled manner (7). The order of limb performance was randomized to help prevent confounding issues from adverse effects of fatigue on balance. Measurements were obtained from the distance from the center of the star to the tap. Subjects performed 3 trials and the results from these trials were averaged. Excursion values were normalized to leg length, as measured from the anterior superior iliac spine to the medial malleolus, to account for the significant correlation between SEBT and leg length (9). Four practice trials were provided to subjects prior to actual testing in order to diminish any effects of motor learning (10).

Vertical Jump: Jump height was determined by performance of a countermovement jump (CMJ) as assessed by Just Jump! Mat (Probotics Inc: Huntsville, AL). Prior to testing, subjects engaged in a brief, general warm-up consisting of several minutes of light cardiovascular exercise, followed by 6 submaximal jumps to heighten neural responses. Vertical jumps were measured in inches using the Just Jump! mat. Subjects were instructed to perform a rapid lower body eccentric contraction followed immediately by a maximal intensity concentric contraction. Subjects were instructed to jump straight up and minimize any in-air hip flexion. The movement was completed by landing on both feet at the same time while maintaining balance on the mat. The best of the three trials was recorded as vertical jump height.

Body Composition: Height was measured using standard anthropometry and body mass was measured using a calibrated scale. Body composition was measured pre- and post-treatment as determined by whole body densitometry using Air Displacement Plethysmography (Bod Pod®, Cosmed, Concord, CA USA). All testing was performed in accordance with the manufacturer's instructions. Briefly, subjects were tested while wearing only tight fitting compression shorts and an acrylic swim cap. The subjects wore the exact same clothing for all testing. Thoracic gas volume was estimated for all subjects using a predictive equation integral to the Bod Pod® software. The calculated value for body density used the Siri equation to estimate body composition. Data obtained from the Bod Pod® included body weight, percent body fat, fat free mass, and fat mass. All testing was done with each subject at approximately the same time of day.

Statistical Analyses

Pre- and post-intervention data were modeled using a linear mixed model for repeated measures, estimated by a restricted maximum likelihood algorithm. Training intervention (leg press, squat, or combination) was included as the between-subject factor, time was included as the repeated within-subjects factor, time × intervention was included as the interaction, and subject was included as a random effect. In cases where statistical interactions were present, *post-hoc* analyses on within-subject changes were carried out using t-tests with a Holm-Bonferroni adjustment. Effect sizes were calculated as the mean pre-post change divided by the pooled pretest standard deviation (11) and 95% confidence intervals (CI) were reported for all primary outcomes. All analyses were performed using R version 3.2.3 (The R Foundation for Statistical Computing, Vienna, Austria). *A priori* alpha level was set to $P \leq 0.05$, and trends were declared at $0.05 > P \leq 0.10$. Effect sizes were defined as small, medium, and large for 0.20, 0.50, and 0.80, respectively. Data are reported as $\overline{x}$ ± SD, unless otherwise specified.

Results

Body Composition

There were significant increases in body mass and fat-free mass from pre- to post- in all 3 groups, with no differences in changes between groups (Table 1). Effect sizes were small, ranging from 0.10 to 0.15. There was a trend for fat mass to increase in all 3 groups ($P = 0.06$), with no differences between groups; effect sizes were very small (0.08 to 0.09). There were no significant main effects or interactions for percent body fat.

Insert Table 1 About Here

Performance

For the squat, there was a significant group by time interaction (P = 0.0004, Table 2). All 3 groups improved over time (P < 0.0001), but the increase was largest in the squat group (+76.2, CI 54.3, 98.2, ES 1.35), followed by the combination group (+53.9, CI 33.2, 74.6, ES 0.95), and lastly the leg press group (+21.1, CI 0.38, 41.8, ES 0.37). For the leg press, all 3 groups improved over time (P < 0.0001), with no differences in improvements between groups; effect sizes ranged from 1.45 to 1.49 (Table 2). For the vertical jump, all 3 groups improved over time (P < 0.0001), with no significant differences in changes between groups (P = 0.15, Table 2). Effect sizes were largest for the squat group (0.62), followed by the combo group (0.49) and the leg press group (0.24).

Insert Table 2 About Here

Balance

SEBT outcomes by group are shown in Table 3. There were significant improvements over time for all measures (P < 0.05), with no significant group by time interactions. Effect sizes favored the combo group in most metrics, followed by the leg press group, with the lowest effect sizes in the squat group. There was a significant effect of group for left anterior (P = 0.02), with the combo group showing a significantly greater value compared to the squat group collapsed over pre- and post (Difference: 7.4, CI 1.0, 13.8, P = 0.02). There was a significant group effect for the left leg sum (P = 0.04), with the combo group showing a significantly greater value compared to the squat group collapsed over pre- and post (Difference: 26.7, CI 0.8, 52.6, P = 0.05). There was a significant group effect for the right anterior (P = 0.004), with the squat showing a significantly greater value than the leg press group (Difference: 5.7, CI: 0.2, 11.3, P = 0.03), as well as the combo showing a significantly greater value than the leg press group

(Difference: 7.9, CI 2.5, 13.2, P = 0.004). For right posteriolateral, there was a significant group effect (P = 0.01), with the combo showing a significantly greater value than the leg press group (Difference: 11.5, CI 2.4, 20.5, P = 0.01). There was also a significant group effect for the right leg sum (P = 0.01), with the combo group showing a significantly greater value compared to the squat group collapsed over pre- and post (Difference: 28.1, CI 6.2, 49.9, P = 0.01). Since there were no significant group by time interactions, SEBT outcomes were collapsed across groups. Changes over time for SEBT outcomes are shown in figure 1. Fifteen out of 18 outcomes showed significant improvements (P < 0.05).

Insert Table 3 About Here

Insert Figure 1 About Here

Discussion

To the authors' knowledge, this is the first study to investigate the effects of training on a machine versus free weights as well as a combination of the two modalities. In addition, we are aware of no other studies that have investigated the effects of different training modalities on dynamic balance. As such, the study helps to fill gaps in the literature on this important topic.

Wirth et al. (5) demonstrated that the squat was superior to the leg press for improving countermovement jump performance. Although our findings suggest this to be the case given the increasing effect sizes from LP (0.24), to SQ-LP (0.49), to SQ (0.62), it cannot be said that this group × time interaction is not due to chance alone. And while Wirth et al. (5) also did not observe an increase in countermovement jump height in the leg press group, Correa et al. (12) recently found that a machine-based program (including the leg press) improved countermovement jump in older women. While the literature on leg press is equivocal, the literature suggesting that squats increase vertical jump performance is compelling, and that deeper is better (13, 14). These apparent advantages to the squat may be attributed to a number of reasons. For one, the knee moved through a greater range of motion in the squat than it did in the leg press. As with previous studies that examined the effects of squat depth on performance (13, 14), the subjects in this study were untrained or detrained, and were therefore conceivably more likely to realize greater adaptations from greater ranges of motion. Furthermore, it appears that the largest mechanical demands from the hip during the countermovement jump occur close to 45º (15), which is where the leg press movement was completed. It may be that greater hip range of motion and net extension moment requisites are required in order to maximize and optimize hip extensor strength adaptations for the vertical jump, as the squat effectively moved through this range of motion (hip flexion < 45º) with resistance. Lastly, it is possible that the differential angular velocities and displacement of the hip and knee during the leg press and squat have implications for transference, in that the triple extension pattern in the squat more closely mimics the vertical jump than does the leg press.

The changes in strength reported by Wirth et al. (5) applied only to the lift that each respective group trained; that is, the LP and SQ groups were only tested in the leg press and squat, respectively, and there were no evaluations of transference. However, in this study, a statistical group × time interaction was observed for the squat, with, increasing effect sizes from LP (0.37), to SQ-LP (0.95), to SQ (1.35), just as was the case with the vertical jump. This reinforces the principle of specificity. Despite the seemingly similar biomechanics of the squat and leg press, in that both involve triple extension and have somewhat similar net knee extension moment requisite-angle relationships (16), the net hip extension moment requisite-angle relationship in the leg press is different from that in the squat. This is in part due to the 45º-angle of the hip in the leg press at lockout (0º knee flexion), while during the squat, when one is in 45º of hip flexion during the concentric phase, they are at approximately 35º of knee flexion (17). Simplistically, the differential hip-to-knee angles inherent to the squat and leg press necessitate unique muscle recruitment strategies for the distinct interjoint, or intersegmental, dynamic interaction of each movement for the purposes of dynamic optimization (18). An example of such a recruitment strategy is the greater electromyography amplitude of the biceps femoris observed in the concentric phase of squat over that in the leg press (16). Moreover, the knee range of motion utilized during the squat was approximately 30º more (33.3%) than during the leg press (19). It is therefore likely that those performing the squat experienced range of motion-specific adaptations (90–120º knee flexion), for which the leg press group did not train. Lastly, it is possible that self-efficacy played a role in these outcomes, as self-efficacy is task-specific (20) and may have a significant effect on strength capacity (21-23).

Unlike the squat, no statistical differences were observed between the SQ, LP or SQ-LP groups, which suggests that leg press strength is not as specific as squat strength; that is, increasing hip and knee extensor strength will increase leg press strength no matter how it is accomplished. However, unlike the squat, the leg press was completed within a range of motion that all groups utilized throughout the trial, in that the knees moved through 90º flexion and extension and the hips did not extend past 45º flexion; however, during a parallel squat, the knees flex to about 120º and the hips well past 45º flexion, to about 20º (17, 19).

The SEBT is a reliable and valid measure of dynamic balance for physically active people (7, 8), and may also be an accurate predictor of lower extremity injury (24). SEBT scores in all three groups statistically increased over the course of the study, with no differences noted between groups. Interestingly, the effect sizes for SQ were much lower than that observed in the SQ-LP and LP groups, suggesting that the leg press, or a combination of exercises, may be more beneficial than squatting alone. These findings are contradictory to Furlong et al. (25), who found no increases in SEBT scores following 12-week training program that incorporated the leg press. Alternatively, Pamukoff et al. (26) found that performance of the leg press, in combination with a number of lower-body focused machine exercises, improved balance recovery in an aging population. Nevertheless, the finding that increasing lower body strength, regardless of mode, appears to increase scores in a test that is predictive of lower-extremity injury. Such findings are supported by meta-analysis showing that strength training helps to prevent injury (27). Further research is warranted to identify whether or not one or multiple mediums (i.e., SQ vs. LP vs. SQ-LP) is more efficacious for enhancing balance and preventing injury.

Conclusion

The results of our study indicate that both free weights and machines can improve functional outcomes, and that the extent of transfer may be specific to the given task. From a practical standpoint, these findings serve two primary functions: First, results reinforce to coaches and athletes the importance of specificity. Back squat training significantly improved back squat strength and tended to improve vertical jump more so than leg press alone or a combination thereof. That said, all of the conditions employed had positive effects on functional outcomes, indicating that functional transfer exists on a continuum and simply improving strength will enhance various measures of function regardless of the modality (28). Second, this study underscores the importance of strength training to improve balance and thereby reduce injury risk. The data demonstrates that, contrary to popular suggestion, strength training exercises that rely exclusively on or include machines are able to enhance dynamic balance in non-athletes, perhaps to an even greater extent than free weight exercise. As such, coaches and practitioners should consider the individual client and/or athlete's needs when selecting resistance training movements.

Disclosure Statement: The authors declare no conflicts of interest associated with this manuscript.

References

1. McBride JM. Machines versus free weights. NSCA Hot Topic Series [Internet]. Available from: http://www.nsca-lift.org. [cited 2016, Sep 9].

2. Stone M, Plisk S, Collins D. Training principles: evaluation of modes and methods of resistance training--a coaching perspective. Sports Biomech. 2002 Jan;1(1):79-103.

3. Schwanbeck S, Chilibeck PD, Binsted G. A comparison of free weight squat to Smith machine squat using electromyography. J Strength Cond Res. 2009 Dec;23(9):2588-91.

4. Shaner AA, Vingren JL, Hatfield DL, Budnar RG,Jr, Duplanty AA, Hill DW. The acute hormonal response to free weight and machine weight resistance exercise. J Strength Cond Res. 2014 Apr;28(4):1032-40.

5. Wirth K, Hartmann H, Sander A, Mickel C, Szilvas E, Keiner M. The impact of back squat and leg-press exercises on maximal strength and speed-strength parameters. J Strength Cond Res. 2015 Sep 25.

6. Baechle TR, Earle RW, editors. Essentials of Strength Training and Conditioning. 3rd ed. Champaign, IL: Human Kinetics; 2008.

7. Flanagan SP. NSCA's Guide to Tests and Assessments. Miller T, editor. Champaign, IL: Human Kinetics; 2012.

8. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J Athl Train. 2012 May-Jun;47(3):339-57.

9. Gribble PA, Hertel J. Considerations for normalizing measures of the star excursion balance test. Measure Phys Educ Exerc Sci. 2003;7:89-100.

10. Robinson RH, Gribble PA. Support for a reduction in the number of trials needed for the star excursion balance test. Arch Phys Med Rehabil. 2008 Feb;89(2):364-70.

11. Morris B. Estimating effect sizes from pretest-posttest-control group designs. Organizational Research Methods. 2008;11(2):364-86.

12. Correa CS, LaRoche DP, Cadore EL, Reischak-Oliveira A, Bottaro M, Kruel LF, et al. 3 Different types of strength training in older women. Int J Sports Med. 2012 Dec;33(12):962-9.

13. Hartmann H, Wirth K, Klusemann M, Dalic J, Matuschek C, Schmidtbleicher D. Influence of squatting depth on jumping performance. J Strength Cond Res. 2012 Feb 15.

14. Bloomquist K, Langberg H, Karlsen S, Madsgaard S, Boesen M, Raastad T. Effect of range of motion in heavy load squatting on muscle and tendon adaptations. Eur J Appl Physiol. 2013 Aug;113(8):2133-42.

15. Vanrenterghem J, Lees A, Clercq DD. Effect of forward trunk inclination on joint power output in vertical jumping. J Strength Cond Res. 2008 May;22(3):708-14.

16. Escamilla RF, Fleisig GS, Zheng N, Barrentine SW, Wilk KE, Andrews JR. Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. Med Sci Sports Exerc. 1998 Apr;30(4):556-69.

17. Escamilla RF, Fleisig GS, Lowry TM, Barrentine SW, Andrews JR. A three-dimensional biomechanical analysis of the squat during varying stance widths. Med Sci Sports Exerc. 2001 Jun;33(6):984-98.

18. Zajac FE, Gordon ME. Determining muscle's force and action in multi-articular movement. Exerc Sport Sci Rev. 1989;17:187-230.

19. Cotter JA, Chaudhari AM, Jamison ST, Devor ST. Knee joint kinetics in relation to commonly prescribed squat loads and depths. J Strength Cond Res. 2013 Jul;27(7):1765-74.

20. Yeo GB, Neal A. An examination of the dynamic relationship between self-efficacy and performance across levels of analysis and levels of specificity. J Appl Psychol. 2006 Sep;91(5):1088-101.

21. Ness G, Patton RW. The effect of beliefs on maximum weight-lifting performance. Cognitive Therapy and Research. 1979;3(2):205-11.

22. Fitzsimmons PA, Landers DM, Thomas JR, van der Mars H. Does self-efficacy predict performance in experienced weightlifters? Res Q Exerc Sport. 1991 Dec;62(4):424-31.

23. Wells CM, Collins D, Hale BD. The self-efficacy-performance link in maximum strength performance. J Sports Sci. 1993 Apr;11(2):167-75.

24. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. J Orthop Sports Phys Ther. 2006 Dec;36(12):911-9.

25. Furlong J, Rynders CA, Sutherlin M, Patrie J, Katch FI, Hertel J, et al. Effect of an herbal/botanical supplement on strength, balance, and muscle function following 12-weeks of resistance training: a placebo controlled study. J Int Soc Sports Nutr. 2014 May 28;11:23,2783-11-23. eCollection 2014.

26. Pamukoff DN, Haakonssen EC, Zaccaria JA, Madigan ML, Miller ME, Marsh AP. The effects of strength and power training on single-step balance recovery in older adults: a preliminary study. Clin Interv Aging. 2014 Apr 17;9:697-704.

27. Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. Br J Sports Med. 2014 Jun;48(11):871-7.

28. Schoenfeld B. Is functional training really functional? ACSM Certified News. 2010;20(3):5-6.

Figure Captions

Figure 1: Graphical representation of pre- and post-intervention changes over time for SEBT outcomes, mean (±SD).

Table 1: Body Composition

Variables	Time	Leg Press (n=9)	%Δ (ES)	Squat (n=8)	%Δ (ES)	Leg Press + Squat (n=9)	%Δ (ES)
FFM (Kg)	Pre	64.9 ± 12.3	1.4%	62.6 ± 10.6	2.2%	62.4 ± 4.8	1.9%
	Post	65.8 ± 13.2	(0.10)	64.0 ± 10.4	(0.15)	63.6 ± 4.9	(0.13)
FFM (%)	Pre	81.6±8.4	-0.5%	79.8±8.7	-0.5%	83.4±8.7	-0.5%
	Post	81.1±9.0	(0.06)	79.3±8.4	(0.06)	82.9±9.2	(0.06)
FM (Kg)	Pre	15.6±9.9	5.1%	17.4±11.4	4.6%	13.3±9.0	5.3%
	Post	16.4±11.2	(0.08)	18.3±11.5	(0.09)	14.1±9.8	(0.08)
FM (%)	Pre	18.4±8.4	0.4%	20.2±8.7	0.5%	16.6±8.7	0.5%
	Post	18.8±9.0	(0.05)	20.7±8.4	(0.06)	17.1±9.2	(0.06)
Body Mass (Kg)	Pre	80.6±18.2	2.1%	80.0±20.5	2.8%	75.7±10.9	2.5%
	Post	82.2±19.8	(0.10)	82.3±20.4	(0.14)	77.7±11.4	(0.12)

Table 2: Strength and Power

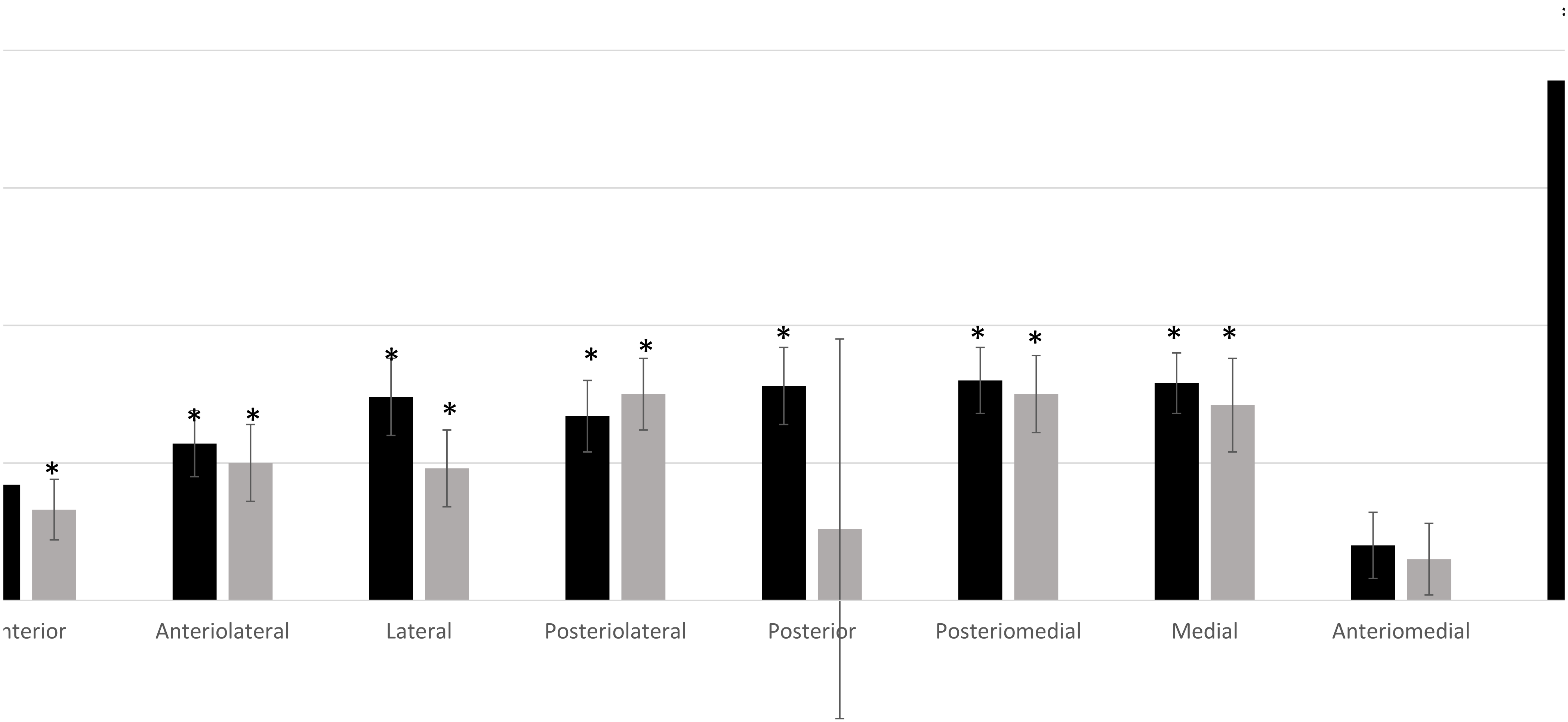
Variables	Time	Leg Press (n=9)	Δ (ES)	Squat (n=8)	Δ (ES)	Leg Press + Squat (n=9)	Δ (ES)
Squat (Kg)	**Pre**	121.0±23.7	7.9% (0.37)	109.7±32.0	31.5%* (1.35)	124.0±22.1	19.8%* (0.95)
	Post	130.6±29.8		144.3±38.5		148.5±16.8	
Leg Press (Kg)	**Pre**	188.6±45.1	34.2% (1.45)	202.5±54.3	34.0% (1.50)	220.9±37.3	31.1% (1.49)
	Post	255.0±73.5		271.3±94.8		289.6±40.5	
Power (cm)	**Pre**	61.5±8.6	3.3% (0.24)	57.4±8.4	8.9% (0.62)	62.0±7.9	6.5% (0.49)
	Post	63.5±11.4		62.5±9.9		66.0±7.6	

* = Significantly different compared to the leg press group.

Table 3: Balance

Variables	Time	Leg Press (n=9)	%Δ (ES)	Squat (n=8)	%Δ (ES)	Leg Press + Squat (n=9)	%Δ (ES)
Left Anterior	**Pre** **Post**	60.2 ± 7.7 64.6 ± 3.5	7.3% (0.60)	63.6 ± 7.8 64.5 ± 4.4	1.4% (0.13)	66.4 ± 5.7 73.2 ± 7.0	10.2% (0.93)
Left Posteriolateral	**Pre** **Post**	65.5 ± 12.6 72.3 ± 8.1	10.4% (0.61)	69.0 ± 9.9 73.0 ± 9.6	5.8% (0.36)	75.0 ± 9.5 84.1 ± 9.3	12.1% (0.83)
Left Posteriomedial	**Pre** **Post**	61.8 ± 12.0 68.6 ± 9.9	11.0% (0.66)	63.6 ± 9.3 71.3 ± 8.7	12.1% (0.75)	69.0 ± 8.4 78.7 ± 10.4	14.1% (0.95)
Left Sum	**Pre** **Post**	187.5 ± 29.9 205.4 ± 18.9	9.5% (0.68)	196.2 ± 25.8 208.8 ± 20.3	6.4% (0.48)	210.3 ± 19.2 236.0 ± 24.0	12.2% (0.98)
Right Anterior	**Pre** **Post**	56.9 ± 6.5 61.0 ± 2.2	7.2% (0.56)	64.6 ± 9.0 64.8 ± 2.3	0.3% (0.03)	64.2 ± 4.0 69.4 ± 4.9	8.1% (0.69)
Right Posteriolateral	**Pre** **Post**	60.4 ± 11.6 69.3 ± 6.8	14.7% (0.85)	69.5 ± 10.3 75.4 ± 8.2	8.5% (0.56)	72.6 ± 5.8 80.1 ± 6.4	10.5% (0.71)
Right Posteriomedial	**Pre** **Post**	55.3 ± 12.2 63.2 ± 10.8	14.3% (0.82)	62.3 ± 9.7 66.0 ± 8.2	5.9% (0.38)	62.7 ± 4.5 73.1 ± 8.1	16.6% (1.08)
Right Sum	**Pre** **Post**	172.5 ± 27.5 193.5 ± 18.5	12.2% (0.83)	196.4 ± 26.6 206.1 ± 16.1	4.9% (0.39)	199.5 ± 12.0 222.6 ± 16.5	11.6% (0.9

Scores reported as normalized % of leg length



nterior
Anteriolateral
Lateral
Posteriolateral
Posterior
Posteriomedial
Medial
Anteriomedial
Left
Right