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The Effects of Bilateral and Unilateral Training on Leg Press Strength and Vertical Jump Height

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ABSTRACT

This investigation assessed the effects of bilateral and unilateral strength training on strength and power development, as measured by uni- and bi-lateral 3-repetition maximum leg press and vertical jump tests, respectively. 14 college-aged participants were randomized into either bilateral or unilateral training conditions. The participants engaged in biweekly strength training sessions for a period of 4 weeks, with strength and power pre- and post-testing in the weeks immediately before and after the training protocol, respectively. There was no significant (F = 0.98, p = 0.33) main effect of condition for vertical jump height. There was no significant (F = 2.48, p = 0.13) main effect of condition for 1RM bilateral strength. There was no significant (F = 1.86, p = 0.19) main effect of condition for 1RM unilateral strength between both right and left legs. While our investigation yielded no significant results, there may be reason to further investigate this area of research, due to professionals wanting to develop weight training protocols for the athletic and/or injured populations to facilitate greater improvements in performance and/or quicker recovery from injuries.

Keywords: Bilateral Deficit, Power, Strength Training, Leg Press, Vertical Jump

INTRODUCTION

Bilateral deficit (BD) refers to the ability to produce more net force from 2 limbs individually (i.e., unilaterally) than when contracting together (i.e., bilaterally) (Železnik et al. 2022). At present, much research has been done in discovering the nature of this phenomenon, although the means by which it may be leveraged for fitness adaptation remain comparatively neglected (Bobbert et al. 2006; Simoneau-Buessinger et al. 2015; van Dieen et al. 2003). Where present, BD entails impressive differences in force production per contracted limb, which may have undiscovered benefits for magnifying the efficacy of strength and power development in the weight room, as well as rehabilitation settings.

Currently, there is no single accepted mechanism behind the BD phenomenon, although several have been proposed in the literature (Bobbert et al. 2006; Simoneau-Buessinger et al. 2015; van Dieen et al. 2003). Some have proposed that BD originates from the nervous system, as evidenced by decrements in electromyographic activity during bilateral contraction (van Dieen et al. 2003), although the precise neural mechanism(s) has/have not been concluded. In a series of 3 experiments, van Dieen and colleagues (2003) investigated BD in finger flexors and knee extensors. In experiment 1, participants performed separate maximal unilateral and bilateral contractions of the finger flexors, as well as maximal bilateral contractions in which 1 arm began contraction prior to the other in order to assess changes in force production upon transition from unilateral to bilateral contraction. Bilateral deficit was present in both protocols, with similar magnitudes of force and electromyographic activity, suggesting a neural cause of BD, although overall correlation was only moderate. In experiment 2, participants performed

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bilateral and unilateral maximal contractions of the knee extensors, maximal unilateral contraction of 1 leg followed by addition of the other, and maximal bilateral contraction followed by relaxation of 1 leg. The results of experiment 2 displayed significant BD. While BD was present, there was not always a significant correlation between force production and EMG amplitude. Finally, in experiment 3, a procedure analogous to that in experiment 2 was used, this time measuring differences in the rate of force development rather than peak force, and again the authors found BD (van Dieen et al. 2003). In light of these findings, the magnitudes of deficit recorded on electromyography were not always consistent with the magnitude of force deficit, which may suggest a non-neural factor in manifestation of BD.

Others have described BD as a product of mechanical advantage, rather than neural output. Simoneau-Buessinger and colleagues performed tests of different dynamometer setups, each with different allowances of body adjustments (Simoneau-Buessinger et al. 2015). The authors made use of 2 varieties of dynamometers; an 'open-unit', which prevented torque generation through body posture outside of the target ankle joint, and a 'locked unit', which allowed all torque generated by the body to be included in the net torque value achieved by contraction at the ankle. The open-unit setup, which excludes torque generated outside the target muscle group, found no significant differences between torque generated during bilateral contraction and summated torque generated during unilateral contraction of homologous limbs ($p = 0.08$), although significance was achieved ($p < 0.01$) in a 'locked-unit' setup, which allows for mechanical advantage through postural change (Simoneau-Buessinger et al. 2015). Furthermore, the authors also made use of superimposed electrical stimulation to control for voluntary activation, and similar results were found between open-unit and locked-unit torque generation. The authors suggest that BD results from a greater potential for mechanical advantage through body adjustment rather than from differential potential for neural drive (Simoneau-Buessinger et al. 2015).

Bilateral deficit also exists in low-load, power movements such as the vertical jump. In a study by Bobbert and colleagues, subjects performed alternated bilateral and unilateral jumps, with surface EMG used to quantify neural drive, and force plates to measure ground reaction force (Bobbert et al. 2006). While BD was present, the magnitude of difference in force production between unilateral and bilateral jumps (peak deficits of 20-30% across measured joints) was much greater than the EMG amplitudes (bilateral amplitude about 95% of unilateral amplitude, averaged across all measured muscles; statistically significant only in the rectus femoris) would have predicted if neural inhibition were the sole cause of BD, leading the researchers to conclude that BD is due to other factors, including different contractile velocities between bi- and unilateral contractions (Bobbert et al. 2006).

Despite how consistently it is reported in the literature, the mechanisms behind BD have been poorly elucidated. The conflicted state of the literature regarding BD mechanisms makes it difficult to understand any practical applications to BD, so investigations such as this may be especially useful in that regard. In order to address this, we are investigating a potential benefit to peak strength development by employing the proposed neural mechanism underpinning the phenomenon. The aim of the present investigation is to elucidate the potential benefits of unilateral training on peak strength development, and to determine if utilizing principles underlying BD can provide additional insight into developing weight training protocols for the athletic and/or injured populations. We hypothesized that the proposed exposure to greater neural drive during unilateral training would yield greater results in peak leg press strength and vertical jump height than bilateral training.

METHODS

Participants

14 college-aged participants (*n* =3 males, *n* =11 females, Table 1.) each participated in 2 weekly strength training sessions, for a 4 week duration. The participants were randomized into either unilateral (*unilat*) or bilateral (*bilat*) training conditions. Exclusion criteria consisted of any contraindications to strenuous exercise (e.g., acute injury, known cardiovascular disease), or conflicting concurrent exercise routines. All participants were informed of risks and benefits that may result from participation, and were asked to refrain from lower- body exercise at least 24-hours prior to all testing and training sessions, as well as any nutrition supplements (e.g., pre-workouts, caffeine, creatine); and to otherwise leave their schedules unchanged. In the weeks precluding the investigation, all participants completed a medical history and informed consent

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Table 1. Average height, weight, and age of all participants.

	Males (*n* = 3)	Females (*n* = 11)
Height (m)	1.81±0.05 m*	1.63±0.02 m
Weight (kg)	80.45±2.84 kg	69.63±3.17 kg
Age (years)	22±0.58 years*	20.36±0.28 years

All data are means ± SD
**males significantly greater than females for height and age*
$p < 0.05$ for all

form. This study was approved by the Hiram College Institutional Review Board.

Familiarisation

For both conditions, participants completed familiarisation with the protocol and the equipment. During familiarisation, participants were given instructions for proper machine usage with respect to their assigned training condition (*bilat* or *unilat*) such that mechanical advantage would be similar. This was accomplished by first instructing all participants to find a comfortable body position for a unilateral leg press, and having them mirror this position when using a bilateral variation. This resulted in a narrow-stance bilateral leg press position that could be comfortably transitioned to a unilateral variation with minimal bodily adjustment aside from removal of 1 leg from the leg press platform.

Testing

A 3-repetition maximum (3RM) protocol adapted from an NSCA 1-repetition maximum (1RM) test for both bilat and unilat conditions on a horizontal leg press machine (Quantum Fitness, Stafford, TX, USA) was used (Hoffman 2012; Marine Corps Community n.d.). This was followed during the pre- and post-testing for both bilat and unilat leg press conditions. All participants also completed an NSCA vertical jump test protocol prior to the leg press pre- and post-testing, according to the protocols outlined by Haff and Triplett (Haff et al. 2021). Vertical jump testing was completed with 3 trials per session, with the highest jump being recorded. Jumps were performed by completing a brief squat countermovement, followed by rapid movement reversal into a max effort vertical jump. 1RM values were estimated using the Epley 1RM prediction equation, which has demonstrable reliability in predicting 1RM from 3RM data (DiStasio et al. 2014). Participants were then randomized into either *bilat* or *unilat* training (Table 2.) for the duration of the investigation.

Training Programme

For the *bilat* condition, participants were instructed to complete their exercise using a bilateral variation of the leg press exercise for the indicated volume and intensity for that week. For the *unilat* condition, participants were instructed to complete their exercise using a unilateral variation of the leg press exercise for each leg, with volume matched between groups for each leg. Volume, intensity, and frequency were held equal for all legs of the participants, with bilateral group completing 7-8 reps of leg press using both legs, unilateral group completing a total of 14-16 reps, or 7-8 reps each leg (Table 2).

Statistical Analysis

All data were analyzed with SPSS version 20.0 (SPSS Incorporated, Chicago IL, USA), with an a-priori α level of ≤ 0.05. Males' and females' physical characteristics (age, height, weight) were compared using independent samples T-tests. 2 condition (*bilat, unilat*) repeated measures ANOVA was used to examine differences in 1RM and vertical jump height. Post-hoc analysis was used for all significant main effects were completed using paired samples T-tests with the Benjamini-Hochberg false discovery rate correction (Benjamini

Table 2. Volume and intensity schemes for all training sessions (per leg).

	Week 1	Week 2	Week 3	Week 4
Days	2	2	2	2
Sets	3	3	3	3
Reps	7-8	7-8	7-8	7-8
Intensity	80% 1RM	85% 1RM	85% 1RM	90% 1RM

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et al. 1995).

RESULTS

Physical Characteristics

Independent samples-t-tests revealed significant differences in males and females physical characteristics for height and age (Table 1).

Vertical Jump Height

There was no significant (F = 0.98, p = 0.33) main effect of condition for vertical jump height. Bilat pre-vertical jump height (46.25 ± 2.51 cm) compared to *bilat* post-vertical jump height (49.81 ± 3.35 cm); *unilat* pre-vertical jump height (40.59 ± 3.23 cm) compared to unilat post-vertical jump height (43.05 ± 2.64 cm). There was a change of 7.14% and 5.72% from pre- to post-testing in the *bilat* and *unilat* conditions, respectively.

1RM Bilateral Strength

There was no significant (F = 2.48, p = 0.13) main effect of condition for 1RM bilateral strength. *Bilat* pre-1RM bilateral strength (149.86 ± 8.65 kg) compared to *bilat* post-1RM bilateral strength (174.84 ± 8.65 kg); *unilat* pre-1RM bilateral strength (141.54 ± 11.37 kg) compared to *unilat* post-1RM bilateral strength (149.03 ± 15.92 kg). There was a change of 14.29% and 5.03% from pre- to post-testing in the bilat and unilat conditions, respectively.

1RM Unilateral Strength

There was no significant (F = < 1.86, p < 0.19) main effect of condition for 1RM unilateral strength between both right and left legs. *Bilat* pre-1RM unilateral strength (right = 82.43 ± 5.9 kg; left = 81.18 ± 6.39 kg) compared to the *bilat* post-1RM unilateral strength (right = 94.91 ± 5.34 kg; left = 91.17 ± 5.49 kg); *unilat* pre-1RM unilateral strength (right= 74.93 ± 7.63 kg; left = 73.27 ± 8.02 kg) compared to the *unilat* post-1RM unilateral strength (right = 81.59 ± 11.07 kg; left = 83.26 ± 10.84 kg). There was a change of 12.05% and 9.68% (right + left limbs) from pre- to post-testing in the *bilat* and *unilat* conditions, respectively.

DISCUSSION

The aim of this investigation was to consider the potential benefits of bilateral training as compared to unilateral training on 2 training variables: leg press strength and vertical jump height. Our results indicated that there is not a significant effect of physiologic adaptation between bilateral and unilateral training conditions, suggesting that neither training approach is uniquely beneficial over the other. With this in mind, it may be ideal to choose the training approach that best suits the individual athlete. Bilateral training will take a few training

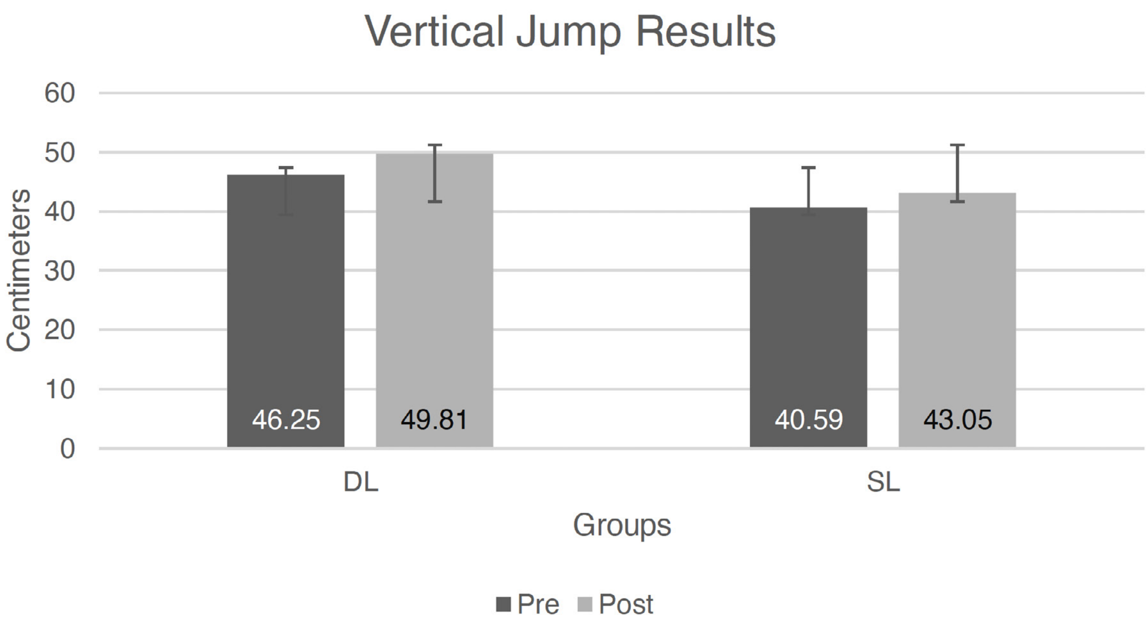

Figure 1. The above figure displays results from pre- and post-testing vertical jump assessments. "DL" represents the *bilat* group and "SL" represents the *unilat* group.

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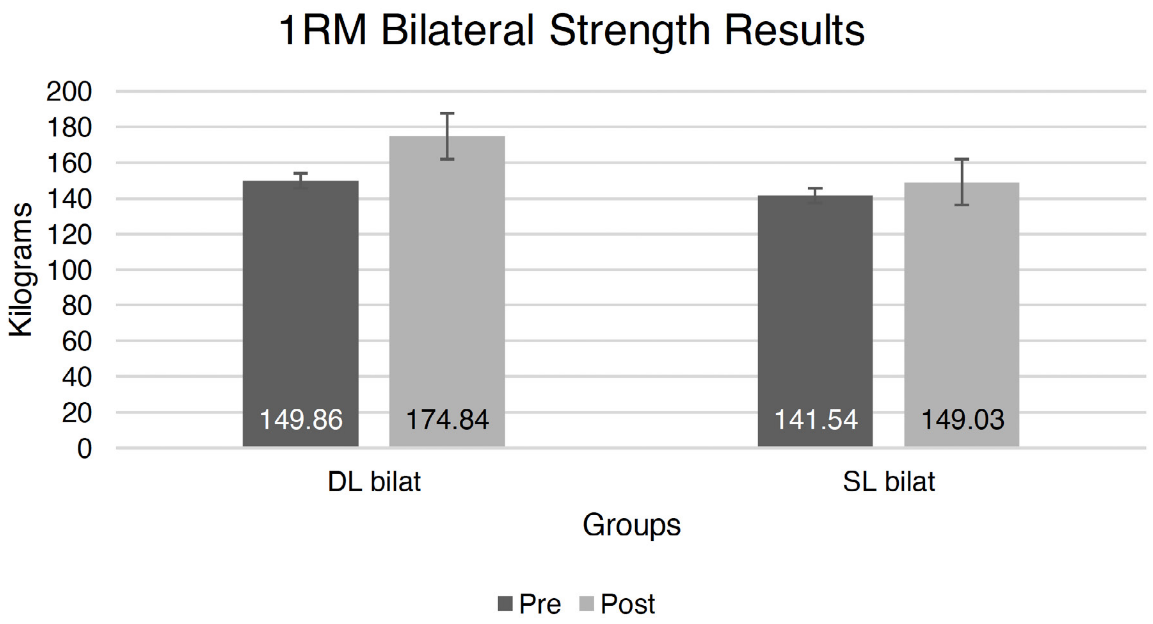

Figure 2. The above figure displays results from pre- and post-bilateral 3RM max testing. "DL bilat" refers to the *bilat* group and "SL bilat" refers to the *unilat* group.

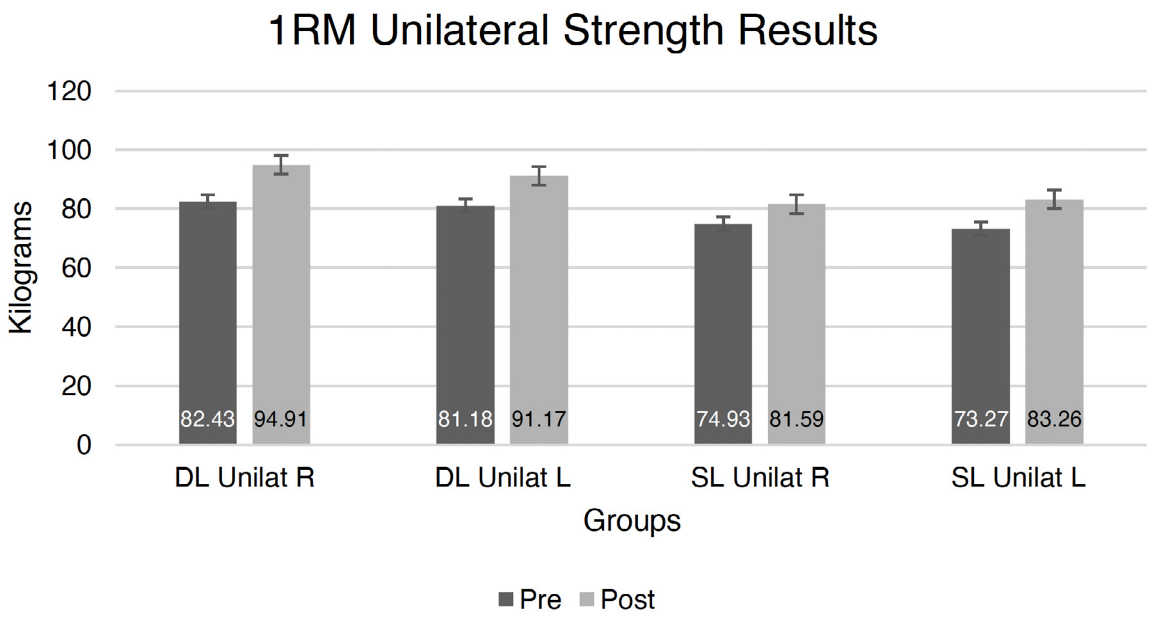

Figure 3. The above figure displays results from pre- and post-3RM testing for both groups in right and left legs. "DL Unilat R" refers to the *bilat* group's right leg, "DL Unilat L" refers to the *bilat* group's left leg, "SL Unilat R" refers to the *unilat* group's right leg, and "SL Unilat L" refers to the *unilat* group's left leg.

sets to complete, and may therefore be preferable to those with limited timeframes for exercise. Unilateral training will require lower absolute loads during each set, which may provide a comfortable option for those training for prevention or recovery of injuries. These results lend credence to the idea that personal preference has a role to play in exercise selection, as the variation in exercise selection did not result in a palpable difference in training outcomes.

Though not in total agreement with prior research, our results are not entirety dissimilar either. A 2022 meta-analysis concerned with uni- and bilateral vertical jump height and strength adaption found that unilateral training was superior in developing unilateral jump performance, but not unilateral strength; whereas bilateral training was superior for developing bilateral strength, but not bilateral jump performance (Hughes et al. 2018). The authors similarly go on to conclude that athletes may wish to choose variations that are in accordance with

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their preference and available equipment. Given the marginal differences in performance outcomes, adherence and effort are likely to be far more important variables than the uni- or bilateral status of an exercise, and we correspondingly arrive upon a similar conclusion as the previously mentioned authors (Liao et al. 2022).

Stanford and colleagues (2021) investigated the acute effects of unilateral, bilateral, and alternating unilateral repetition schemes on acute responses to blood flow restriction training. Electromyographic (EMG) analysis showed no difference in muscle excitation between uni- and bi-lateral exercise, although the alternating exercise was found to produce a lower amount of excitation than the other two repetition schemes. Rather than to a factor of the scheme itself, the researchers attribute this to the inclusion of rest intervals in the data recording, while the uni- and bilateral exercise did not contain these periods of no activity. The authors suggest that, in light of the similarity of results between the groups, this may indicate that uni- and bi-lateral rep schemes may be preferable due to the greater time cost of alternated rep training (Stanford et al. 2021). These results lend further credence to our own conclusions that choosing uni- and bi-lateral training depends on the preference of the athlete, as both yield similar training adaptations.

Jacksteit and colleagues (2021) investigated the use of continuous passive motion (CPM), as current standard of care, versus low-load resistance training (LLRT) using continuous active motion (CAM) unilaterally and bilaterally in early post-op total knee arthroplasty (TKR). It was found that both unilateral and bilateral CAM groups were superior to the CPM group at post-test with the bilateral group showing greater differences than unilateral in knee flexion, knee extension, reduced swelling, and timed-up-and-go tests. In both CAM groups, research showed decreased levels of swelling and C-reactive protein compared to the CPM group showing effects of resistance training's anti-inflammatory effects. Investigators hypothesized that the differences between bilateral and unilateral groups can be attributed to cross education between limbs when training bilaterally with changes in the neuromuscular system while also reducing muscle atrophy in the unaffected leg (Jacksteit et al. 2021). Although these results do not align with our own study, this research sheds light on the rehabilitative effects of bilateral and unilateral training compared to the standard-of-care protocols within the injured population compared to our own research better fitted for the athletic population.

Eliassen and colleagues (2018) investigated bilateral versus unilateral squats of the same external load and their effects on muscle activity, kinetics, and barbell kinematics in experienced resistance trained participants. Peak vertical ground reaction force was greater in the unilateral than the bilateral squats. Furthermore, it was found that there was no significant differences in quadricep, biceps femoris, and erector spinae EMG activity between both unilateral and bilateral squats (Eliassen et al. 2018). The findings from this investigation can be left to interpretation for the reader and the choice of unilateral versus bilateral squats can come down to the preference of the lifter.

Our investigation has several limitations of note. The particular leg press machine available for use had only 20-pound weight increments, meaning that the loads used to calculate 1RM were imprecise. This impacted the investigation as some participants' training loads were further from their calculated training resistance than others', creating dissimilar relative effort of some participants. This was addressed in part by the addition of a weighted plate onto the weight stack, although this still could not produce complete precision and variance between participants' relative loading still existed during the training. All participants remained within their volume ranges, and loads were the nearest possible to the prescribed intensity for each respective training session. Furthermore, the time constraints of the academic semester allowed for only 4 total training weeks. This timeframe may not have been sufficient to produce statistically significant training adaptations in our participants, as strength adaptations appear to require 8 weeks to manifest to a significant degree (Hughes et al. 2018). If there were differential effects between training conditions, significant imparity may not have had sufficient time to appear. In addition, our study was conducted on a relatively small college campus, and this was reflected in the similarly small sample size of participants. With a small sample size, it is possible that a small number of participants with anomalous results may sway the net results of our study. Furthermore, the relative effort of our participants was not gauged beyond their projected 1RM-based training loads, creating further possibility for differential strength adaptations. Our participants were of various training backgrounds, which will impact their individual potential for adaptation within the study, as those who are seasoned athletes will have less total room for growth than those who may be untrained by comparison. We

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did not prevent participants from engaging in physical activities that they had a commitment to prior to initiation of our study, which may have impacted the efficacy of the allotted rest intervals programmed into our procedure. Lastly, while we instructed our participants to maintain similar body mechanics (foot placement, hip and knee angle) in their bilateral and unilateral exercise sessions, we did not have a mechanism through which we may force this to occur, allowing for possible changes of mechanical advantage gained through alteration of body posture.

Future investigations of this topic would benefit from an apparatus that prevents potentially advantageous changes in body posture so as to isolate the bilateral/unilateral variable more reliably. In addition, a machine that allows for greater precision when selecting training loads would allow for greater adherence to target training intensities, as well as to gain greater accuracy in 1RM test results. Lastly, future research would ideally have a larger sample size, and last for 8 or more weeks to tease out potentially significant training effects.

PRACTICAL APPLICATIONS

Bilateral and unilateral exercises appear to have a similar magnitude of effect in regards to strength and power development. In keeping with these results, it may be advisable to choose a variation that is more preferable to the athlete, as adherence to the exercise protocol will likely be of greater importance to physiologic adaptation than the bilateral/unilateral status of the chosen exercises.

REFERENCES

1. Benjamini Y, Hochberg Y (1995) Controlling the false discovery rate: a practical and powerful approach to multiple testing. J R Stat Soc Series B 57(1):289-300
2. Bobbert MF, de Graaf WW, Jonk JN, et al (2006) Explanation of the bilateral deficit in human vertical squat jumping. J Appl Physiol 100(2):493–499. https://doi.org/10.1152/japplphysiol.00637.200
3. DiStasio TJ (2014) Validation of the Brzycki and Epley equations for the 1 repetition maximum back squat test in division I college football players. Master's thesis, Southern Illinois University, Carbondale
4. Eliassen W, Saeterbakken AH, van den Tillaar R (2018). Comparison of bilateral and unilateral squat exercises on barbell kinematics and muscle activation. Int J Sports Phys Ther. 13(5):871–881. https://doi.org/10.26603/ijspt20180871
5. Haff G, Triplett NT (2021) Essentials of Strength Training and Conditioning. Champaign, IL: Human Kinetics
6. Hoffman J (2012) Athlete Testing and Program Evaluation. In NSCA's Guide to Program Design. Champaign, IL: Human Kinetics
7. Hughes DC, Ellefsen S, Baar K (2018) Adaptations to endurance and strength training. Cold Spring Harb Perspect Med 8(6):a029769. https://doi.org/10.1101/cshperspect.a029769
8. Jacksteit R, Stöckel T, Behrens M, Feldhege F, Bergschmidt P, Bader R, Mittelmeier W, Skripitz R and Mau-Moeller A (2021) Low-load unilateral and bilateral resistance training to restore lower limb function in the early rehabilitation after total knee arthroplasty: a randomized active-controlled clinical trial. Front. Med. 8:628021. doi: 10.3389/fmed.2021.628021
9. Liao KF, Nassis GP, Bishop C, et al (2022) Effects of unilateral vs. bilateral resistance training interventions on measures of strength, jump, linear and change of direction speed: a systematic review and meta-analysis. Biol Sport 39(3):485–497. https://doi.org/10.5114/biolsport.2022.107024
10. Marine Corps Community (n.d.) Repetition Max Protocol. https://www.usmc-mccs.org/ mccs/assets/File/PDFs/3%20Repetition%20Max%20Protocol.pdf. Accessed 27 January 2023
11. Simoneau-Buessinger E, Leteneur S, Toumi A, et al (2015) Bilateral strength deficit is not neural in origin; rather due to dynamometer mechanical configuration. PloS One 10(12):e0145077. https://doi.org/10.1371/journal.pone.0145077
12. Stanford, D.M., Park, J. & Jessee, M.B. Unilateral, bilateral, and alternating muscle actions elicit similar muscular responses during low load blood flow restriction exercise. Eur J Appl Physiol 121, 2879–2891 (2021). https://doi.org/10.1007/ s00421-021-04757-7
13. van Dieen JH, Ogita F, De Haan A (2003) Reduced neural drive in bilateral exertions: a performance-limiting factor? Med Sci Sports Exerc 35(1):111–118. https://doi.org/ 10.1097/00005768-200301000-00018
14. Železnik P, Slak V, Kozinc Ž, et al (2022) The association between bilateral deficit and athletic performance: a brief review. Sports 10(8):112. https://doi.org/10.3390/sports10080112

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