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Effects of a six-week hip thrust versus front squat resistance training program on performance in adolescent males: A randomized-controlled trial

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Running head: Squat vs. hip thrust training study

ABSTRACT

The barbell hip thrust may be an effective exercise for increasing horizontal force production and may thereby enhance performance in athletic movements requiring a horizontal force vector, such as horizontal jumping and sprint running. The ergogenic ability of the squat is well known. The purpose of this study was to compare the effects of six-week front squat and hip thrust programs in adolescent male athletes. Vertical jump height, horizontal jump distance, 10 m and 20 m sprint times, and isometric mid-thigh pull peak force were among the measured performance variables, in addition to front squat and hip thrust three-repetition maximum (3 RM) strength. Magnitude-based effect-sizes revealed potentially beneficial effects for the front squat in both front squat 3 RM strength and vertical jump height when compared to the hip thrust. No clear benefit for one intervention was observed for horizontal jump performance. Potentially beneficial effects were observed for the hip thrust compared to the front squat in 10 m and 20 m sprint times. The hip thrust was likely superior for improving normalized isometric mid-thigh pull strength, and very likely superior for improving hip thrust 3 RM and isometric mid-thigh pull strength. These results support the force vector theory.

Keywords: squat; hip thrust; sprint performance; jump performance; vertical jump; horizontal jump; force vector theory; hip extension; Resistance training

INTRODUCTION

The barbell hip thrust, introduced in the literature by Contreras et al. (13), is a loaded bridging exercise used to target the hip extensor musculature, which includes the gluteus maximus and hamstrings. Because the hip thrust requires consistent hip extension moment production throughout its entire range of motion, it may effectively enhance horizontal force production, improve sprint-running speed, and promote gluteus maximus hypertrophy (4, 13, 18, 19). The consistent hip extension moment requisites of the hip thrust may play a crucial role in transference, as it has been theorized that hip extension moment-angle curves play a role in transfer to athletic performance, such as sprint running (16). Furthermore, because the hip thrust is performed such that the force vector is anteroposterior relative to the human body (Figure 1), the force vector hypothesis states that it may better transfer to sports that are dependent upon horizontal force production, because, when standing, horizontal force vectors are anteroposterior. Sprinting is particularly relevant in this context, as horizontal force, horizontal force times horizontal velocity (often misappropriated as ‘horizontal power’), and horizontal impulse have strong associations with sprint running, both at maximal speed and during acceleration (7, 8, 35). Randell et al. (41) proposed that training adaptations may be direction-specific, and that anteroposteriorly-loaded exercises may transfer better to horizontal force production, and vice-versa for axially loaded exercises. To date, only one study has investigated the effects of the hip thrust exercise on performance (34). The hip thrust was incorporated into an intervention program consisting of free sprints, sled towing, single leg exercises, Nordic hamstring curls, and horizontal plyometrics, although very light loads were utilized in the hip thrust (50-70% of bodyweight for 2-3 sets of 6-8 reps) (34). The intervention group displayed superior increases in accelerating sprint running ability (over 5 m) and both concentric and eccentric isokinetic knee flexion force compared to the control group (34).

Insert Figure 1 about here.

The squat is one of the most well-studied and utilized exercises in strength and conditioning. A recent meta-analysis on the squat found that increases in back squat strength transfer positively to sprint performance (*r* = -0.77) (43). These data are not surprising, as there is a strong relationship between relative squat strength and sprint performance (11, 42). Nevertheless, it is important to note that the hip extension moment requisites of a squat decrease throughout the ascending concentric range of motion (6), suggesting that squats might not be as beneficial for developing end-range hip extension strength as exercises that do emphasize such a range of motion. Moreover, the previously described data on the relationship between squat strength and sprinting performance may not be applicable to all athletes. Research on American football players has shown that increases in squat and vertical jump performance are unaccompanied by an increase in sprint running speed (26, 29). Similarly, many training studies involving squats have consistently shown improvements in vertical jump (9, 25, 39, 47). Since the squat has an axial force vector and the hip thrust has an anteroposterior force vector, it is possible that the hip thrust has stronger transference to sprint running, while the squat has stronger transference to the vertical jump. This is important, as the identification of how different exercises transfer optimally to sport performance is paramount for strength and conditioning exercise selection. Deep front squats and deep back squats have both been shown to lead to larger vertical jump improvements than shallow squats (24). And yet, both the front squat and back squat have been shown to have similar muscle activation and hip moments (21, 51). On the other hand, the hip thrust appears to activate the hip extensor musculature to a greater extent than the back squat (14).

Research examining specificity has shown that during one-repetition maximum (1 RM) testing, training specificity is a primary factor (37, 48). In other words, those more familiar with the 1 RM test or exercise are likely to perform better during that specific 1 RM test. Thus, it is likely that the group training a specific movement will have an advantage during 1 RM testing for that movement. Nagano et al. (38) described how both horizontal and vertical jumps require similar quadriceps and gluteus maximus involvement, which are both targeted during the squat and hip thrust (14). The isometric mid-thigh pull is one measure that appears to have implications for sport performance, during which, the athletes' chosen body position has knee and hip angles of 133º and 138º, respectively (12).

Therefore, the purpose of this study was to compare the effects of six-week hip thrust and front squat training programs on 10 m and 20 m sprint times, horizontal jump distance, vertical jump height, isometric mid-thigh pull performance, and both 3 RM front squat and 3 RM hip thrust strength in adolescent males. It was hypothesized that (1) the hip thrust group would improve 3 RM hip thrust to a greater extent than the front squat group, due to specificity; (2) the front squat group would improve 3 RM front squat to a greater extent than the hip thrust group, due to specificity; (3) the hip thrust group would improve 3 RM front squat, but not as much as the front squat group; (4) the front squat group would improve 3 RM hip thrust, but not as much as the hip thrust group; (5) the hip thrust group would improve 10 m and 20 m sprint times to a greater extent than the front squat group, as hip thrusts elicit greater gluteus maximus and hamstrings activation; (6) the front squat group would improve vertical jump better than the hip thrust group, as the front squat involves a vertical load vector and displays greater quadriceps activation; (7) both groups would improve horizontal jump distance to a similar degree, as the horizontal jump utilizes both vertical and horizontal external force vectors and display similar levels of gluteus maximus and quadriceps activity; and (8) both groups would improve the isometric mid-thigh pull force to a similar degree, as both the quadriceps and gluteus maximus are heavily relied upon.

Methods

Experimental Approach to the Problem

This was a single-center, investigator-blinded, parallel-group, randomized-controlled trial with equal randomization (1:1). Each group was assigned to perform the hip thrust or front squat twice per week for six weeks, for a total of 12 sessions. Performance variables were collected prior to, and following, the six-week training period.

Subjects

Eligible participants were all adolescent athletes, ages 14 to 17, and were enrolled in a New Zealand rugby and rowing athlete development program (Table 1). All subjects had one year of squatting experience and no hip thrusting experience. An *a priori* power analysis was performed for increases in acceleration ($\alpha = 0.05$; $\beta = 0.80$; Cohen's $d = 2.44$) (30), and it was determined that at least 8 subjects (4 for each group) would be adequate to observe decreases in 10 m sprint times; however, in order to maximize statistical power, a convenience sample of 28 subjects (14 for each group) were recruited. All subjects and their legal guardians were required to complete Informed Consent and Assent forms, in addition to a Physical Activity Readiness

Questionnaire (PAR-Q). All subjects were healthy and injury-free at the commencement of training. This study was approved by the Auckland University of Technology Ethics Committee.

Table 1 about here.

Procedures

On the first day, subjects completed the necessary forms (Informed Consent, Assent, PAR-Q) and completed a familiarization protocol for the hip thrust and isometric mid-thigh pull. Three days later, subjects performed a 10-minute lower body dynamic warm-up before undertaking baseline testing. This included the recording of physical characteristics before progressing to measurement of vertical jump, horizontal jump, and sprinting. On the second day, after the 10-minute lower body dynamic warm-up, the subjects' front squat and hip thrust 3 RM were assessed followed by their isometric mid-thigh pull.

Familiarization Protocol

Three days before baseline testing, familiarization protocols were completed for the hip thrust and isometric mid-thigh pull, as the subjects were not familiar with these movements or testing procedures. For the hip thrust, subjects performed sets with 10, 6, and 4 repetitions with 20, 40, and 60 kg, respectively. Isometric mid-thigh pull familiarization was completed by having subjects perform three, five second pulls of increasing intensity (50, 70, and 90%) with thirty seconds between each pull; finally, a five second isometric mid-thigh pull was performed at 100% intensity.

Dynamic Warm-up

A 10-minute lower body dynamic warm-up was employed, consisting of two sets of 10 repetitions of the following movements: standing sagittal plane leg swings, standing frontal plane leg swings, body weight squats, and hip thrusts. Herein, all references to a 10-minute lower body dynamic warm-up refer to this procedure.

Vertical & Horizontal Jumps

Vertical jump height was measured by calculating the difference between standing reach height and maximum jump height from a Vertec (Jump USA, Sunnyvale, CA, USA). Horizontal jump distance was measured by calculating the difference between the starting heel position and the landing heel position of the most rearward landing foot, measured using a tape measure. The vertical and horizontal jumps were performed using a countermovement jump with arm swing; that is, athletes were allowed to flex at the hips, knees, and ankles to a self-selected depth in order to utilize the stretch-shortening cycle during triple extension. Subjects were given three trials for each test, separated by three minutes of rest. The highest and farthest jumps from the three trials of each respective jump were analyzed.

Sprinting Performance

Following the vertical and horizontal jump testing, subjects were given 10 minutes rest before performing 20 m sprint testing. Three warm-up 20 m sprint trials at approximately 70, 80, and 90% of maximum sprinting speed were performed prior to testing. Data was collected using three sets of single beam timing lights (SmartSpeed, Fusion Sport, Coopers Plains, Australia), placed at 0 (start), 10 m, and 20 m distances, respectively, wherein 0–10 m and 0–20 m split times from the fastest 20 m trial were used for analysis. All timing lights were set to a height of 60 cm (17). The subjects were required to start in a split stance 50 cm behind the first set of timing lights. Subjects were given three, 20 m sprint trials separated by five minutes.

Front Squat and Hip Thrust 3 RM Strength Testing

Subjects first performed a 10-minute lower body dynamic warm-up. First, three progressively heavier specific warm-up sets were performed (~60, 70 and 80% of predicted 3 RM), for the front squat, followed by two to three sets of 3 RM testing sets. 3 RM was chosen over 1 RM due to safety concerns. During the front squat, subjects' feet were slightly wider than shoulder width apart, with toes pointed forward or slightly outward. Subjects descended until the tops of the thigh were parallel with the floor (40). After 10 minutes of rest, subjects performed three progressively heavier specific warm-up sets for the barbell hip thrust. In accordance with Contreras et al. (13), the barbell hip thrust was performed by having subjects' upper backs on a bench. Subjects' feet were slightly wider than shoulder width apart, with toes pointed forward or slightly outward. The barbell was padded with a thick bar pad and placed over the subjects' hips. Subjects were instructed to thrust the bar upwards while maintaining a neutral spine and pelvis.

Isometric Mid-thigh Pull

Subjects, still warm from strength testing, performed an isometric mid-thigh pull while standing on a tri-axial force plate (Accupower, AMTI, Watertown, MA, USA) within a squat rack sampled at a frequency of 400 Hz. Each subject held onto an adjustable bar using an alternate grip (power grip) that was locked at a height situated halfway between (mid-thigh position) each subject's knee (top of the patella) and top of the thigh (inguinal crease). Each subject was permitted to self-select his own joint angles, so long as the bar was situated halfway between his knee and inguinal crease. On the command “go”, the subjects were instructed to pull the fixed bar “hard and fast” and maintain maximal effort for five seconds, with the intention of generating maximum vertical ground reaction force. Peak vertical ground reaction force was recorded from two trials separated by three minutes of rest. The force-time data were filtered using a second order low-pass Butterworth filter with a cut off frequency of 16 Hz. The maximum force generated during the 5-second isometric mid-thigh pull was reported as the peak force. The highest peak force from both trials was used for analysis. Peak force was used, as it was the most reliable variable (CV = 3.4%; ICC = 0.94). Other variables, such as time-to-peak force (ICC = 0.71; CV = 16%) and average rate of force development (ICC = 0.64; CV = 23%), were unreliable, possibly due to the 400 Hz sampling frequency. For rate-dependent variables, 1000 Hz or higher is recommended (23, 33). Normalized values were normalized to body mass, in kilograms.

Training Protocol

Subjects were matched according to total strength and then randomly allocated to one of two training groups (front squat or hip thrust) via a coin flip. Statistical analysis (*t*-test) was carried out to ensure that there were no statistical differences between groups ($p < 0.05$) in the measured baseline variables (Table 1). For lower body, one group performed front squats only, while the other group performed hip thrusts only. The repetition scheme utilized for the front squat and hip thrust is presented in Table 2. In addition to lower body training, both groups performed upper body and core exercises, consisting of: four sets of incline press or standing military press; four sets of bent over rows, bench pull, or seated rows; and four sets of core exercises for the abdominals/lower back. Each week, on two separate days spaced at least 72 hours apart, the front squat group performed four sets of fronts squats and the hip thrust group performed four sets of hip thrusts in a periodized fashion (Table 2). The aforementioned 10-minute dynamic warm-up followed by three progressively heavier specific warm-up sets was performed prior to each session. Three-minute rest periods in between sets were used throughout the duration of the training. During week one, 60% 3 RM loads were utilized. Loads were increased gradually each week, assuming the subject completed all repetitions with proper form.

Table 2 about here.

Training records were kept in order to analyze loading progressions. During the week following the six weeks of training, post-testing was conducted in the same fashion as the pre-testing. Subjects were instructed to maintain their current diet and to abstain from performing any additional resistance training.

Statistical Analysis

All data were reduced and entered into Stata (StataCorp, College Station, TX), wherein Shapiro-Wilk tests were performed to ensure normality, where $p \leq 0.05$ in a Shapiro-Wilk test is indicative that the data are nonparametric. For normal data, effect sizes (ES) were calculated using Cohen's d (between group: $d = \frac{M_1 - M_2}{s_{pooled}}$, where M_1 and M_2 are the mean changes ($M_{\text{post}} - M_{\text{pre}}$) for each group, and s_{pooled} is the pooled standard deviation of changes from each group; within group: $d = \frac{M_d}{s_d}$, where M_d is the mean difference from pre-to-post and s_d is the standard deviation of differences between subjects), which was defined as small, medium, and large for 0.20, 0.50, and 0.80, respectively (10). The within-group Cohen's *d* better represents changes due to the intervention, as it utilizes within-subject differences rather than between-subject differences (5, 36, 45). For non-normal data, as determined by a *p*-value of less than or equal to 0.05 in the Shapiro-Wilk test, ES were reported in terms of Pearson's *r* ($r = \frac{z}{\sqrt{n}}$, where *z* is the *z*-score from a Wilcoxon signed-rank or rank-sum test, for within- and between-subject comparisons, respectively), which was defined as small, medium, and large for 0.10, 0.30, and 0.50, respectively (10). Ninety percent (90%) confidence limits (CL) of ES were calculated for magnitude-based inferences (28). Ninety percent was used rather than 95% in order to prevent readers from utilizing the CL to re-interpret the results in terms of 'statistical significance'; rather, the 90% CL defines the likely range of the 'true' effect-size (3). Qualitative probabilistic terms were then assigned using the following scale (27): most unlikely, <0.5%; very unlikely, 0.5-5%; unlikely, 5-25%; possibly (or, in the case of between-group comparisons, unclear), 25-75%; likely, 75-95%; very likely, 95-99.5%; and most likely, >99.5%.

Results

Of the 29 athletes recruited for this experiment, a total of 24 athletes completed the training protocol, as three athletes were removed due to non-adherence and two athletes were removed due to injury, not due to the training protocol. Thirteen subjects successfully adhered to the hip thrust protocol and 11 subjects successful adhered to the squat protocol for all six weeks.

Within-Group Outcomes for the Hip Thrust Group

Within the hip thrust group, very likely beneficial effects were observed for 20 m sprint time (Δ = −1.70%; *d* = 1.14 (0.67, 1.61)); peak force during the isometric mid thigh-pull (Δ = +9.27%; *d* = 1.01 (0.52, 1.51)); and 3 RM hip thrust strength (Δ = +29.95%; *d* = 2.20 (1.71, 2.69)). A likely beneficial effect was observed for the normalized peak force during the isometric mid-thigh pull, which increased by 7.12% (*d* = 0.77 (0.27, 1.27)). Possibly beneficial effects were observed for 3 RM front squat strength (Δ = +6.63%; *d* = 0.64 (0.15, 1.13)); vertical jump (Δ = +3.30%; *d* = 0.43 (−0.07, 0.93)); horizontal jump (Δ = +2.33%; *d* = 0.51 (0.02, 1.00)); and 10 m sprint times (Δ = −1.06%; *d* = 0.55 (0.06, 1.04)) (Figure 2, Table 3).

Figure 2 about here.

Within-Group Outcomes for the Front Squat Group

Within the front squat group, most likely beneficial effects were observed for 3 RM front squat strength (Δ = +11.39%; *d* = 1.66 (1.10, 2.22)) and 3 RM hip thrust strength (Δ = +17.40%; *d* = 1.59 (1.03, 2.15)). A very likely beneficial effect was observed for vertical jump height, which increased by 6.81% (*d* = 1.11 (0.56, 1.66)). A likely beneficial effect was observed for horizontal jump (Δ = +1.69%; *r* = 0.39 (−0.17, 0.76)). Possibly beneficial effect was observed for peak force (Δ = +1.87%; *r* = 0.32 (−0.24, 0.72)) and normalized peak force (Δ = +1.94%; *r* = 0.27 (−0.30, 0.69)) during the isometric mid-thigh pull. Lastly, unlikely beneficial effects were observed for 10 m (Δ = +0.10%; *d* = −0.02 (−0.54, 0.40)) and 20 m (Δ = –0.67%; *d* = 0.19 (−0.34, 0.72)) sprint times (Figure 3, Table 3).

Figure 3 about here.

Between-Group Comparisons

For all between-group comparisons, a positive ES favors the hip thrust. Between the front squat and hip thrust groups, both the vertical jump (*d* = −0.47 (−1.20, 0.23)) and front squat 3 RM strength squat (*d* = −0.55 (−1.25, 0.15)) possibly favored the front squat. It is unlikely that one intervention was better than the other for improving horizontal jump (*d* = 0.15 (−0.57, 0.87)). Changes in both 10 m (*d* = 0.32 (−0.39, 1.03)) and 20 m (*d* = 0.39 (−0.31, 1.09)) sprint times possibly favored the hip thrust. Changes in normalized peak force during the isometric mid-thigh pull strength were likely superior in the hip thrust (*r* = 0.28 (−0.07, 0.57)). Lastly, very likely benefits to the hip thrust were observed in both hip thrust strength (*d* = 1.35 (0.65, 2.05)) and peak force during the isometric mid-thigh pull (*r* = 0.46 (0.14, 0.69)) (Figure 4, Table 3).

Figure 4 about here.

Table 3 about here

Discussion

The purpose of this study was to examine and compare the effects of a six-week squat or hip thrust program on performance measures in male adolescent athletes. Hip thrust within-group analyses revealed possibly to most likely beneficial effects for all outcomes. The large effect size noted for hip thrust strength changes (*d* = 2.20) is in line with the principle of specificity. Clearly beneficial effects for the hip thrust group to improve front squat strength were noted (*d* = 0.64). Because the hip thrust has been shown to elicit similar quadriceps EMG amplitude as compared to, and greater hip extensor EMG amplitude than, the squat, these results are intuitive (14). The decreases in 10 m (*d* = 0.55) and 20 m (*d* = 1.14) sprint times are in line with the force vector hypothesis, as the hip thrust likely develops an anteroposterior force vector, and sprint performance is highly correlated with horizontal force output, which is directed anteroposteriorly (35). Clearly beneficial effects in peak force during the isometric mid-thigh pull (*d* = 1.02; Normalized *d* = 0.77) were observed as hypothesized. These effects are likely due to the position-specific adaptations of end-range hip extension, which is required during the isometric mid-thigh pull, in addition to the high EMG amplitudes of the hip and knee extensors during the hip thrust (14). Lastly, possibly beneficial effects in vertical (*d* = 0.43) and horizontal (*d* = 0.51) jump measures were observed, but with small-to-medium ES. These outcomes are likely due to the ability of the hip thrust to place mechanical demands on the hip and knee extensors (14). Additionally, large horizontal impulses are needed for horizontal jump distance (50), so the anteroposterior force vector employed in the hip thrust may be beneficial for improving horizontal force when upright, and thus, potentially horizontal impulse production, if time components do not change (or increase).

Numerous within-group effects were observed in the front squat group. As per our hypotheses, increases in both front squat (*d* = 1.66) and hip thrust (*d* = 1.59) 3 RM were observed. These increases are likely due to the front squat's hip and knee extension moment requisites (22), which require activation of the hip and knee extensors (15), and as per previous research by our group, both the squat and hip thrust utilize the hip and knee extensors to a significant degree (14). In addition, likely and very likely beneficial effects were observed for both horizontal (*r* = 0.39) and vertical (*d* = 1.11) jumps, respectively. The axial force vector of the front squat may have helped subjects develop larger vertical force during jumping, thus increasing vertical impulse, which is directed axially and is a key factor for both horizontal (50) and vertical (1, 49) jumps. However, this cannot be said for certain, as propulsion times were not measured. Likely and very likely beneficial improvements in both peak force ($r = 0.32$) and normalized peak force ($r = 0.27$) during the isometric mid-thigh pull, respectively, were also observed. Again, these adaptations may be due to the vertical force vectors of both the front squat and isometric mid-thigh pulls. It is surprising, however, that the front squat only elicited unclear or trivial effects in 10 m ($d = –0.02$) and 20 m ($d = 0.19$) sprint performance, as previous research has shown the squat to be an effective intervention for increasing speed (43).

The primary purpose of this investigation was to compare the two interventions, the front squat and barbell hip thrust, on the aforementioned performance outcomes. Possibly beneficial effects for the hip thrust were noted for 10 m ($d = 0.32$) and 20 m ($d = 0.39$) sprint times, which provides further support for the force vector theory. The hip thrust was also very likely beneficial in increasing hip thrust 3 RM strength ($d = 1.35$) and peak force during the isometric mid-thigh pull ($r = 0.46$), while likely beneficial effects were observed for normalized peak force during the mid-thigh pull ($r = 0.28$). While the former was to be expected, as per the principle of specificity, the latter result was unexpected, as the isometric mid-thigh pull utilizes a vertical external force vector. This may have to do with the hip extension moment requisites of the isometric mid-thigh pull, which the hip thrust may be more effective in improving. As per our hypotheses, the front squat was possibly beneficial for improving vertical jump ($d = –0.47$) and front squat 3 RM strength ($d = –0.55$) over the hip thrust, which also supports the force vector theory. Lastly, as per our hypothesis, no clear effect was observed for horizontal jump performance (*d* = 0.15). This may be because both horizontal and vertical components are important for the horizontal jump (50). The anteroposterior external force vector utilized in the hip thrust would thus translate to the horizontal external force vector in the horizontal jump, while the axial external force vector utilized in the front squat would carry over to the vertical external force vector in the horizontal jump. Because kinetic analyses were not performed during the jump, this cannot be said for certain and requires further investigation.

To the authors' knowledge, only one other study has demonstrated transfer from one resisted hip extension exercise to another. Speirs et al. (46) investigated the transfer from unilateral (Bulgarian split squats) to bilateral (back squats) hip extension exercises, and vice versa, in addition to their effects on performance. Both exercises were found to have carryover and improve performance. The observed effects in this study were quite fascinating in that each group gained about half that of their exercise-specific counterpart. In other words, for front squat 3 RM strength, the front squat group increased by 11.4% and the hip thrust group increased 6.63%. This effect was also noticed for hip thrust 3 RM strength (+30.0% (hip thrust group) versus 17.4% (front squat group)).

In both groups, absolute hip thrust 3 RM strength and changes in hip thrust 3 RM were much greater than absolute front squat 3 RM strength and changes in front squat 3 RM. The front squat group increased their hip thrust 3 RM by 23.5 ± 14.7 kg (111 ± 20.9 – 134 ± 11.2 kg), while their front squat 3 RM increased by 9.64 ± 5.80 kg (75.0 ± 10.4 – 84.6 ± 10.0 kg). The differences in the hip thrust group were even more pronounced, in that their front squat 3 RM increased by 5.50 ± 8.53 kg (77.6 ± 12.3 – 83.1 ± 13.7 kg), while their hip thrust 3 RM increased by 49.5 ± 22.4 kg (115 ± 23.5 – 165 ± 33.0 kg). These differences are likely due to the nature of the hip thrust exercise, in that there is more stability and decreased coordination requirements. However, a full kinetic analysis of the hip thrust is needed for further insight.

The front squat's ability to increase vertical jump height is quite intuitive, as both the front squat and vertical jump utilize the same external force vector direction (vertical). Additionally, the substantial utilization of the quadriceps in both the front squat and vertical jump (22, 31, 51) demonstrates a possible underlying mechanism for beneficial vertical jump adaptations (6). Lastly, a qualitative analysis of both movements reveals that they are similar in nature. On the other hand, the effects on horizontal jump distance are rather surprising, as it was hypothesized that squats and hip thrusts would lead to similar improvements in this test due to the large vertical and horizontal force and impulse requirements of the task (32, 50). However, despite clear strength gains in axially- and anteroposteriorly-oriented lower body exercises, neither group saw statistical or clearly beneficial improvements in horizontal jump performance.

It is surprising that, although squats have been shown to improve sprint performance (43), no clear effects were observed in the front squat group for sprint performance. It cannot be said whether this is due to the short duration of training (six weeks) as weight training has previously been shown to improve 10 m sprint times in the same six-week period (30), and because a moderate, possibly beneficial effect was observed in the hip thrust group. While it is surprising that the front squat did not decrease 20 m times, the effects of the hip thrust make sense, as anteroposterior (or horizontal, in the case of the sprint) force production is a key component in sprint performance (7, 8, 35), and the hip thrust is an anteroposterior forcedominated movement. These findings are in line with what Randell et al. (41) proposed, in that horizontal-dominated movements have better carryover to horizontal-dominated activities, while vertical-dominated movements have better transference to vertical-dominated activities. On a musculoskeletal level, this may be due to the ability of the hip thrust to recruit the hip extensor musculature (14). Furthermore, the hip thrust has a hip extension moment requisite throughout the entire range of motion, including end-range hip extension, whereas the hip extension moment requisites of the front squat decrease as one approaches full hip extension. In other words, the hip thrust is more hip-dominant than the front squat.

Hip thrust training resulted in greater improvements in the isometric mid-thigh pull peak force compared to squat training, even though the pull involved a vertical force vector. It is proposed that this is due to the hip extension moment-angle curves of the squat versus that of the hip thrust, in that the hip thrust likely has a greater hip extension moment requisite at the angle at which the isometric mid-thigh pull is performed, but these joint-specific kinetic hypotheses require further investigation.

There are a number of limitations that must be borne in mind when interpreting the results from this study. Adolescent males have changing hormone levels and a large number of life stressors (2, 44). Therefore, these results cannot be extrapolated to other populations, such as female or adult populations. Second, the short, six-week duration (12 total sessions) of this study may not have been enough time to elicit adequate, observable results. This short time span may not be adequate for a squat program, as it requires more coordination than the hip thrust, which is easier to learn since it requires less stability. Third, although front squats were only performed to parallel, deeper squats tend to elicit greater adaptations (6). This study also dichotomized exercise selection, and it is very likely that a combined group would have the “best of both worlds,” or the benefits from both axial- and anteroposterior-specific training. The sprinting measured during this trial was of short distance (10 m and 20 m), which is the early phase of acceleration. It is possible that with longer distances, different observations may have been made. For example, one group may have increased their top speed but not acceleration, thus leading to lower sprint times at 100 m but not 20 m.

Future research should duplicate these methods in other populations, such as females, adults, and athletes from various sports. In addition, these findings cannot necessarily be extrapolated to those without squatting experience and with hip thrusting experience, as novelty may bias the hip thrust. Further, finding a proper protocol to maximize transference is imperative, as, for example, light, explosive hip thrusts may be better for improving power production, but heavy hip thrusts may be better for improving the contribution of the hip joint to horizontal force production. The dichotomization of exercise selection in this study must be eliminated from future research, as combining exercises tends to elicit greater adaptations than one exercise (20). Determining the transfer of these movements to other movements, such as the transfer of the squat or hip thrust to the deadlift would be helpful for program design purposes. As previously noted, a joint kinetic analysis of the hip thrust to compare to existing analyses on the squat is needed, as this may reveal biomechanical mechanisms for adaptation. Lastly, the hip thrust should be compared to different squat variations, such as the back squat.

Practical Applications

In line with previous literature, specificity is critical for improving the strength in a lift. This indicates that athletes that participate in sports like basketball and volleyball, which are predicated on vertical jump, may benefit more from the front squat rather than the hip thrust. However, in sports such as rugby and American football, it may be more beneficial for athletes to perform the hip thrust, due to its carryover to acceleration. Because the hip thrust does seem to increase front squat performance, it is possible that the hip thrust may be a viable option to perform during times of injury in order to maintain or increase front squat strength. The direction of the resistance force vector relative to the body appears to play a role in transference, in that axially-resisted movements (front squat) appear to better transfer to vertical-based activities (vertical jump), and anteroposterior-resisted movements (hip thrust) appear to better transfer to horizontal-based activities (20 m sprint). The carryover of the hip thrust to peak isometric mid-thigh pull force is indicative that the hip thrust may have carryover to deadlift lockout, even though the positions are slightly different. Lastly, it is likely best to perform a combination of movements rather than just one; it is recommended that athletes incorporate both the squat and hip thrust for complementary improvements in performance. Future studies are needed in adults and female populations, as these findings cannot be extrapolated.

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Figure 1. Hip thrust technique.

Figure 2. Within-subject effect sizes (Cohen's *d* ± 90% CL) following six weeks of hip thrusting.

Figure 3. Within-subject effect sizes (ES ± 90% CL) following six weeks of front squatting. Black diamond = Cohen's *d*, open diamond = Pearson's *r*.

Figure 4. Magnitude-based effect sizes (ES ± 90% CL) of performance measures. Black diamond = Cohen's *d,* open diamond = Pearson's *r*.

Table 1. Comparison of baseline characteristics of the front squat and hip thrust groups.

	Hip Thrust	**Front squat**	***p*-value**
Age (years)	15.49 ± 1.16	15.48 ± 0.74	0.980
Height (cm)	178.73 ± 5.02	181.61 ± 5.51	0.194
Body mass (kg)	78.32 ± 12.47	81.16 ± 12.37	0.582
Vertical jump (cm)	56.31 ± 8.44	52.27 ± 8.40	0.255
Horizontal jump (m)	2.33 ± 0.20	2.28 ± 0.24	0.611
10 m sprint (s)	1.76 ± 0.07	1.79 ± 0.08	0.244
20 m sprint (s)	3.13 ± 0.13	3.16 ± 0.14	0.493
Hip thrust (kg)	115.85 ± 23.53	111.36 ± 20.99	0.630
Front squat (kg)	77.57 ± 12.38	75.00 ± 10.49	0.592
Isometric mid-thigh pull (N)	2554.31 ± 419.03	2683.18 ± 258.35	0.386
Isometric mid-thigh pull (normalized) (N/kg)	32.84 ± 4.39	33.41 ± 3.37	0.729

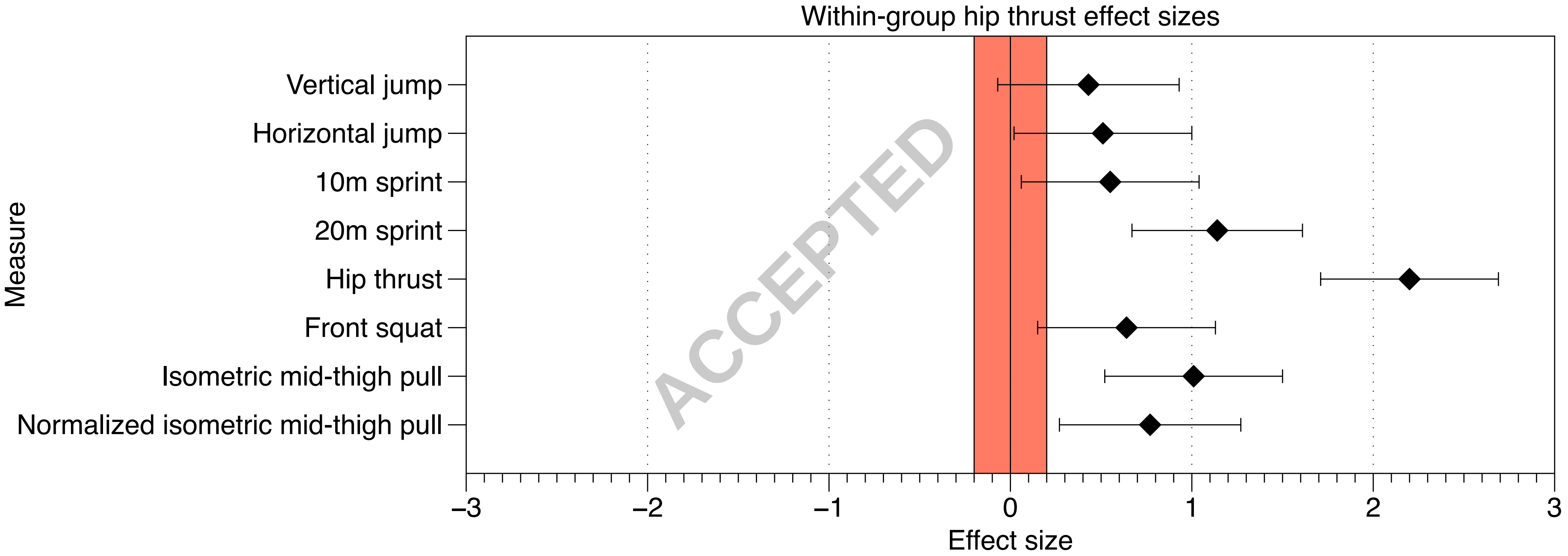
Table 2. Sets, repetition schemes, and loads utilized for the front squat and hip thrust.

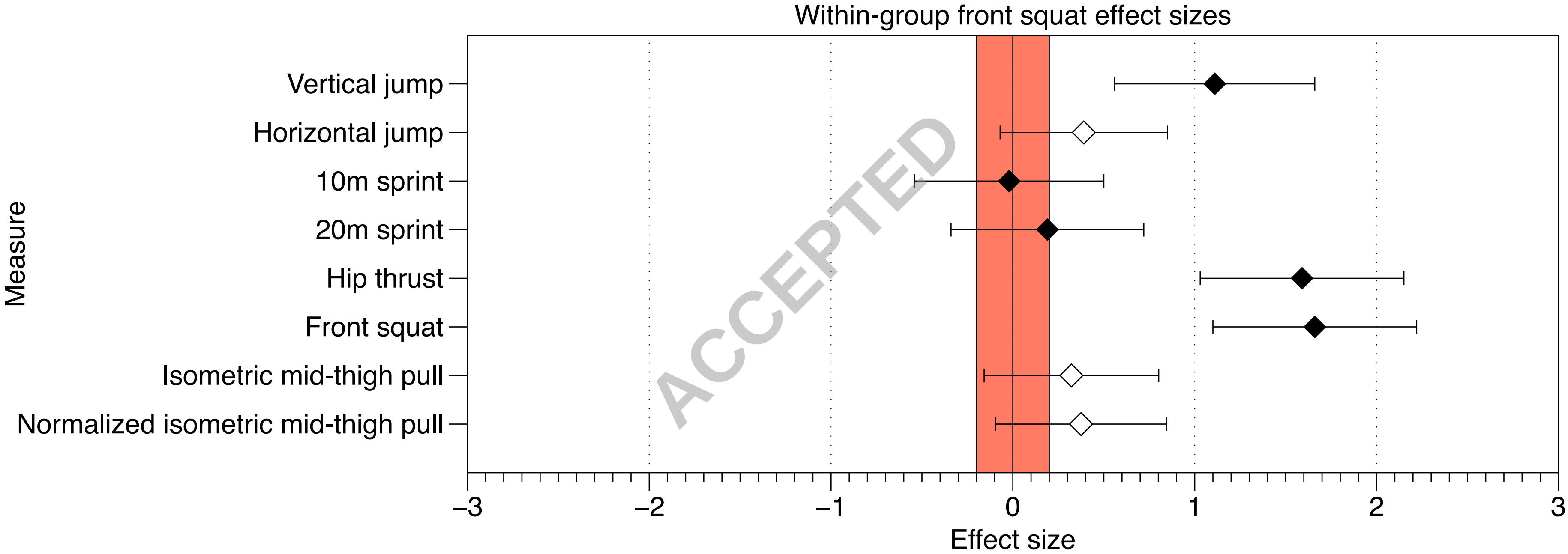
Week	Sets	Repetitions	Load
1	4	12	12 RM
2	4	10	10 RM
3	4	10	10 RM
4	4	8	8 RM
5	4	8	8 RM
6	4	6	6 RM

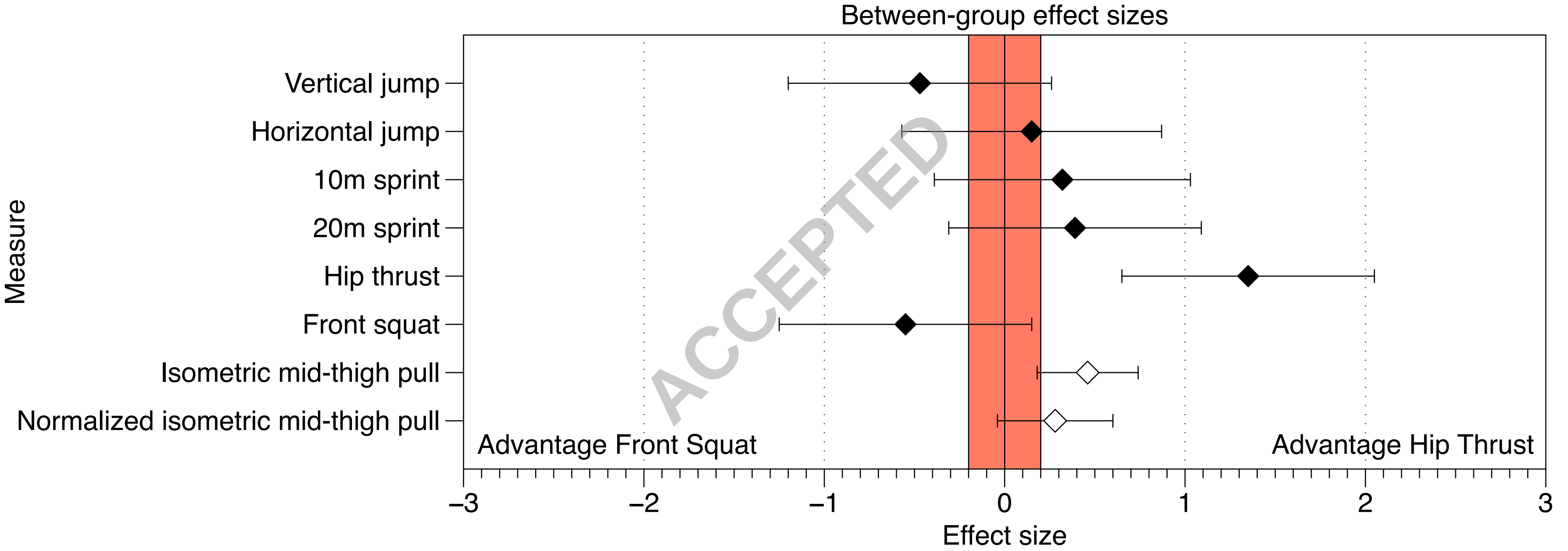
RM = repetition maximum

Table 3. Pre- and post- measures, differences, and percent changes of all performance measures.

	Hip Thrust				Front Squat			
	Pre	**Post**	**Δ (abs)**	**Δ (%)**	**Pre**	**Post**	**Δ (abs)**	**Δ (%)**
Body mass (kg)	78.32 ± 12.5	79.82 ± 12.7	+1.49 ± 1.38	+1.87	81.16 ± 12.37	81.71 ± 12.55	+0.55 ± 1.69	+0.67
Vertical jump (cm)	56.31 ± 8.44	58.23 ± 7.82	+1.92 ± 4.48	+3.30	52.27 ± 8.40	56.09 ± 8.22	+3.82 ± 3.43	+6.81
Horizontal jump (m)	2.33 ± 0.20	2.38 ± 0.22	+0.06 ± 0.11	+2.33	2.28 ± 0.24	2.32 ± 0.28	+0.04 ± 0.15	+1.69
10 m sprint (sec)	1.76 ± 0.07	1.74 ± 0.08	–0.02 ± 0.03	–1.06	1.79 ± 0.08	1.80 ± 0.11	+0.00 ± 0.09	+0.10
20 m sprint (sec)	3.13 ± 0.13	3.07 ± 0.14	–0.05 ± 0.05	–1.70	3.16 ± 0.14	3.14 ± 0.16	–0.02 ± 0.11	–0.67
Hip thrust (kg)	115.85 ± 23.53	165 ± 33.07	+49.54 ± 22.49	+29.95	111.36 ± 20.99	134.82 ± 11.20	+23.45 ± 14.77	+17.40
Front squat (kg)	77.57 ± 12.38	83.08 ± 13.77	+5.50 ± 8.53	+6.63	75.00 ± 10.49	84.64 ± 10.03	+9.64 ± 4.80	+11.39
Isometric mid-thigh pull (N)	2554.31 ± 419.03	2815.31 ± 504.21	+261.00 ± 257.86	+9.22	2683.18 ± 258.35	2734.18 ± 213.09	+51.00 ± 210.83	+1.52
Normalized isometric mid-thigh pull (N/kg)	32.84 ± 4.39	35.36 ± 4.12	+2.52 ± 3.30	+7.06	33.41 ± 3.37	34.07 ± 4.98	+0.66 ± 2.35	+1.56


Within-group hip thrust effect sizes
Measure
Vertical jump
Horizontal jump
10m sprint
20m sprint
Hip thrust
Front squat
Isometric mid-thigh pull
Normalized isometric mid-thigh pull
−3
−2
−1
0
1
2
3
Effect size


Within-group front squat effect sizes
Measure
Vertical jump
Horizontal jump
10m sprint
20m sprint
Hip thrust
Front squat
Isometric mid-thigh pull
Normalized isometric mid-thigh pull
−3
−2
−1
0
1
2
3
Effect size


Between-group effect sizes
Measure
Vertical jump
Horizontal jump
10m sprint
20m sprint
Hip thrust
Front squat
Isometric mid-thigh pull
Normalized isometric mid-thigh pull
Advantage Front Squat
Advantage Hip Thrust
−3
−2
−1
0
1
2
3
Effect size