Training with weightlifting derivatives: The effects of force and velocity overload stimuli

ABSTRACT

The purposes of this study were to compare the training effects of weightlifting movements performed with (CATCH) or without (PULL) the catch phase of clean derivatives performed at the same relative loads or training without the catch phase using a force- and velocity-specific overload stimulus (OL) on isometric and dynamic performance tasks. Twenty-seven resistance-trained men completed 10 weeks of training as part of the CATCH, PULL, or OL group. The CATCH group trained using weightlifting catching derivatives, while the PULL and OL groups used biomechanically-similar pulling derivatives. The CATCH and PULL groups were prescribed the same relative loads, while the OL group was prescribed force- and velocity-specific loading that was exercise and phase specific. Pre- and post-intervention isometric mid-thigh pull (IMTP), relative one repetition maximum power clean (1RM PC), 10-, 20-, and 30-m sprint, and 505 change of direction on the right (505R) and left (505L) legs performance were examined. Statistically significant differences in pre- to post-intervention percent change were present for relative IMTP peak force, 10-, 20-, and 30-m sprints, and 505L (all $p < 0.03$), but not for relative 1RM PC or 505R ($p > 0.05$). The OL group produced the greatest improvements in each of the examined characteristics compared to the CATCH and PULL groups with generally moderate to large practical effects being present. Using a force- and velocity-specific overload stimulus with weightlifting pulling derivatives may produce superior adaptations in relative strength, sprint speed, and change of direction compared to submaximally-loaded weightlifting catching and pulling derivatives.

Keywords: isometric mid-thigh pull; power clean; strength; sprinting; change of direction

INTRODUCTION

Researchers have demonstrated that weightlifting movements may provide a superior strength-power training stimulus compared to jump training (50, 51), traditional resistance training (25), and kettlebell training (31). One reason for these training effects may be due to the similarity between the second pull of weightlifting movements and the coordinated triple extension of the hips, knees, and ankles (plantar flexion) that occurs during the propulsive phases of jumping, sprinting, and change of direction tasks (26). In addition, weightlifting movements may provide a superior overload stimulus compared to other training methods given their requirement to move moderate to heavy loads with ballistic intent. In fact, researchers have indicated that weightlifting movements and their derivatives produce greater power outputs compared to the majority of other resistance training exercises (38). Thus, given their potential to improve strength-power performance, it is not surprising that many practitioners implement the weightlifting movements and their derivatives within resistance training programs (22, 33).

Weightlifting movements and their derivatives are traditionally implemented by practitioners to include the catch phase of the movement. While weightlifting catching derivatives (i.e. those that remove an aspect of the full weightlifting movement movement) have been shown to produce positive strength-power training effects and load absorption benefits, more recent literature has indicated that weightlifting pulling derivatives (i.e. those that exclude the catch phase) may provide a comparable (4, 5) or superior (27, 28, 47-49) training stimulus compared to weightlifting catching derivatives with regard to peak force, velocity, power, rate of force development, impulse, and work. Despite the existence of several cross-sectional studies, only one study has compared the effects of longitudinal training with either weightlifting catching or pulling derivatives.

Comfort et al. (7) indicated that there was no statistical or practically meaningful difference between training two times per week for eight weeks with either weightlifting catching or pulling derivatives on rapid force development during isometric mid-thigh pulls (IMTP), one repetition maximum power clean (1RM PC) performance, squat jumps, or countermovement jumps. While these findings are important, it should be noted that the loading between the catching and pulling derivative groups was identical (volume and relative loads matched), which may partly explain the similarity in the observed adaptations. Thus, further research is needed to determine if differences in loading produce unique performance adaptations.

Weightlifting pulling derivatives may provide a greater force and velocity overload stimulus compared to catching derivatives (39, 40). While practitioners are limited to prescribing up to the 1RM of weightlifting catching derivatives, pulling derivatives may benefit force production (i.e. strength) characteristics to a greater extent due to their ability to use loads in excess of an athlete's 1RM PC. For example, some pulling derivatives, such as the mid-thigh pull and countermovement shrug may be loaded up to 140% of 1RM PC (8, 9, 30). In addition to greater potential force production, pulling derivatives, such as the jump shrug and hang high pull, produce greater movement velocities (49), which may result in rapid force production characteristics. Based on the kinetic similarities between weightlifting catching and pulling derivatives presented in a recent study (7), it is possible that both modes of training (inclusion or exclusion of the catch phase) may be implemented to enhance an athlete's performance. However, it is possible that superior training benefits may be displayed if a force- (e.g. loads in excess of catching derivative 1RM) and velocity-specific (e.g. greater velocities via more ballistic exercises) overload stimulus is provided with weightlifting pulling derivatives. Thus, further research is needed to explore this notion to better inform strength training prescription. The purposes of this study were to compare the training effects of weightlifting movements performed with (CATCH) or without (PULL) the catch phase of clean derivatives performed at the same relative loads or training without the catch phase using a force- and velocity-specific overload stimulus (OL) on isometric and dynamic performance tasks. In line with previous research (7), it was hypothesized that there would be no statistical or practically meaningful differences between the CATCH and PULL groups. However, it was also hypothesized that the OL group would demonstrate the greatest adaptations in isometric and dynamic performance compared to both the CATCH and PULL groups.

METHODS

Experimental Approach to the Problem

To examine the differences in isometric and dynamic performance enhancement following resistance training programs that used weightlifting catching or pulling derivatives, a repeated measures between-group design was used. The participants completed 10 weeks of training (three times per week) and were assessed prior to the training intervention and again after 10 weeks of training (Figure 1). Changes in isometric and dynamic performance were assessed using the IMTP and a 1RM PC, 30-m sprints, and 505 change of direction.

(Figure 1 about here.)

Participants

Male collegiate athletes and resistance-trained men with previous experience with the PC and its derivatives were recruited to participate in this study. Twenty-nine participants volunteered and were randomly assigned to either the CATCH, PULL, or OL group. Two participants voluntarily withdrew from the study, one because of an injury sustained during intramural sports outside of the study, and the other due to a desire to train more than three days per week. The characteristics of the participants in each group are displayed in Table 1. All participants who completed the study attended 100% of the training sessions. Prior to their participation, each participant read and signed a written informed consent form, in accordance with the university's institutional review board.

An *a priori* power analysis was completed using G*Power (version 3.1.9.2). At a power level of 0.90, for an *a priori* alpha level of ≤ 0.05, it was determined that at least 24 participants were needed to display at least moderate effect sizes (Hedge's $g \geq 0.50$) between groups, based on previous findings (12).

(Table 1 about here.)

Procedures

As displayed in Figure 1, pre- and post-intervention testing was completed over the course of two testing sessions separated by 48-72 hours to decrease the overall volume of tests as well as to accommodate the participants' schedules. The time between the two post-intervention sessions was kept consistent with the two pre-intervention testing sessions. In addition, a minimum of 48 hours of recovery was required prior to the participants' testing sessions. Each testing session was scheduled to take place within two hours of participants' pre-intervention testing sessions in order to account for changes in Circadian rhythm. Prior to each testing session, the participants performed the same standardized warm-up that consisted of stationary cycling, dynamic stretching, body weight squats, and progressive vertical jumps (45, 47, 48).

Isometric Mid-thigh Pull Assessment

The methodology used for IMTP testing have been previously described (3). Briefly, each participant was positioned within an adjustable IMTP rig (Kairos Strength, Murphy, NC, USA). An immovable barbell (Werksan Olympic Bar, Werksan, Moorsetown, NJ, USA) was positioned at a height which replicates the start of the second pull phase of the clean, resulting in knee and hip angles between 125-135° and 140-150°, respectively, based on previous recommendations (6). Individual angles were recorded and replicated during the post-intervention testing session. In accordance with previous methods (3), the participants' hands were strapped and taped to the barbell to prevent grip from being a limiting factor. After being given instructions regarding the countdown procedures, each participant performed two submaximal pulls, with one each at 50% and 75% of their perceived maximal effort, separated by one minute of rest. Following a two minute rest period, each participant performed the first of at least two maximal effort pulls.

Prior to the maximal effort pulls, participants were given final instructions. Specifically, the participants were instructed to pull "as fast and hard as possible" and "push their feet down into the force plates." After being instructed to, participants first positioned their feet on the dual force plates (PASPORT force plate, PASCO Scientific, CA, USA) located under the immoveable barbell. Next, the participant was instructed to get into their "ready position", which was the previously measured starting position. The participants were then instructed to remove any slack in their arms with the cue "tension on the bar." Once the participants' body position was stabilized (verified by watching the force trace), the participant was given a countdown of "3, 2, 1, Pull!" Each IMTP trial was performed for approximately five seconds and strong verbal encouragement was provided. Participants performed two maximal IMTP trials with two minutes of rest between trials. If the difference in peak force between the trials was greater than 250 N, or a visible countermovement was performed prior to the pull, a third trial was performed (3, 6). The vertical ground reaction force data for the IMTP trials was recorded by the force plates sampling at 1000 Hz. As displayed in Figure 1, IMTP testing was performed during all four testing time points (i.e. pre-intervention, mid-test 1, mid-test 2, and post-intervention).

1RM Power Clean

The 1RM PC of each participant was established using previously discussed methods (49). A self-selected warm-up with a 20 kg barbell was followed with warm-up PC sets using submaximal loads (e.g. five repetitions at 30 and 50%, three repetitions at 70%, and one repetition at 90% 1RM. During the pre-intervention testing session, participants warmed-up using percentages of their estimated 1RM PC, while percentages of the 1RM established during the pre-intervention session were used within the warm-up during the post-intervention session. Following the final warm-up repetition, the principal investigator and the participant determined each maximal attempt load. A minimum 2.5 kg increase was required and loads were progressively increased until a failed attempted occurred. Participants were given at least three minutes of rest in between 1RM attempts. Any PC repetition caught with the top of the subject's thigh below parallel was ruled as an unsuccessful attempt. This was visually monitored during each 1RM attempt. It should be noted that 1RM PC testing was only completed during the pre- and post-intervention testing sessions due to the impact that a greater volume-load experienced during the strength-endurance and maximal strength blocks may have on maximal strength and technique.

Sprint Performance

Thirty-meter sprint performance, with splits at 10- and 20-m, was assessed on an indoor track surface in the University's athletic fieldhouse using laser timing gates, which were positioned at approximately hip height (Brower Timing Systems, Draper, UT, USA). Following the standardized warm-up, each participant completed submaximal warm-up sprints at 50%, 75%, and 90% of their perceived maximum effort. The participants were positioned 30-cm behind a marked starting line to prevent an inadvertent triggering of the timing system. Following the last warm-up sprint, participants received a 2-3 minute rest period before completing maximum effort sprints. Each participant performed two, 30-m sprints with three minutes of rest between each sprint. However, a third sprint was performed if a tenth of a second difference existed between each sprint. All sprints were performed using a staggered, two-point static starting stance. The principle investigator demonstrated the starting position and the participants were asked to refrain from any preparatory movement (e.g. rearward sway) prior to the start of each sprint. It should be noted that sprint testing was not completed during the first mid-intervention testing session due to the potential muscle fatigue and soreness that may result from high volume training. This was done in attempt to minimize injury risk.

Change of Direction Performance

Following a self-selected rest period after the 30-m sprints, participants completed the 505 test to assess change of direction performance (1). Timing gates (Brower Timing Systems, Draper, UT, USA) and cones were set up 10- and 15-m from the start line, respectively. Participants lined up in a staggered stance and ran 15-m crossing through the timing gates at 10-m, made a 180° turn at 15-m, and ran 5-m back through the timing gates. Foot placement during the 180° turn was visually monitored during each trial. Prior to the maximal trials, each participant performed completed a warm-up a 75% of their perceived maximum. The participants then performed three maximal effort repetitions each, cutting with both their right (505R) and left (505L) legs, with one minute of rest between trials. The order of which leg was used for cutting was randomized during the pre-intervention testing session and kept consistent for each individual participant throughout the study. Similar to the sprint testing, 505 testing was not completed during the first mid-intervention testing session in an attempt to minimize injury due to fatigued and sore musculature following high volume training.

Training Intervention

As mentioned above, each group trained three days per week for 10 weeks under the supervision of a certified strength and conditioning coach. The program was modified from a recent review article that provided 18 weeks of programming with weightlifting derivatives in accordance with each group (39). Each weightlifting catching and pulling derivative was programmed based on the 1RM PC achieved during the pre-intervention testing session, similar to previous research (7, 9, 35, 37, 49). In addition, all weightlifting derivatives prescribed within the training program were coached using the technique described within previous literature (17-19, 36, 41, 42). Non-weightlifting derivative exercises were added to the training intervention to increase the ecological validity of each program as weightlifting movements are rarely programmed in isolation for non-weightlifting athletes. Prior to the start of the training program, each participant provided the heaviest loads lifted, sets, and repetitions for the non-weightlifting derivative exercises (e.g. back squat, bench press, bent-over row, etc.) during their most recent training sessions. The 1RM for each exercise was then estimated and the relative loads (Table 2) were determined using the set-repetition best method as discussed within previous literature (15, 16). Using this method of loading, relative loads were based on percentages of the RM of the prescribed repetitions. For example, 90% of three sets of 10 repetitions uses 90% of the participant's estimated 10RM weight. However, while a range of loads was prescribed, this method of loading also allowed the participants to gauge the appropriate loads based on how many repetitions they feel that they could have performed beyond the prescribed number of repetitions (16). It should be noted that the 1RM for each non-weightlifting derivative exercise was recalculated throughout the study based on the loads that were performed in training. Finally, weightlifting derivatives prescribed using three sets of ten repetitions were programmed using cluster sets of 5 repetitions with 30-40 seconds of intra-set rest based on previous recommendations (23).

(Table 2 about here.)

The differences between the training programs were that the CATCH group trained using PC derivatives with the catch phase during every repetition, while the PULL and OL groups trained using biomechanically similar PC derivatives that removed the catch phase (Table 3). The PULL group performed their derivatives with the same relative load as the CATCH group based on their 1RM PC (e.g. CATCH = PC at 80% 1RM; PULL = clean pull from the floor at 80% 1RM). This was done to match the volume-load between the CATCH and PULL groups. In contrast, the OL group performed their PC derivatives with either a force or velocity overload stimulus, using either heavier (e.g. CATCH = PC at 80% 1RM; OL = clean pull from the floor with 100% 1RM) or lighter loads (e.g. CATCH = hang PC at 65% 1RM; OL = jump shrug at 30% 1RM), respectively. The velocity overload stimulus was also provided by prescribing pulling derivatives that are more ballistic in nature (e.g. jump shrug) (47-49). While the volume-load was different between the OL group and other groups, this was done to increase the ecological validity of prescribing pulling derivatives in line with previous recommendations (39). Further detail on the relative load progression for the weightlifting derivatives of each training group is displayed in Table 4.

(Tables 3 and 4 about here.)

Data Analyses

A laptop computer and specialist software (PASCO Capstone, PASCO Scientific, CA, USA) were used to directly record force-time data during the IMTP trials. Because low-pass filtering procedures may underestimate IMTP kinetics (20), unfiltered data were used for data analysis. The force-time data of each trial were exported to and graphed in Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Each participant's body mass in Newtons was subtracted from the force-time data, to provide net force, and the maximum force recorded from the force-time curve during the IMTP trials was recorded as the peak force. The average of the two most similar trials, with regard to peak force production, were used for statistical comparisons. Finally, relative peak force was calculated by dividing the peak force of each IMTP trial by each participant's body mass that was recorded during each testing session. Similar to IMTP peak force, relative 1RM PC data was determined by dividing the 1RM PC of each participant by their body mass during each respective testing session. For sprinting performance, 10-, 20-, and 30-m times were recorded during each sprint. The average time of the two sprints was used for statistical analysis. In the event that the participant had to complete a third sprint, the average of the two most similar times was used for comparison. Similar to the sprints, the average of the two most consistent times for the 505R and 505L COD performances were used for statistical analysis. The percent change of each participant was calculated from pre- to post-intervention by using the below equation. The average of the individual percentage changes was then used to assess the changes of each group throughout the study.

$$\textit{Percent change in performance (\%)} = ((\textit{New score} - \textit{Old score}) \cdot (\textit{Old score})^{-1}) \cdot 100$$

Finally, the weekly volume-load and pre-post intervention volume-load completed by each group was calculated as the product of sets, repetitions, and load.

Statistical Analyses

Normality of all data was examined using the Shapiro-Wilk test of normality. The criteria for the removal of outliers was if a data point was greater than three times the standard deviation of that specific test. However, because the sprinting data all took place as part of the same test, outliers were removed from all sprint test comparisons. Levene's test was used to assess the heterogeneity of variance between groups. Test-retest reliability was assessed during each testing session using two-way mixed intraclass correlation coefficients (ICC) and typical error expressed as a coefficient of variation percentage (CV%). The ICCs were interpreted as poor (< 0.50), moderate (0.50-0.74), good (0.75-0.90), and excellent (> 0.90) (29). Acceptable within-session variability was classified as <10% (11). A series of one-way ANOVA with Bonferroni *post hoc* analyses were used to examine the percent change differences in pre- to post-intervention relative IMTP peak force, relative 1RM PC, 10-, 20-, and 30-m sprint time, 505 change of direction times, and volume-load between the CATCH, PULL, and OL groups. A criterion p-value of ≤0.05 was used to identify statistical significance. In addition, the magnitude of any changes was determined via the calculation of effect sizes (Hedge's *g*). Effect sizes were interpreted based on the 'highly trained' status (i.e. individuals training for at least 5 years) outlined in previous literature (32). Specifically, effect sizes were interpreted as trivial, small, moderate, and large when magnitudes were < 0.25, 0.25-0.49, 0.50-1.0 and >1.0, respectively. All statistical analyses were performed using SPSS (Version 25, IBM, New York, NY, USA).

RESULTS

All percent change data were normally distributed and demonstrated similar variance within each group. The reliability of all testing data from each testing session ranged from good to excellent (ICC = 0.75-0.99) with acceptable variability (CV% = 0.5-3.6%) for each group. The descriptive testing data and volume-load data of each group is displayed in Tables 5 and 6, respectively. Statistically significant differences in pre- to post-intervention percent change were present for relative IMTP peak force ($p = 0.005$), 10- ($p = 0.023$), 20- ($p = 0.028$), and 30-m sprints ($p = 0.028$), and 505L ($p = 0.018$), but not for relative 1RM PC ($p = 0.369$) or 505R ($p = 0.405$). Furthermore, no statistically significant differences existed between groups for weekly ($p = 0.288$-0.998) or total volume-load ($p = 0.331$) Individual data and effect size comparisons between groups are displayed in Figures 2-5.

(Table 5 about here.)

(Figures 2-5 about here.)

Post hoc analysis revealed that the OL group produced statistically greater relative IMTP peak force improvements compared to the CATCH group ($p = 0.005$, $g = 1.64$), but not the PULL group ($p = 0.931$, $g = 0.43$). There was also no statistical difference between the CATCH and PULL group ($p = 0.056$, $g = 1.21$). Regarding sprint performance, *post hoc* analysis revealed that 10-m improvements were greater for the OL group compared to the CATCH group ($p = 0.026$, $g = 1.32$), but not the PULL group ($p = 0.121$, $g = 1.35$). Furthermore, no statistical difference in 10-m sprint improvements existed between the CATCH and PULL group ($p = 1.000$, $g = 0.29$). Although the OL group produced the greatest improvements in 20- and 30-m sprint performance, these differences were not statistically different from the CATCH ($p = 0.056$, $g = 1.17$; $p = 0.065$, $g = 1.10$) or PULL groups ($p = 0.064$, $g = 1.26$; $p = 0.053$, $g = 1.44$). No statistical difference existed between the CATCH and PULL groups for either variable (both $p = 1.000$, $g = 0.03$-0.04). Finally, *post hoc* analysis for the 505L test revealed that the OL group produced greater improvements compared to the CATCH group ($p = 0.017$, $g = 1.29$), but not the PULL group ($p = 0.178$, $g = 0.69$). No statistical differences were present between the CATCH and PULL groups ($p = 1.000$, $g = 0.80$).

DISCUSSION

The aim of this study was to examine the isometric and dynamic performance adaptations following a 10-week training program that included weightlifting catching or pulling derivatives. An additional goal of this study was to examine the effect of providing a force- and velocity-specific overload stimulus using weightlifting pulling derivatives. In line with our hypotheses, statistically significant differences existed between groups for relative IMTP peak force, 10-, 20-, and 30-m sprint performance, and 505L performance with effect sizes ranging from moderate to large between the OL group and the CATCH and PULL groups. While no statistical difference in the percent change in 1RM PC or 505R existed between groups, moderate effect sizes were still present, indicating that meaningfully greater effects were produced by the OL group. Also in line with our hypotheses, no statistical or practically meaningful differences existed between the CATCH and PULL groups; the only exceptions were the large and moderate effects that favored the PULL group during the IMTP and 505L tests, respectively.

IMTP peak force is an effective measure of isometric strength (6) that has a moderate to large relationship with a variety of performance characteristics such as sprinting, change of direction, jumping, etc. (46). The OL group in the current study produced the greatest improvements in relative IMTP peak force (13.8%) and displayed large and small practical differences when compared to the CATCH (-2.9%) and PULL (9.0%) groups, respectively. Heavier loading in the mid-thigh position during certain weightlifting pulling derivatives throughout the training program may have contributed to the improvements of the OL group. For example, the OL group used up to 135%, 110%, and 102.5% of their PC 1RM during the mid-thigh pull, countermovement shrug, and clean pull from the floor, respectively. In addition to the potential for greater positional strength gains, the supramaximal loads used during the OL program likely required greater propulsive forces during the second pull phase of each derivative, which may have led to greater force output (8, 9). Similar to the OL group, there was a large practical difference between the PULL and CATCH groups. These findings are in contrast to a recent study that compared training with load-matched catching or pulling derivatives two days per week in-season for eight weeks

(7). Beyond the potential fatigue effects of in-season training, the differences displayed in the current study may have been due to greater variation in exercise selection and phases of training and the longer duration of the present intervention. It is interesting that the CATCH group, on average, decreased their relative IMTP peak force; however, this may be due to the effort put forth by the participants during the second pull of their derivatives during their training program. Results from a recent study demonstrated that maximal effort PCs result in greater lower extremity work compared to minimal height PCs (13). Due to the exclusion of the catch phase, the PULL and OL groups may have been able to emphasize the second pull phase of each derivative. It has been reported in previous studies that greater forces are applied in the last 85-100% of the second pull phase during pulling derivatives compared to catching derivatives (27, 47). The previous findings suggest that in preparation to catch the barbell, individuals may have less intent to maximize their second pull effort, especially when submaximal loads are used. Collectively, the current results suggest that weightlifting pulling derivatives may provide a greater stimulus for isometric peak force production. Furthermore, a greater benefit may be provided by prescribing loads in excess of a 1RM catching derivative when implementing certain pulling derivatives (e.g. mid-thigh pull, countermovement shrug, clean pull from floor, etc.).

Relative 1RM hang PC strength has been correlated to superior sprint and jump performance (26), which is likely due to similar movement characteristics. The greatest increase in relative 1RM PC performance was produced by the OL group (6.8%), which was followed by the PULL (4.3%) and CATCH (3.5%) groups. Comfort et al. (7) reported no statistical or practically meaningful difference in 1RM PC changes following an eight week training program that featured load-matched weightlifting catching or pulling derivatives, in line with the comparisons between the

CATCH and PULL groups in this study. However, the results of the current study show moderately greater increases in relative 1RM PC in the OL group compared to the other two groups. A potential issue that arises with heavier loads during weightlifting catching derivatives is that the athlete may not achieve full hip and knee extension in preparation to drop under and catch the barbell (27, 40, 47). Recent literature indicated that maximum effort PCs may increase lower extremity work, knee extensor work, and knee joint excursion compared to a minimal height PC (13). The previous authors noted that maximal effort during the second pull (i.e. triple extension) may also elevate the barbell to a greater extent. Because weightlifting pulling derivatives emphasize the second pull phase, it is possible that the PULL and OL groups may have been able to elevate the barbell to a greater extent during their post-intervention testing. Combined with heavier loading, the OL group may have been able to optimize their post-intervention 1RM PC adaptations. It should be noted that several of the participants within the PULL and OL groups mentioned that the PC catch felt "strange", "awkward", or "unnatural" during their post-intervention 1RM test. However, this may be due to the fact that neither group performed the catch phase nor front squat for the duration of the 10 week program.

The theory behind implementing weightlifting derivatives to improve sprint performance has previously been discussed (14). Specifically, weightlifting derivatives may provide a unique training stimulus that may be used enhance both rate of force development and power characteristics. Moreover, these exercises can be programmed in a phase specific manner to not only enhance the desired fitness characteristics, but also mimic joint angles that are common during various sprint phases. The sprint distances examined within the current study are classified as accelerations given that athletes may require distances longer than 30-m to reach their maximum speed (2). In order to accelerate effectively, athletes must produce large impulses via a combination of large forces during longer ground contact times (14, 24). While trivial to small effects existed between the CATCH and PULL groups at each sprint distance, the OL group displayed large improvements compared to the other two groups. Weightlifting pulling derivatives may produce greater impulses during the second pull phase compared to catching derivatives (27, 47). This is likely due to a greater emphasis on accelerating throughout the second pull phase and omitting the need to drop under and catch the barbell. Thus, an emphasis on the triple extension movement, as well as heavier loading, may have contributed to the improvements in sprint performance by the OL group. Practically speaking, weightlifting derivatives (catching and pulling) may be implemented to help improve accelerative sprint performance. However, it appears that exercises that provide a large force overload stimulus may produce superior training effects. While the current study focused on accelerative sprint performance, future research should consider examining the effect of weightlifting derivatives on sprint performance over longer distances.

The 505 test has been described as a reliable method that assesses change of direction ability on both legs (1), which is a frequent physical component of many sports (e.g. stop and go movements, cutting, etc.). Similar to the other performance tests, the OL group produced the greatest improvements in both 505R (3.7%) and 505L (5.1%) performance. These results were followed in order by the PULL (505R = 2.6% and 505L = 1.9%) and CATCH groups (505R = 1.5% and 505L = 0.3%). Previous literature indicated that athletes with faster 505 times possess greater eccentric and isometric strength (34), but may also produce greater horizontal propulsive and braking forces (21). As shown above, the OL group produced greater improvements in isometric and dynamic strength, which may have contributed to their 505 improvements. Although not measured in the current study, additional literature indicated that weightlifting pulling derivatives may require similar (10) or greater (10, 43, 44) work to be performed during the load absorption phase compared to catching derivatives. Thus, it is possible that the use of weightlifting pulling derivatives with heavier loads during the OL program may have contributed to a greater capacity to absorb force and create larger braking forces during the 505 test. As mentioned above, larger propulsive impulses during pulling derivatives may have also contributed to the current results. Despite the current findings, it should be noted that additional literature has suggested that motor control and coordination may be the primary factors that contribute to 505 performance (52). Thus, further analysis of change of direction characteristics following training programs that implement weightlifting derivatives may be warranted.

When implementing weightlifting movements into resistance training programs, it is important to prescribe an exercise and load combination that will match the fitness demands of each training phase. Interestingly, no statistically significant differences existed between groups when comparing the volume-load completed. It should be noted however that moderate effect sizes were present when comparing the volume-load completed by the OL group and CATCH and PULL groups during the max-strength and speed-strength phases of the study. A primary benefit of prescribing weightlifting pulling derivatives is that the exercises allow for a wider spectrum of loads to be prescribed. While catching derivatives are limited to their 1RM on the high load end of the spectrum, loads for pulling derivatives may exceed the 1RM PC as discussed above, or increase up to 140% 1RM as shown in previous literature (8, 9, 30). On the low load end of the spectrum, it is difficult for athletes to maximize their effort when they perform the second pull during catching derivatives due to the potential to 'overpull' the barbell, which may lead to poor technique during the catch phase. The lowest loads used for pulling derivatives in the current study were 30 and 35% 1RM for the jump shrug and hang high pull, respectively, which was in line with previous literature for peak power development (28, 35, 37). Because maximal effort can be given on both ends of the loading spectrum while providing a force and velocity overload stimulus, it appears that implementing pulling derivatives may be highly beneficial to resistance training programs. It should be noted that the findings of the current study do not discount the effectiveness of training with weightlifting catching derivatives as a number of studies have shown how beneficial they are compared to other training methods (31, 50, 51). While the current study compared only catching or pulling derivatives within a training program, it is possible and encouraged to implement both variations when training athletes. In fact, weightlifting catching derivatives may provide a similar training stimulus to load-matched pulling derivatives (4, 5, 7). Thus, both types of derivatives may be used interchangeably based on the goals of each fitness phase. For an example of how implement both weightlifting catching and pulling derivatives in the same program, readers are directed to a previous review (39).

A potential limitation to the current study is that fact that each weightlifting derivative was programmed based on each participants' pre-intervention 1RM PC. If the PC is regularly prescribed in training, the use of this method may not detrimental. However, if an individual does not perform a 1RM PC, practitioners may find it difficult to prescribe loads for pulling derivatives. Only one study has examined an alternative method of loading for a weightlifting pulling derivative (e.g. percentage of body mass) (45) and thus, further research on this topic is warranted. A second limitation may have been the length of the overall training program. While the 10 week program allowed for strength-endurance, strength, overreach, and taper phases to take place, low repetition strength work (e.g. three sets of three repetitions at 85% 1RM or higher) was not performed. This was in part due to the length of the academic semester and the need to work around breaks during the academic year. While each participant experienced the same volume within each training block, the CATCH and PULL group did not experience loads greater than 82.5% of their 1RM PC during their prescribed weightlifting exercises. While this may have contributed to the lack of improvement in relative IMTP peak force for the CATCH group, it should be noted that both the weakest and strongest individuals (based on relative squat strength) within the group decreased their relative IMTP peak force by at least 7.5%. Furthermore, while five out the nine participants in the CATCH group decreased their relative IMTP peak force, only one individual in the PULL group failed to improve their performance. Finally, the volume-load completed by each group may be listed as a limitation (albeit a necessary one). A purpose of this study was to examine the effect of manipulating exercises and load using weightlifting derivatives to benefit strength-power characteristics. The current results indicate that a benefit of implementing weightlifting pulling derivatives is the ability to prescribe loads that emphasize either force (heavier loads) or velocity (lighter loads), which may modify the overall volume-load completed. From a training efficiency standpoint, it is recommended that future research should continue to examine the relationship between performance changes and volume-load when using weightlifting derivatives. Specifically, researchers should consider examining volume-load calculated using the displacement of the barbell. Although not examined in the current study, it may be argued that weightlifting pulling derivatives performed at the same loads (or heavier) as catching derivatives may produce a lower overall volume-load given that the barbell displacement for certain exercises (e.g. mid-thigh pull, pull from the floor, etc.) is smaller and thus, may be more efficient at producing a strength-power stimulus compared to catching derivatives.

PRACTICAL APPLICATIONS

The findings of the current study indicate that weightlifting catching and pulling derivatives may improve a variety of isometric and dynamic performance characteristics. However, it appears that training with a force- and velocity-specific overload stimulus using weightlifting pulling derivatives may produce superior training effects compared to submaximal load-matched weightlifting catching and pulling derivatives. It should be noted that submaximally-loaded pulling derivatives may also produce superior performance gains compared to using catching derivatives at the same relative loads when it comes to relative IMTP peak force. Practitioners should consider implementing weightlifting pulling derivatives to expand the loading spectrum that an athlete can experience within their training program. Specifically, it may be beneficial from a force production standpoint to implement loads in excess of an athlete's 1RM PC, but also lighter, submaximal loads to provide a greater velocity stimulus. However, it is important to match the demands of each fitness phase by prescribing the most effective exercise and load combinations. While weightlifting pulling derivatives may have the potential to maximize adaptations on the heavy- and light-load ends of the loading spectrum, it is important to note that weightlifting catching derivatives may be effectively implemented with pulling derivatives rather than prescribing only one method or the other.

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TABLE AND FIGURE LEGENDS

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Table 3. 10 week resistance training program.

Table 4. Clean derivative relative load progression for each training group.

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Figure 5. Percent change in 505 change of direction performance on the right (A) and left (B) legs from pre- to post-intervention with Hedge's *g* comparisons between groups. Bold line denotes group average and open circles denote individual changes.

Table 1. Participant demographics for the CATCH (n = 9), PULL (n = 9), and OL (n = 9) groups.

	CATCH	PULL	OL
Age (y)	22.8 ± 3.6	22.2 ± 2.3	22.3 ± 1.2
Body mass (kg)	85.8 ± 13.4	84.3 ± 17.3	83.0 ± 13.6
Height (cm)	180.8 ± 5.8	179.6 ± 3.7	173.4 ± 9.3
Power clean experience (y)	7.2 ± 3.7	6.4 ± 2.4	6.4 ± 1.8
Relative 1RM power clean ($kg \cdot kg^{-1}$)	1.20 ± 0.16	1.19 ± 0.18	1.25 ± 0.15
Relative 1RM squat ($kg \cdot kg^{-1}$)	1.75 ± 0.40	1.73 ± 0.17	1.76 ± 0.32

Notes: 1RM = one repetition maximum. Relative 1RM squat strength was estimated using the participants' heaviest loads lifted, sets, and repetitions of their most recent training phase completed prior to the start of the training program.

Table 2. Relative loading based on set-repetition best for the non-weightlifting derivative exercises.

Week:	Volume (sets x repetitions)	Day 1	Day 2	Day 3
1	3 x 10	80%	80%	70%
2	3 x 10	85%	85%	75%
3	3 x 10	90%	90%	80%
4	3 x 5	85%	85%	70%
5	3 x 5	90%	90%	75%
6	3 x 5	95%	95%	77.5%
7	3 x 5	80%	80%	65%
8	5 x 5	85%	85%	75%
9	3 x 3	90%	90%	77.5%
10	3 x 2	85%	85%	75%

Notes: Relative loads were based on percentages of the repetition maximum (RM) of the prescribed repetitions (e.g. 90% of 3 x 10 uses 90% of the participant's estimated 10RM weight). Relative intensities were described as very light (65-70%), light (70-75%), moderately light (75-80%), moderate (80-85%), moderately heavy (85-90%), heavy (90-95%), and very heavy (100%) (15).

Table 3. 10 week resistance training program for the CATCH, PULL, and OL groups.

Training Block	Day 1	Day 2	Day 3
Strength-endurance	Back squat Military press Split squat Bench press	Power clean from floor / Clean pull from floor⸸ Stiff-legged deadlift Bent-over row Pull-up	Power clean from floor / Clean pull from floor⸸ Back squat Incline bench press Bent-over row
Max-strength + Overreach	Push press Back squat Bench press Lunge	Mid-thigh power clean / Mid-thigh pull⸸ Power clean from floor / Clean pull from floor⸸ Stiff-legged deadlift Pull-up	Mid-thigh power clean / Mid-thigh pull⸸ Back squat Incline bench press Dumbbell row
Speed-strength	Jerk ¼ squat + Squat jump Bench press	CM power clean / CM shrug⸸ Hang power clean / Hang high pull⸸	Jerk Hang power clean / Jump shrug⸸

Notes: ⸸ = weightlifting pulling derivative prescribed for the Pull and Overload groups; CM = countermovement. ¼ squats were performed using a concentric-only movement off of the safety bars of a squat rack from a knee angle of 115-125° and squat jumps were performed from a knee angle of approximately 90°.

Table 4. Clean derivative relative load progression for each training group.

Training Group	Training Block	Clean Derivative(s)	Load Progression (% 1RM Power Clean)
CATCH	Strength-endurance	Power clean from floor	Wk 1: 55-57.5% Wk 2: 57.5-60% Wk 3: 60-62.5%
	Max-strength + Overreach	Mid-thigh power clean, Power clean from floor	Wk 4: 55-60%, 70-75% Wk 5: 60-65%, 75-80% Wk 6: 65-70%, 80-82.5% Wk 7: 50-55%, 65-70% *Wk 8: 53-58%, 63-68%
	Speed-strength	Countermovement power clean, Hang power clean	Wk 9: 60-65%, 70-75% (Day 2) & 55-60% (Day 3) Wk 10: 55-60%, 65-70% (Day 2) & 50-55% (Day 3)
PULL	Strength-endurance	Clean pull from floor	Wk 1: 55-57.5% Wk 2: 57.5-60% Wk 3: 60-62.5%
	Max-strength + Overreach	Mid-thigh pull, Clean pull from floor	Wk 4: 55-60%, 70-75% Wk 5: 60-65%, 75-80% Wk 6: 65-70%, 80-82.5% Wk 7: 50-55%, 65-70% Wk 8: 53-58%, 63-68%
	Speed-strength	Countermovement shrug, Hang high pull, Jump shrug	Wk 9: 60-65%, 70-75%, 55-60% Wk 10: 55-60%, 65-70%, 50-55%
OL	Strength-endurance	Clean pull from floor	Wk 1: 75-77.5% Wk 2: 77.5-80% Wk 3: 80-82.5%
	Max-strength + Overreach	Mid-thigh pull, Clean pull from floor	Wk 4: 110-120%, 90-95% Wk 5: 120-127.5%, 95-100% Wk 6: 127.5-135%, 100-102.5% Wk 7: 112.5-120%, 85-87.5% Wk 8: 107-112%, 80-85%
	Speed-strength	Countermovement shrug, Hang high pull, Jump shrug	Wk 9: 105-110%, 40-45%, 35-40% Wk 10: 100-105%, 35-40%, 30-35%

Notes: Wk = week

Table 5. Descriptive strength, sprint, and change of direction data for each training group.

Variable		CATCH		PULL		OL	
		Pre	Post	Pre	Post	Pre	Post
IMTP PF	Mean	36.7	35.6	38.5	42.0	37.3	42.2
(N·kg^{-1})	SD	5.2	5.7	5.1	6.9	11.9	13.5
	Pre-Post *g*	-0.19		0.55		0.37	
1RM PC	Mean	1.20	1.24	1.19	1.24	1.25	1.34
(kg·kg^{-1})	SD	0.16	0.13	0.18	0.17	0.15	0.15
	Pre-Post *g*	0.26		0.27		0.57	
10 m (s)	Mean	1.88	1.87	1.89	1.86	1.92	1.83
	SD	0.08	0.08	0.13	0.09	0.12	0.11
	Pre-Post *g*	-0.12		-0.25		-0.74	
20 m (s)	Mean	3.16	3.13	3.17	3.14	3.22	3.10
	SD	0.12	0.09	0.19	0.15	0.19	0.16
	Pre-Post *g*	-0.27		-0.17		-0.65	
30 m (s)	Mean	4.37	4.33	4.38	4.35	4.45	4.30
	SD	0.15	0.14	0.26	0.23	0.27	0.24
	Pre-Post *g*	-0.26		-0.12		-0.56	
505R (s)	Mean	2.32	2.28	2.34	2.26	2.33	2.24
	SD	0.14	0.11	0.16	0.14	0.13	0.05
	Pre-Post *g*	-0.30		-0.50		-0.87	
505L (s)	Mean	2.29	2.28	2.34	2.26	2.37	2.25
	SD	0.08	0.12	0.19	0.13	0.11	0.09
	Pre-Post *g*	-0.09		-0.46		-1.14	

Notes: Pre = pre-intervention testing session; Post = post-intervention testing session; IMTP = isometric mid-thigh pull; PF = peak force; 1RM = one repetition maximum; PC = power clean; 505R = right leg 505 change of direction; 505L = left leg 505 change of direction; Pre-Post *g* = pre- to post-intervention Hedge's *g* effect size

Table 6. Comparison of the volume load (Mean ± SD) completed by the CATCH, PULL, and OL groups.

Week	**CATCH**	**PULL**	**OL**	***p***	**CATCH-PULL *g***	**CATCH-OL *g***
1	21,924.2 ± 4475.9	22,017.3 ± 3830.0	21,888.7 ± 3902.2	0.998	0.02	0.01
2	23,192.1 ± 4616.5	23,176.6 ± 3410.1	23,438.4 ± 3751.8	0.988	0.00	0.06
3	25,779.1 ± 6882.7	23,911.6 ± 3593.0	24,821.5 ± 3900.9	0.735	0.32	0.16
4	16,543.6 ± 3548.6	16,173.0 ± 2698.2	18,360.7 ± 3245.8	0.314	0.11	0.51*
5	17,933.4 ± 3606.6	17,285.2 ± 2548.6	19,497.0 ± 3106.3	0.319	0.20	0.44
6	18,985.0 ± 3868.8	18,101.8 ± 2778.4	20,611.4 ± 3268.1	0.288	0.25	0.43
7	13,759.0 ± 2618.2	13,451.2 ± 1711.4	14,175.8 ± 2504.9	0.802	0.13	0.15
8	16,652.0 ± 3559.5	15,764.4 ± 2410.7	17,049.7 ± 3342.1	0.678	0.28	0.11
9	5899.3 ± 1279.0	5679.6 ± 881.8	5646.4 ± 992.6	0.861	0.19	0.21
10	4251.7 ± 1270.7	3680.4 ± 556.3	3662.6 ± 653.3	0.294	0.55*	0.56*
Total	164,919.5 ± 34282.2	159,241.1 ± 22668.6	169,152.3 ± 27414.1	0.331	0.19	0.13

Notes: * = moderate effect

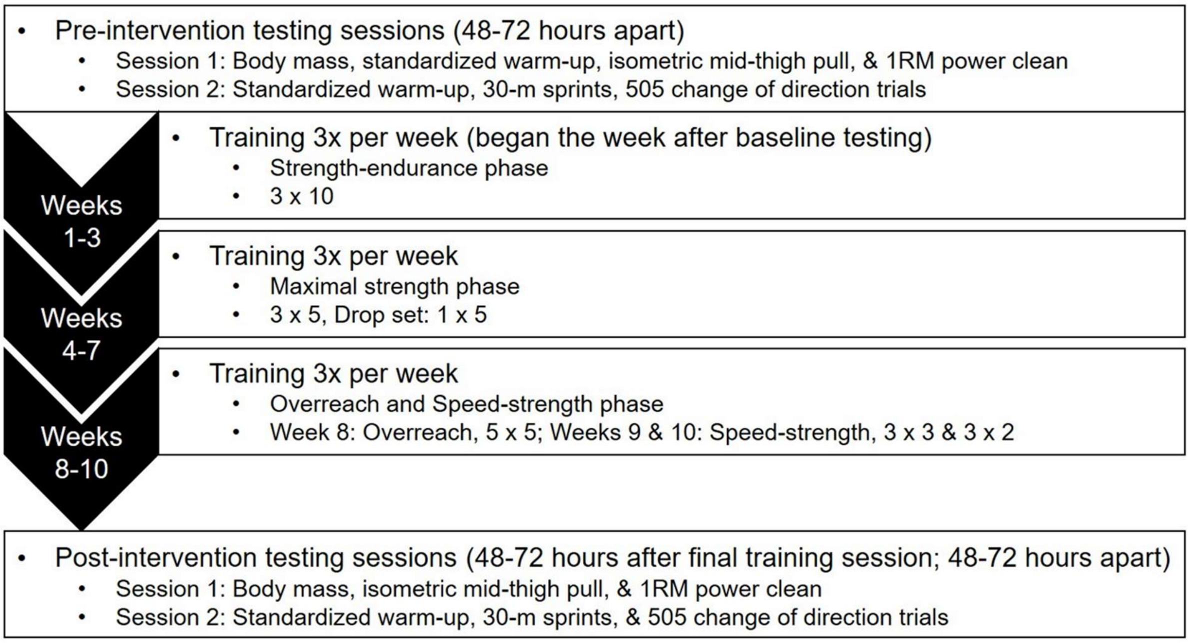
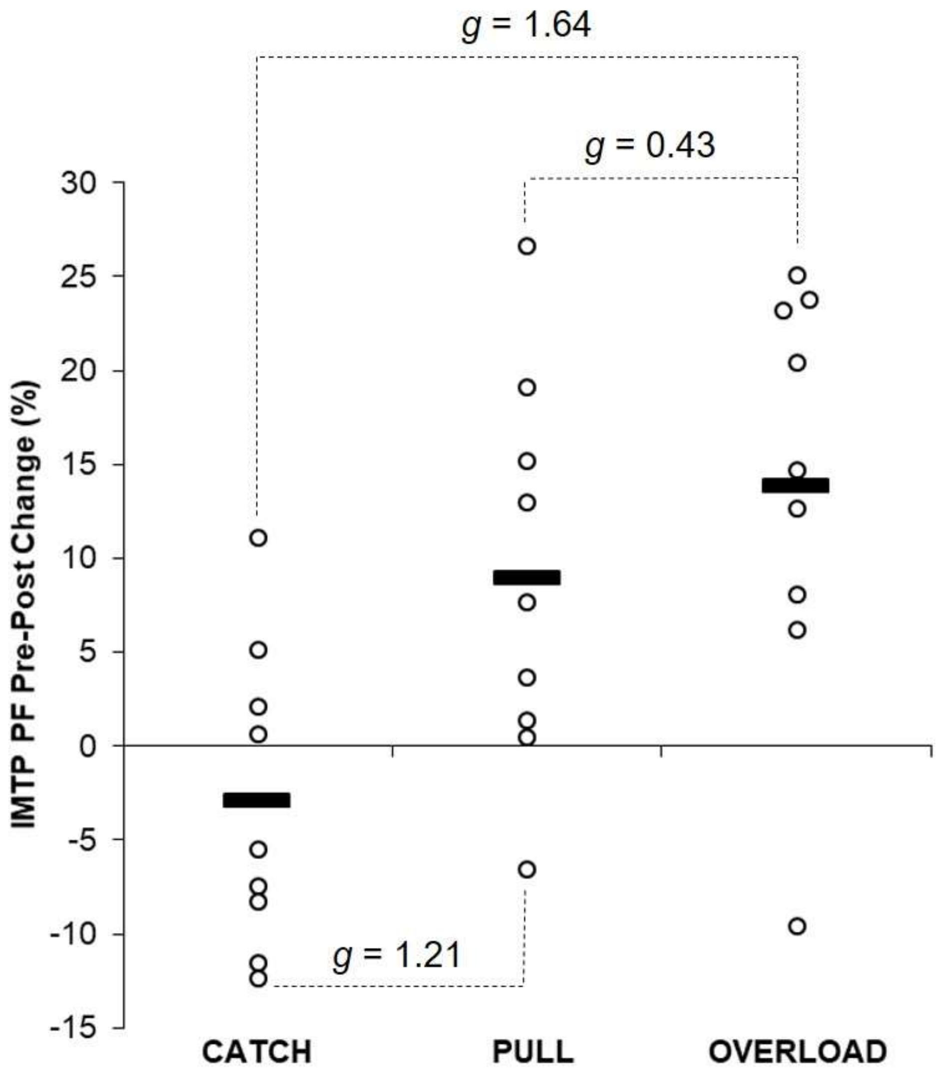
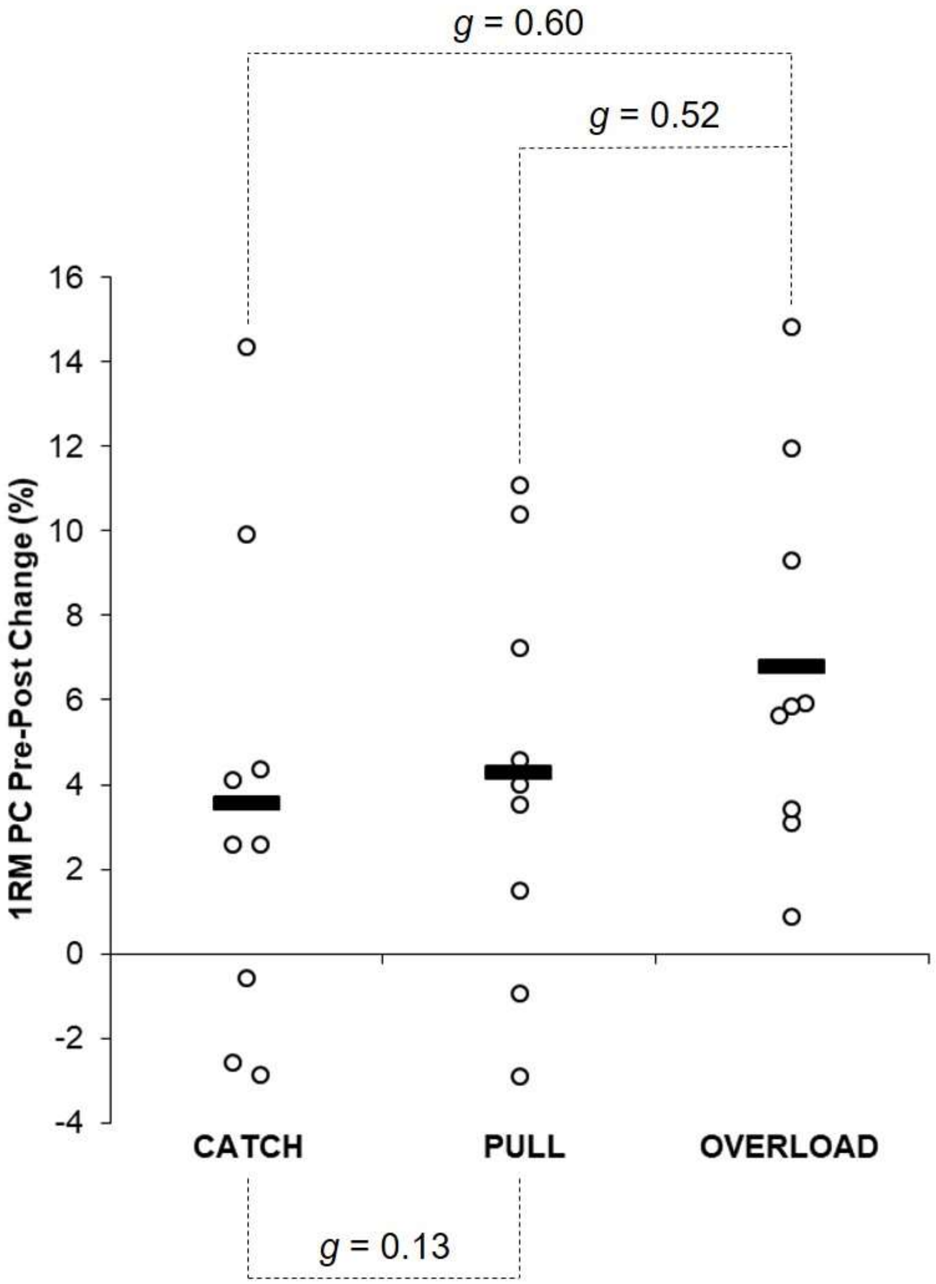


Figure 1



g = 1.64
g = 0.43
g = 1.21
30
25
20
15
10
5
0
-5
-10
-15
IMTP PF Pre-Post Change (%)
CATCH
PULL
OVERLOAD

Figure 2


g = 0.60
g = 0.52
16
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0
-2
-4
1RM PC Pre-Post Change (%)
CATCH
PULL
OVERLOAD
g = 0.13

Figure 3

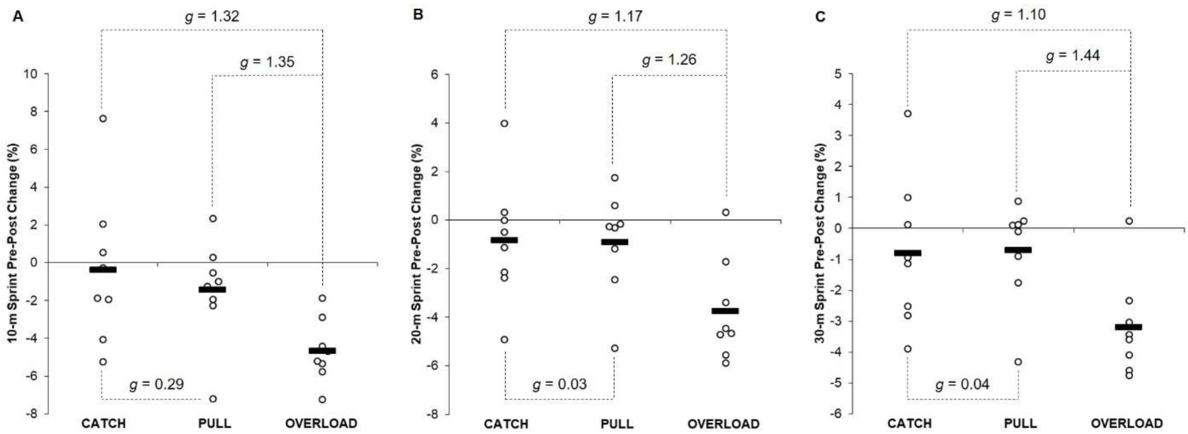

Figure 4

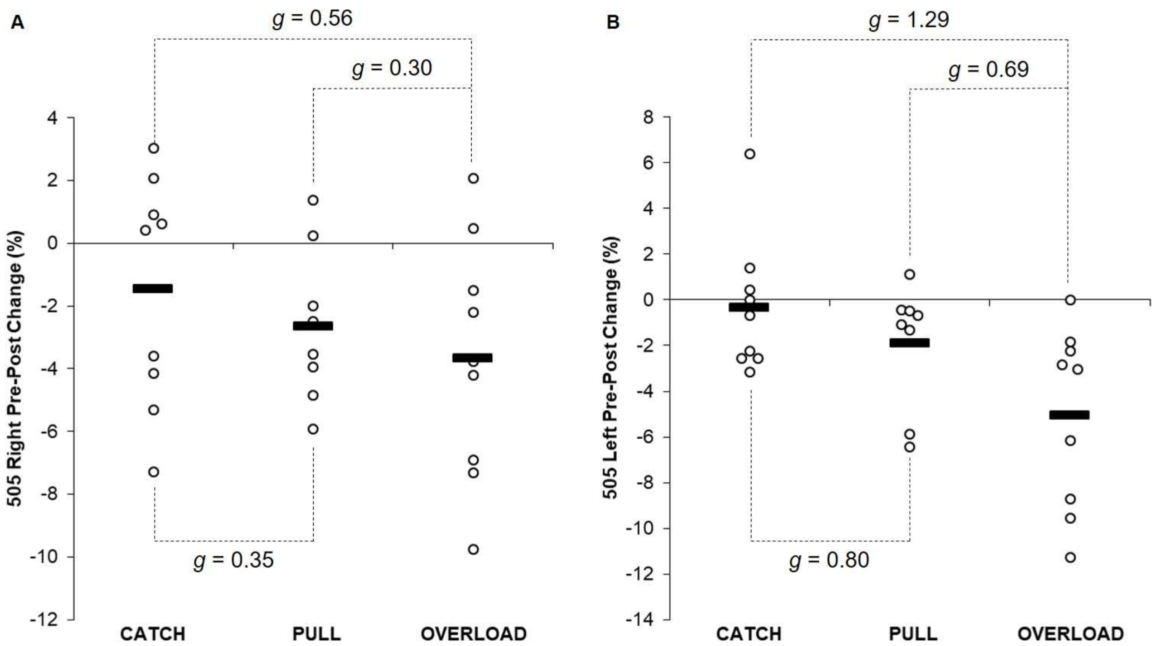

Figure 5