Changes in Bench Press Velocity and Power After 8 Weeks of High-Load Cluster or Traditional Set Structure: A Replication Study

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Abstract

This investigation was a replication of Davies et al. (2020), in which the effects of resistance training with divergent set structures were investigated in the barbell bench press (BP). Resistance-trained males (n = 16) and females (n = 9) participated in this study. Subjects completed eight weeks of training with traditional (TRAD) or cluster (CLUS) set structure. Testing was conducted pre- and post-training for maximal strength, mean and peak velocity and power, and load-velocity profiling. Mixed ANOVAs were conducted to assess differences in BP one repetition maximum (1RM) and mean and peak velocity and power with loads between 45% and 95% 1RM. A z-test was used to assess the compatibility of original and replication effect sizes for peak power at 45% 1RM. Unlike in the original study, the main effects for peak power were not statistically significant ($p > 0.05$); however, the original and replication effect sizes were compatible at 45% 1RM ($z = 1.07$, $p = 0.14$). In further contrast to the original findings, main time effects for peak velocity were not statistically significant at 55% or 65% 1RM ($p > 0.05$). Main time effects for mean velocity were partially replicated, as a statistically significant effect was observed at 65% ($p = 0.014$), but not at 55% 1RM ($p > 0.05$). The current results indicate that TRAD and CLUS set structures do not have robust effects on velocity and power in the BP, contradicting previous results. However, the TRAD and CLUS set structures investigated promote similar increases in maximal strength.

Keywords: Replicability, strength, resistance training, testing

Introduction

One of the pillars of the scientific method is that findings from a study are expected to be replicable. However, rarely are investigations replicated to examine the reproducibility of findings. The replication process involves reinvestigating previous findings using the same or similar methods used in the original study with newly collected data used to determine if the original findings can be replicated (19). A previous large-scale replication project in psychology yielded a low success rate (36% of replications were deemed successful, using *p*-value as a criterion), i.e., the researchers were unable to replicate many of the selected effects successfully (24). More recently, sports and exercise science researchers have called for improving research practices, as many believe similar replicability and transparency issues may exist within these fields (13).

A collaborative replication project was undertaken by the Sports Science Replication Centre to evaluate the replicability of recent scientific investigations in sports and exercise science (18). This project created a selection protocol to replicate studies in a randomized and unbiased manner (18). As per the selection protocol, we were tasked with the replication of the study titled, *"Changes in Bench Press Velocity and Power After 8 Weeks of High-Load Cluster- or Traditional-Set Structures"* authored by Davies et al. (7), which investigated the effects of CLUS and TRAD set structures on BP movement velocity and power output after high-load resistance training. For this replication, we replicated measures of barbell velocity, power, and muscular strength. However, per the selection protocol, one dependent variable was selected for the replication analysis: absolute peak power at 45% of one repetition maximum (1RM).

Muscular power has been identified as a characteristic important to athletic performance (12,28). Indeed, power output has been associated with sprinting, jumping, change of direction, throwing, and weightlifting (12,28). Therefore, developing power and methods that improve power output would be valuable for athletes. There are many ways to develop muscular power, such as heavy resistance exercises, weightlifting movements, plyometrics, and throwing exercises (27). In addition, depending on the exercise and execution, a wide range of loading may be implemented to elicit improvements in power development (14).

Typically, resistance training is carried out using a TRAD set structure, in which the applied load intensity remains constant, and all intended repetitions are performed consecutively without rest during each set. While TRAD sets provide an effective stimulus promoting gains in muscular strength and power over time (1), acute fatigue increases with greater consecutive repetitions, which may decrease the movement velocity (23) and power output (22) achieved in subsequent repetitions. Although greater consecutive repetition volume within a set may promote greater metabolic stress (22,23), metabolic adaptations (25,26), and improvements in work capacity and high-intensity exercise endurance (25), these effects may be achieved at the expense of acute mechanical variables (22,23), which may affect performance adaptations. Alternative set configurations, such as CLUS sets, have been proposed to reduce the decay in velocity and power observed during TRAD (5). During CLUS sets, small breaks (e.g., 10 to 30 seconds) are provided between repetitions, which is believed to enhance fatigue management, promote greater velocity maintenance, and, ultimately, result in superior mean power output within a set (11). These effects may be beneficial, particularly during key times of the training program when both high velocity and muscular power output are sought. Previous research on CLUS sets has demonstrated that this method may reduce acute losses in force, velocity, and power (11,16). However, few chronic studies exist in which changes in strength and power were investigated following CLUS set training, with available data showing mixed outcomes concerning velocity and power output

(7,17,20). Therefore, it remains to be determined if the acute benefits associated with CLUS sets translate to superior performance adaptations compared to TRAD.

This study replicated the work of Davies et al. (7) partially, and tested the hypothesis that resistance training with CLUS sets would be different than TRAD sets in barbell bench press (BP). Specifically, it was hypothesized that CLUS sets would result in greater strength development, concentric velocity, and power output compared to TRAD sets in previously resistance-trained males and females. However, unlike Davies and colleagues (7), the current investigation did not examine the maintenance of barbell kinematics and kinetics during exercise (i.e., mean velocity and power output across a set of repetitions).

Methods

Experimental Approach to the Problem

This replication study attempted to match the methods of the original study as closely as possible (2), therefore, a randomized comparative design was used for pre- and post-study variables, examining within- and between-group differences. This study was pre-registered on the Open Science Framework (https://doi.org/10.17605/OSF.IO/H63VC), and ethical approval was obtained from the university Institutional Review Board before any data collection (IRB# 220125A). The original authors were contacted for raw data, were helpful with queries, and were provided with the opportunity to provide feedback on this manuscript.

Subjects completed 14 weeks of testing and training. Testing for BP 1RM was performed one week before a three-week familiarization period. During familiarization, all subjects completed identical training procedures. Following the standardized familiarization period, subjects completed baseline 1RM testing and load-velocity profiling, followed by eight weeks of resistance training.

A post-intervention 1RM and load-velocity profile were determined one week after completing the eight-week training period. A detailed breakdown of the study procedures can be found in Table 1. Subjects completed identical testing and training procedures, except when performing the BP exercise. The TRAD set group completed four sets of five repetitions at 85% 1RM with five minutes of passive rest between sets and no inter-repetition rest. The CLUS set group completed the same set and repetition scheme but was provided 30 seconds of passive rest between each repetition and three minutes between sets. The different set x rep configurations resulted in different total durations of the rest provided during the BP, where the CLUS set group was provided additional rest due to the prescription of intra-set rest intervals (17 vs 15 minutes per session). This discrepancy was also present in the original study (7). The complete list of exercises prescribed during the training period can be found in the supplementary file in the original study (7).

Insert Table 1 about here.

Participants

A priori sample size calculation methods are detailed in the study selection protocol (18) which also states that the replication sample size must be larger than the original sample size. The original effect size point estimate was calculated as partial eta squared = 0.304 [95% CI: 0.00, 0.54] using the original data provided to us by the original authors. This was then used to estimate the sample size to be recruited for a two-way mixed ANOVA at an alpha of 0.05, which resulted in 32 participants. All calculations and power analyses are available online (https://doi.org/10.17605/OSF.IO/U6HQX).

Thirty-two subjects volunteered for the study (13 females and 19 males); however, seven subjects dropped out during the study due to time commitments. Therefore, 25 subjects (9 females and 16 males) completed all study procedures. Subject demographic data can be found in Table 2. Similar to the original study, all subjects were required to have regularly performed resistance training prior to the start of the study, training a minimum of twice each week and to have been performing the BP weekly. Subjects were not recruited if they had sustained an upper-body injury that prevented them from performing the BP in the past three months or if it was reported that they had been using performance-enhancing drugs at any point during the 12 months preceding the study. During the initial session, subjects were informed of all testing procedures, time commitments, and risks/benefits. They were allowed to ask questions, and when necessary, procedures were clarified before participants read and signed a written informed consent document indicating their willingness to participate.

Insert Table 2 about here.

Procedures

One Repetition Maximum Testing

During weeks 1, 5, 8, 10, 12, and 14, subjects completed a maximal BP strength assessment. During intervention weeks (weeks 8 – 12), 1RM testing occurred before any other training during that session. Prior to 1RM attempts, subjects completed a standardized general and BP specific warm-up. The specific warm-up consisted of five repetitions with an unloaded barbell (20kg), five repetitions with 50%, and five repetitions with 70% of their self-reported 1RM. Subjects then completed single repetitions at 80% and 90% of their self-reported 1RM. After completing the specific warm-up, subjects completed 3-5 maximal attempts with progressive loading to determine their 1RM. The minimal load increase between testing loads was 2.5kg. Subjects were provided with 3 minutes of passive rest between each effort to prevent fatigue. For a repetition to be considered successful, subjects needed to lower the barbell fully to the sternum and press to arm's length without bouncing or using momentum. Subjects were instructed to keep their feet flat on the floor and their glutes, upper back, and head against the bench at all times during the execution of the lifts. All repetitions were observed and spotted by a strength coach certified through the National Strength and Conditioning Association. Subjects were instructed to control the eccentric portion and attempt to lift the concentric portion as fast as possible.

Familiarization Phase and Training Intervention

During weeks 2, 3, and 4, subjects completed a standardized training protocol consisting of two upper-body and one lower-body session per week for a total of nine sessions. All exercises can be found in the supplementary material. Following this period, subjects were randomly assigned to the TRAD or CLUS set group using a random number generator (random.org). During the first four weeks of the intervention period (weeks 6 – 9), regardless of group, subjects completed one lower and two upper body sessions per week for a total of 12 sessions. Next, during the final four weeks (weeks 10 – 13), subjects completed two lower and two upper body sessions per week for a total of 16 sessions. Subjects needed to complete all training sessions throughout the study to be included in the final analysis.

Barbell Velocity, Power Output, and Load-Velocity Profiling

Barbell velocity and power output were obtained during weeks 5 (after familiarization and before the intervention period) and 14 (post-intervention) by using a GymAware linear position transducer (version 4.1.5, Performance Technology, Mitchell, Australia) affixed to the barbell. This device has been determined to be both valid and reliable for measurements of the BP (21). Furthermore, this device was used by the original study's authors for the same purpose (7). Concentric mean and peak velocity, and power were sampled at 20-ms time points. Subjects completed each repetition with a controlled eccentric and maximal concentric intent. A load-velocity profile was created using progressively heavier relative loads of the subjects' 1RM. Following a standardized general warm-up, two repetitions were completed with loads from 45% to 95% in 10% intervals. Subjects were provided 30 seconds of passive rest between repetitions at loads of 45% and 55%, one minute at 65%, two at 75%, and three at 85% and 95% of their 1RM, respectively. Between each set, subjects rested for one minute at 45% and 55%, two minutes at 65% and 75%, and three minutes between 75%, 85%, and 95% 1RM, respectively. Therefore, in each testing session, subjects completed 12 measured repetitions; however, only the best trial for each relative load was used for analysis in accordance with the methods used in the original study.

St*atistical Analysis*

The normality of data was assessed using Shapiro-Wilk testing, and homogeneity of variance was assessed using Levene's test. Independent t-tests were conducted for subject baseline characteristics. To be consistent with methods used in the original study (7), within-group changes for maximal strength from baseline to post-intervention were evaluated with paired samples t-tests. A series of 2x2 (group [between factor] x time [within factor]) mixed analysis of variance (ANOVA) were completed to examine the effect of the resistance training on maximal strength and mean and peak concentric velocity and power output at all tested relative loads between 45% and 95% 1RM. When a statistically significant interaction effect was observed, post hoc testing with Bonferroni adjustment was conducted. Effect sizes were calculated as partial eta squared (η_p^2) for each ANOVA and Cohen's d_z for the within-group changes, to permit comparisons with effect sizes reported in the original study. Although the authors of the original study (7) indicated that within-group estimates of effect size were calculated using independent-group calculations, the analysis could not be replicated as described. In accordance with methods used in the original study, between-group effect sizes (Cohen's *d*) were calculated using within-group mean differences (post - pre) divided by the pooled standard deviation of the group mean differences. Confidence intervals (95%) were calculated for each effect size. The effect size and 95% confidence intervals reported were interpreted as very small < 0.20, small = 0.20 to 0.49, medium = 0.50 to 0.79, large ≥ 0.80 (13). Reliability was assessed using intraclass correlation coefficients (ICC) and coefficient of variation (CV). ICC values were interpreted as < 0.5 as poor, 0.5 to 0.75 as moderate, 0.75 to 0.90 as good, and > 0.9 as excellent (15). CV values < 5% were interpreted as good, 5-10% as moderate, and >10% as poor reliability (15). Demographic data was calculated in Microsoft Excel (Microsoft, Redmond, WA, USA). All statistical analyses were completed in JASP (version 0.18.2.0, Amsterdam, North Holland, NL). The alpha level was set at 0.05 for all analyses.

Replication Analysis

To assess the replication outcome, the replication effect must be statistically significant and in the same direction as the original effect, and the original effect size must fall within the 95% confidence interval of the replication effect size. A one-tailed z-test was also used to determine if the original effect size estimate was significantly larger than the replication effect size estimate using the *TOSTER R* package (version 0.8.0) (3). The raw data and code for the replication analyses are available at https://doi.org/10.17605/OSF.IO/U6HQX. Therefore, a replication was considered successful when it was significant and when effect sizes were compatible across the original and replication studies.

Results

Strength

Differences between TRAD and CLUS in maximal strength (BP 1RM) were not statistically significant at pre-training ($p > 0.05$). There was a significant time effect for maximal strength ($F_{1,10} = 36.613$, $p < 0.001$), but the group ($F_{1,10} = 0.896$, $p = 0.366$) and interaction effects ($F_{1,10} = 0.485$, $p = 0.502$) failed to reach statistical significance. The paired t-tests showed that both groups significantly increased their maximal strength from pre- to post-intervention, with the CLUS group increasing by 7.5kg (9.3%, $t_{13} = -5.048$, $p < 0.001$, $d_z = 1.3$) and the TRAD group by 5.8kg (6.1%, $t_{10} = -3.802$, $p = 0.003$, $d_z = 1.1$).

Peak Velocity and Power

Results for peak velocity and peak power are presented in Table 3 and effect sizes and confidence intervals can be found in Table 5. Peak velocity data were statistically significantly different between conditions at pre-training at 75% 1RM ($p < 0.05$). Differences in peak power were not statistically significant ($p > 0.05$). A statistically significant time effect was found for peak velocity at 85% 1RM ($p = 0.033$); however, there was no statistically significant time effect observed for peak power at any relative load ($p > 0.05$). Group-by-time interaction effects were not statistically significant for peak velocity or peak power at any relative load ($p > 0.05$).

Reliability data, including 95% confidence intervals for peak velocity and peak power, can be found in Table 6. The ICC values for peak velocity ranged from 0.68 to 0.90 for loads ranging from 45-85% 1RM (moderate to excellent), and 0.45 for 95% 1RM (poor reliability). The CV values for peak velocity data ranged from 3.7% to 5.3% (good-to-moderate) for loads ranging from 45-85% 1RM, and 11.2% for 95% 1RM, indicating poor reliability. The ICC values for peak power ranged from 0.97 to 0.99 (excellent reliability). The CV values for peak power data ranged from 4.3% to 5.9%, indicating good-to-moderate reliability.

Insert Table 3 about here

Mean Velocity and Power

Results for mean velocity and mean power are presented in Table 4 and effect sizes and associated confidence intervals can be found in Table 5. Mean velocity data was statistically significantly different between conditions at pre-training at 65% ($p = 0.019$), 75% ($p = 0.02$), and 85% 1RM ($p = 0.006$). Differences in mean power were not statistically significant ($p > 0.05$). A statistically significant time effect was observed for mean velocity at 65% ($p = 0.014$) and 85% 1RM ($p = 0.004$). However, no statistically significant time effect was observed for mean power at any relative load ($p > 0.05$). A statistically significant group effect was observed for mean velocity at 65% ($p = 0.021$), 75% ($p = 0.007$), and 85% 1RM ($p = 0.027$). There were no statistically significant group effects observed for mean power at any relative load ($p > 0.05$). Group-by-time interaction effects were not statistically significant for mean velocity or mean power at any relative load ($p > 0.05$).

Table 6 contains reliability and 95% confidence interval data for mean velocity and power. The ICC values for mean velocity ranged from 0.79 to 0.95 (good to excellent) for loads from 45-85%, whereas 95% 1RM displayed poor reliability (0.48). CV values ranged from 3.4% to 9.9%, indicating good-to-moderate reliability. The ICC values for mean power output ranged from 0.87 to 1.00 (good to excellent). CV values for mean power data ranged from 3.1% to 6.4% (good-to-moderate) for loads ranging from 45-85% 1RM, and 10.3% for 95% 1RM, indicating poor reliability.

Insert Table 4 about here

Insert Table 5 about here

Insert Table 6 about here

Replication Outcomes

When examining the replication outcome of the main effect for time, our results showed a non-significant main effect on absolute peak power at 45% of 1RM ($F_{1, 23} = 3.40$, $p = 0.08$, $\eta_p^2 = 0.129$, 0.000 to 0.373), in contrast to the original study ($F_{1, 12} = 5.24$, $p = 0.041$, $\eta_p^2 = 0.304$, 0.007 to 0.541). The z-test showed that the original effect size estimate ($\eta_p^2 = 0.304$) was not significantly larger than the replication effect size estimate ($\eta_p^2 = 0.129$), and they were compatible ($z = 1.07$, $p = 0.14$). Although the null hypothesis significance testing outcome differed in the replication and original studies, the original and replication effect size estimates were not significantly different and can be considered compatible. Furthermore, the effect size estimate reported in the original study was within the 95% confidence interval calculated for the effect size observed in the replication. This replication outcome is therefore deemed inconclusive (2).

Discussion

The purpose of this study was to replicate closely (2) the study conducted by Davies et al. (7), which examined eight weeks of high-load CLUS or TRAD resistance training on maximal strength, velocity, and power output in the barbell BP (7). The main findings of this study are partially aligned with those of the original research. Maximal strength outcomes observed in the current study and previously (7) were similar, but mixed results were observed for mean and peak velocity and peak power. Specifically, Davies et al. (7) found no significant group or interaction (group-by-time) effects for either peak and mean velocity or peak and mean power, which were replicated in our study. Considering peak velocity and power, the current study results differed from those reported by the original authors in that no statistically significant time effects were observed in the current investigation across the tested loads, except at 85% 1RM. In contrast, Davies et al. reported that multiple-time effects were statistically significant (7). The current results are partially aligned with those reported previously regarding mean power and velocity. This investigation demonstrated similar statistically significant time effects for velocity at moderate loads (65% and 85% 1RM) but differed from the original investigation in that group effects were also statistically significant.

When examining training-induced maximal strength outcomes, the results of the current investigation align with those reported by Davies et al. (7) in that both training groups experienced statistically significant improvements. However, it should be noted that, in the current study, subjects presented greater relative strength values at pre-training ($0.93kg \cdot kg^{-1}$ for CLUS and $1.11kg \cdot kg^{-1}$ for TRAD) compared to participants recruited by Davies et al. (7) ($0.9kg \cdot kg^{-1}$ for CLUS and $0.85kg \cdot kg^{-1}$ for TRAD), particularly when considering those subjects assigned to the TRAD group. Indeed, strength gains experienced by the CLUS group were similar in the current study compared to the previous results (9.3% vs. 9.9%, respectively) (7). However, a notable discrepancy in strength improvement was observed for TRAD between the current and former investigations (6.0% vs. 11.0%, respectively). As initial strength levels may indicate greater training status, the subjects who completed TRAD in the current investigation were likely more trained at pre-training compared to subjects who completed TRAD in the original investigation and, therefore, were closer to their genetic potential for muscular strength. Although stronger than the original subjects, when considering relative strength for the BP, the subjects who completed TRAD in the current study (males and females) were considered to possess “good” strength levels when compared to normative values (6), and therefore were not likely to be advanced trainees. Nevertheless, the noted discrepancies in pre-training relative strength might explain, in part, the discrepancies in strength gain between CLUS and TRAD in the current study, as well as between the TRAD groups in the current and original investigations.

In the current study, absolute changes in maximal strength were not statistically different between groups (7.5kg for CLUS and 5.7kg for TRAD). These relative and absolute change outcomes align with other studies conducted with males and females (9), and the results of a recent meta-analysis in which CLUS and TRAD were found to facilitate similar strength gains (8). Considering the results of the current investigation and those reported previously, it appears that the chronic inclusion of a CLUS set configuration, particularly one providing inter-repetition rest, may not meaningfully impact the rate of maximal strength improvement compared to TRAD sets. As such, CLUS set or TRAD set structures may be appropriate when training to develop muscular strength, although TRAD set structures, requiring less time due to less passive rest provided, maybe a more efficient use of training time.

Changes in peak velocity partially aligned with the results reported by Davies et al. (7) at any relative load investigated. Davies et al. (7) found a statistically significant time effect for peak velocity at 55% and 65% 1RM. In contrast, a statistically significant time effect was observed only at 85% 1RM in the current investigation. The authors of the original investigation (7) also reported statistically significant time effects for mean velocity at moderate loads (55% and 65% 1RM). In partial agreement with these observations, a statistically significant time effect was observed at 65% and at 85% 1RM in the current investigation. Furthermore, the observed group effects are an additional primary difference between the current and former studies. The original study reported no statistically significant group effect, whereas statistically significant group effects were observed at 65%, 75%, and 85% 1RM for mean velocity and at 75% 1RM for peak velocity in the current investigation. The group effects observed here may be explained by greater mean velocity at pre-training for CLUS at moderate-to-high relative loads (65%, 75%, and 85% 1RM) and greater pre-training peak velocity at 75% 1RM, which were not reported by the authors of the original investigation (7).

The rationale for prescribing a CLUS set structure is to better maintain acute barbell velocity by providing intra-set rest, potentially mitigating fatigue (11,16). However, in this investigation, the CLUS set structure did not result in superior chronic improvements in mean velocity compared to TRAD. This finding agrees with Davies et al. (7), where decrements in velocity were associated with the CLUS set structure. Furthermore, the current results agree with the results and conclusions of a recent systematic review and meta-analysis, in which no statistically significant differences were reported for mean or peak velocity when comparing CLUS and TRAD set structures (8). Although acutely, CLUS set structures have demonstrated superior effects on barbell velocity in the barbell BP (7,10), such effects do not appear to consistently translate to chronic velocity improvements.

Interestingly, in the previous and current study, mean velocity was reduced at post-training for every relative load investigated for CLUS and TRAD groups, except at 95% 1RM for TRAD. An explanation for these results is not entirely clear; however, it is noteworthy to highlight that the relative load intensity used in this study and in the original study (7) (i.e., 85% 1RM) is not generally recommended when training to enhance velocity and power (12). Considering this, it’s plausible that the relative load intensity prescribed led to improvements in muscular strength but failed to facilitate robust favorable training effects on velocity and power due to task specificity (8,14). Moreover, the traditional strength training exercises prescribed in this study (i.e., barbell

BP) may not be optimal for enhancing velocity and power (11,14). However, as previously mentioned, the results of the original investigation (7) partially align with the findings of the replication study despite the prescription of identical relative load intensity and exercise selection. Concerning these discrepancies, it should be noted that both the current and original studies were statistically underpowered; however, the current study, having achieved a larger sample size, might be expected to have a lower relative type I error risk. Therefore, the statistical results of this replication study may be considered with greater confidence. Indeed, the results reported here are in agreement with those reported in a recent meta-analysis (8), indicating that CLUS and TRAD do not result in statistically different improvements in velocity. Considering the observations made here, and those reported by Davies et al. (8), it may be that the results of statistical testing conducted by the authors of the original study (7) were more susceptible to false positives compared to the current study.

In the original study conducted by Davies et al. (7), the authors reported statistically significant time effects for peak power at 45%, 65%, and 75% 1RM, while statistically significant time effects for mean power were reported at every load investigated between 45% and 75% 1RM. In contrast, the current investigation revealed no statistically significant time, group, or time-by-group interaction effects for peak and mean power at any relative load investigated. A primary recommended use of CLUS set structures is to promote maintenance or improve power output by mitigating the loss of concentric velocity across repetitions in a given set, which might be suspected to translate to superior chronic improvements. However, this could not be confirmed with the results of the current study as no statistically significant differences were observed in peak or mean power between TRAD and CLUS set groups, a finding that is in agreement with results reported from a recent meta-analysis (8). These results indicate that favorable acute effects on power associated with CLUS set structures (29) may not consistently translate to chronic improvements with training.

Interestingly, evaluation of within-subject effects revealed that the CLUS set configuration reduced mean and peak power output at 65%, 75%, and 85% 1RM. However, reductions were not statistically significant, with the exception of decreases in mean power observed at 85% 1RM. These results are in opposition to those reported by Davies et al. (7) and diverge from earlier research in which investigators reported improvements in power achieved at lighter loading magnitudes (45% to 75%) with no effects reported at heavier loading magnitudes (80% to 95%) (7,17,20). Therefore, similar to results concerning peak and mean velocity, it appears that peak and mean power may not have responded as favorably to the training program, compared to muscular strength, due to the relative load intensity and exercise selection prescribed (8,14). However, a notable finding in the current investigation is that peak power at 45% 1RM was statistically significantly greater at post-training after CLUS only, which agrees with previous findings (7, 8, 17, 20), perhaps indicating greater effects when using light relative load intensities.

It should be noted that the training intervention prescribed in the current and original investigations (7) did not incorporate "light" training days throughout the intervention, and subjects did not complete a "deloading" period before post-training testing. Incorporating light training days, with reduced load intensity and volume and deloading by acutely reducing training volume load, intensity, or both, has been shown to reduce training strain and monotony, (25) and enhance fatigue management and recoverability (4). It's plausible that the recovery effects promoted by incorporating a deloading period and lighter training days throughout the training period may have led to greater improvements in kinetic and kinematic variables during post-training testing. However, as both the original and replication studies were conducted without including light training days and a deloading period, the absence of these loading paradigms would not explain discrepancies in the results reported.

This study is not without limitations. We attempted to recruit subjects with similar demographic characteristics compared to those recruited by the original authors; however, notable discrepancies in physical ability were observed. When considering relative bench press strength at pre-training, male subjects in the current investigation were considered to be "good" ($1.23 kg \cdot kg^{-1}$), compared to "fair" ($1.07 kg \cdot kg^{-1}$) in the original study, while female subjects were considered to be "fair" ($0.65 kg \cdot kg^{-1}$) compared to "poor" ($0.58 kg \cdot kg^{-1}$) (6). We do not suspect that the strength differences contributed to the discrepancies in results reported in the current and original studies, with the potential exception of the strength gains observed in TRAD. Nevertheless, differences in subject relative bench press strength at pre-training should be considered as a potential limitation of this replication study.

We also attempted to replicate the methods of the earlier investigation conducted by Davies et al. (7) as closely as possible. However, post-training body weight values were not collected, preventing the derivation of relative strength, power, and velocity changes, which may have provided additional insight into pre- to post-training effects. Additionally, the subjects recruited in the current and former investigations (7) were described as recreationally trained. These results should be considered within this context and not extrapolated to other populations with different resistance training backgrounds. Finally, the required number of participants (n = 32) was met. However, 7 participants dropped out of the study due to time constraints, leading to a final sample of 25. This limits the study's overall statistical power, increasing the risk of a type I error (false positive) and reducing the confidence in the statistical results in general. Nevertheless, after dropouts, this investigation achieved a larger sample size compared to that of the original study (n

= 25 vs n = 21, respectively). Furthermore, evidence was provided here for compatibility of the results of the current and former investigations for the primary dependent variable (peak power at 45% 1RM). As such, although some of the results reported here may provide questionable evidence for generalizability, the successfully replicated findings and those that agree with Davies et al. (7) may be considered with greater confidence.

Practical Application

This close replication study partially supports the results of the original study. No differences were observed over eight weeks for the CLUS group compared to the TRAD group. Both groups experienced improvements in maximal strength with equivocal changes in mean and peak velocity and power. When using load-matched, volume-equated training protocols, the acute changes in intra-set rest structure provide no additional benefits compared to traditional sets in resistance-trained males and females. For this reason, practitioners can drive changes in maximal strength, velocity, and power output through either CLUS or TRAD set configurations. When training to elicit improvements in velocity and power, training relative load intensities and exercise selection must be carefully considered in the context of task specificity.

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Table 1. Study Procedures

	Week 1	Week 2 – 4	Week 5	Week 6 – 9*	Week 10 – 13*	Week 14
	Baseline Test & Demographics	Fam	Pre-Test	INT	INT	Post- Test
Main set x repetition scheme for bench press	1RM	3x8 at 70-75%	1RM & Velocity Testing	4x5 at 85%	4x5 at 85%	1RM & Velocity Testing
Days Per Week	1	3	1	3	4	1
Session type	Test day	2 upper, 1 lower	Test day	2 upper, 1 lower	2 upper, 2 lower	Test day

Note: 1RM=One repetition maximum; Fam = Familiarization; INT = intervention period, * indicates 1RM assessments during weeks 8, 10, and 12, all loads are % 1RM

Table 2. Subject Demographics

Group (n)	Age (yrs)	Training Age (yrs)	Height (cm)	Body Mass (kg)	Initial Relative Strength (kg/kg)	Pre 1RM (kg)	Post 1RM (kg)
Cluster (14)	23.1 ± 5.9	4.4 ± 2.5	174.8 ± 7.6	79.9 ± 16.5	0.93 ± 0.42	80.0 ± 38.2	87.5 ± 36.9
Males (9)	23.7 ± 7.5	5.0 ± 2.8	179.1 ± 86.1	86.1 ± 15.3	1.15 ± 0.36	97.5 ± 28.5	110 ± 24.1
Female (5)	22.0 ± 1.2	3.4 ± 1.5	167.0 ± 4.5	68.8 ± 13.3	0.53 ± 0.12	35.8 ± 5.5	47.0 ± 8.4
Traditional (11)	23.0 ± 3.3	4.3 ± 2.8	173.7 ± 9.3	82.3 ± 15.6	1.11 ± 0.33	95.3 ± 36.2	101.1 ± 36.8
Males (7)	22.1 ± 3.9	5.1 ± 3.4	178.4 ± 7.5	86.9 ± 13.9	1.30 ± 0.19	113.1 ± 22.3	124.0 ± 22.9
Female (4)	24.5 ± 2.3	3.0 ± 1.4	165.3 ± 7.9	74.4 ± 19.2	0.77 ± 0.20	54.2 ± 7.1	61.2 ± 10.7

Note: All data Mean ± SD; 1RM = one repetition maximum; Pre = before intervention; Post = Post intervention

Table 3. Changes in peak bench press power and velocity

	Cluster Group (n = 14) (paired t-test)			Traditional Group (n = 11) (paired t-test)			ANOVA ($df_1 = 1$, $df_2 = 23$)								
							Time			Group			G X T		
	Pre	Post	*p*	Pre	Post	*p*	*F*	*p*	η^2p	*F*	*p*	η^2p	*F*	*p*	η^2p
45% 1RM															
Absolute (W)	491.72 ± 246.41	563.29 ± 255.38	0.037*	590.16 ± 292.24	591.95 ± 255.76	0.935	3.397	0.078	0.129	0.377	0.545	0.016	3.074	0.093	0.118
Velocity ($m \cdot s^{-1}$)	1.11 ± 0.18	1.16 ± 0.18	0.375	1.12 ± 0.20	1.09 ± 0.19	0.378	0.078	0.783	0.003	0.228	0.637	0.010	1.402	0.248	0.057
55% 1RM															
Absolute (W)	477.13 ± 240.53	483.0 ± 217.51	0.758	573.68 ± 260.82	575.83 ± 235.66	0.916	0.085	0.773	0.004	0.997	0.329	0.042	0.018	0.893	0.001
Velocity ($m \cdot s^{-1}$)	0.98 ± 0.16	0.97 ± 0.19	0.785	0.96 ± 0.11	0.90 ± 0.15	0.117	0.993	0.329	0.041	0.629	0.436	0.027	0.297	0.591	0.013
65% 1RM															
Absolute (W)	501.35 ± 258.33	441.54 ± 188.48	0.135	516.76 ± 227.76	530.95 ± 218.25	0.589	0.899	0.353	0.038	0.360	0.554	0.015	2.366	0.138	0.093
Velocity ($m \cdot s^{-1}$)	0.87 ± 0.15	0.78 ± 0.12	0.101	0.77 ± 0.11	0.73 ± 0.14	0.276	3.865	0.061	0.144	3.209	0.086	0.122	0.724	0.404	0.031
75% 1RM															
Absolute (W)	444.37 ± 223.54	428.46 ± 213.04	0.536	459.11 ± 208.57	472.50 ± 206.40	0.658	0.004	0.948	0.000	0.123	0.729	0.005	0.583	0.453	0.025
Velocity ($m \cdot s^{-1}$)	0.69 ± 0.11	0.63 ± 0.13	0.171	0.60 ± 0.10	0.56 ± 0.10	0.341	2.872	0.104	0.111	5.127	0.033*	0.182	0.173	0.681	0.007
85% 1RM															
Absolute (W)	396.71 ± 193.83	362.21 ± 165.96	0.070	422.29 ± 202.93	416.78 ± 206.88	0.763	2.506	0.127	0.098	0.277	0.604	0.012	1.315	0.263	0..054
Velocity ($m \cdot s^{-1}$)	0.55 ± 0.11	0.49 ± 0.10	0.104	0.48 ± 0.08	0.44 ± 0.10	0.104	5.171	0.033*	0.184	2.772	0.109	0.108	0.255	0.618	0.011
95 % 1RM															
Absolute (W)	354.11 ± 162.34	326.23 ± 159.33	0.120	386.54 ± 210.0	420.67 ± 176.83	0.249	0.040	0.842	0.002	0.839	0.369	0.035	3.988	0.058	0.148
Velocity ($m \cdot s^{-1}$)	0.52 ± 0.21	0.39 ± 0.07	0.069	0.45 ± 0.22	0.44 ± 0.15	0.882	2.018	0.169	0.081	0.027	0.870	0.001	1.419	0.246	0.058
Note: 1RM= One Repetition Maximum															

*Note: * p < 0.05; W = watts; ANOVA = analysis of variance; df = degrees of freedom; Pre = pre-training; Post = post training; T = time effect; G = group effect; G X T = group by time interaction; 1RM = one repetition maximum*

Table 4. Changes in mean bench press power and velocity

	Cluster Group (n = 14) (paired t-test)			Traditional Group (n = 11) (paired t-test)			ANOVA ($df_1 = 1$, $df_2 = 23$)								
							T			G			G x T		
	Pre	Post	*p*	Pre	Post	*p*	*F*	*p*	*η2p*	*F*	*p*	*η2p*	*F*	*p*	*η2p*
45% 1RM															
Absolute (W)	285.65 ± 146.69	303.26 ± 118.49	0.299	334.69 ± 161.97	354.80 ± 167.25	0.192	2.844	0.105	0.110	0.740	0.399	0.031	0.012	0.912	0.0005
Velocity ($m \cdot s^{-1}$)	0.77 ± 0.11	0.77 ± 0.12	0.933	0.75 ± 0.12	0.73 ± 0.11	0.441	0.420	0.523	0.018	0.616	0.441	0.026	0.283	0.600	0.012
55% 1RM															
Absolute (W)	303.96 ± 156.34	313.47 ± 136.36	0.598	351.20 ± 155.58	352.72 ± 141.25	0.904	0.236	0.632	0.010	0.549	0.466	0.023	0.124	0.728	0.005
Velocity ($m \cdot s^{-1}$)	0.71 ± 0.11	0.68 ± 0.11	0.341	0.66 ± 0.08	0.62 ± 0.10	0.089	2.824	0.106	0.109	1.970	0.174	0.079	0.009	0.927	0.000
65% 1RM															
Absolute (W)	315.93 ± 159.07	303.98 ± 128.61	0.472	344.32 ± 146.39	337.04 ± 144.75	0.575	0.809	0.378	0.034	0.286	0.598	0.012	0.048	0.829	0.002
Velocity ($m \cdot s^{-1}$)	0.64 ± 0.10	0.56 ± 0.09	0.046*	0.55 ± 0.07	0.50 ± 0.10	0.105	7.046	0.014*	0.235	6.153	0.021*	0.211	0.677	0.419	0.029
75% 1RM															
Absolute (W)	303.58 ± 147.52	290.54 ± 126.78	0.374	305.62 ± 129.61	319.72 ± 142.44	0.411	0.002	0.961	0.000	0.083	0.776	0.004	1.576	0.222	0.064
Velocity ($m \cdot s^{-1}$)	0.52 ± 0.07	0.47 ± 0.09	0.075	0.43 ± 0.05	0.41 ± 0.09	0.407	3.858	0.062	0.144	8.935	0.007*	0.280	0.760	0.392	0.032
85% 1RM															
Absolute (W)	265.98 ± 126.20	238.30 ± 102.08	0.037*	260.74 ± 101.05	270.77 ± 137.54	0.552	0.802	0.380	0.034	0.087	0.771	0.004	3.661	0.068	0.137
Velocity ($m \cdot s^{-1}$)	0.40 ± 0.07	0.33 ± 0.08	0.012*	0.32 ± 0.04	0.29 ± 0.06	0.110	10.232	0.004*	0.308	5.609	0.027*	0.196	1.974	0.173	0.079
95 % 1RM															
Absolute (W)	184.29 ± 85.35	192.13 ± 85.66	0.544	186.05 ± 84.40	202.96 ± 93.18	0.394	1.270	0.271	0.052	0.036	0.852	0.002	0.171	0.683	0.007
Velocity ($m \cdot s^{-1}$)	0.30 ± 0.14	0.23 ± 0.06	0.125	0.20 ± 0.04	0.21 ± 0.07	0.744	1.466	0.241	0.059	4.024	0.057	0.149	2.203	0.151	0.087

Note: 1RM=One repetition Maximum

*Note: * $p \leq 0.05$; W = watts; ANOVA = analysis of variance; df = degrees of freedom; Pre = pre-training; Post = post training; T = time effect; G = group effect; G X T = group by time interaction; 1RM = one repetition maximum*

Table 5: Effect sizes for the change in peak and mean power and velocity

	Within-Group ES								Between-Group ES			
	Cluster Group (n = 14)				Traditional Group (n = 11)				CS vs TRAD		CS vs TRAD	
	Peak		Mean		Peak		Mean		Peak		Mean	
	ES	95% CI of ES	ES	95% CI of ES	ES	95% CI of ES	ES	95% CI of ES	ES	95% CI of ES	ES	95% CI of ES
45% 1RM												
Absolute (W)	0.620	0.035 to 1.184	0.289	-0.251 to 0.819	0.025	-0.567 to 0.615	0.422	-0.208 to 1.031	0.706	-0.116 to 1.515	-0.045	-0.834 to 0.745
Velocity (m·s^{-1})	0.246	-0.291 to 0.773	-0.023	-0.546 to 0.501	-0.278	-0.875 to 0.331	-0.242	-0.837 to 0.364	0.477	-0.329 to 1.274	0.214	-0.580 to 1.004
55% 1RM												
Absolute (W)	0.084	-0.442 to 0.607	0.144	-0.385 to 0.668	0.033	-0.559 to 0.623	0.037	-0.555 to 0.627	0.055	-0.736 to 0.844	0.142	-0.650 to 0.931
Velocity (m·s^{-1})	-0.074	-0.598 to 0.452	-0.264	-0.793 to 0.274	-0.517	-1.138 to 0.126	-0.568	-1.197 to 0.084	0.22	-0.575 to 1.009	0.037	-0.753 to 0.827
65% 1RM												
Absolute (W)	-0.426	-0.967 to 0.130	-0.198	-0.723 to 0.335	0.168	-0.431 to 0.759	-0.175	-0.766 to 0.425	-0.620	-1.423 to 0.196	-0.088	-0.877 to 0.703
Velocity (m·s^{-1})	-0.472	-1.017 to 0.090	-0.591	-1.151 to -0.011	-0.348	-0.949 to 0.270	-0.537	-1.160 to 0.109	-0.343	-1.135 to 0.457	-0.332	-1.123 to 0.467
75% 1RM												
Absolute (W)	-0.170	-0.695 to 0.361	-0.246	-0.774 to 0.290	0.137	-0.460 to 0.728	0.258	-0.349 to 0.854	-0.308	-1.099 to 0.490	-0.506	-1.303 to 0.302
Velocity (m·s^{-1})	-0.387	-0.924 to 0.164	-0.517	-1.067 to 0.052	-0.301	-0.899 to 0.311	-0.261	-0.857 to 0.347	-0.167	-0.957 to 0.625	-0.351	-1.144 to 0.449
85% 1RM												
Absolute (W)	-0.528	-1.080 to 0.042	-0.620	-1.185 to -0.036	-0.093	-0.683 to 0.501	0.188	-0.415 to 0.778	-0.462	-1.258 to 0.344	-0.771	-1.583 to 0.057
Velocity (m·s^{-1})	-0.468	-1.013 to 0.093	-0.781	-1.372 to -0.168	-0.538	-1.162 to 0.108	-0.529	-1.151 to 0.116	-0.204	-0.992 to 0.590	-0.566	-1.367 to 0.246
95 % 1RM												
Absolute (W)	-0.445	-0.988 to 0.113	0.167	-0.364 to 0.691	0.369	-0.252 to 0.972	0.269	-0.340 to 0.865	-0.805	-1.619 to 0.028	-0.167	-0.956 to 0.626
Velocity (m·s^{-1})	-0.529	-1.082 to 0.041	-0.438	-0.980 to 0.119	-0.046	-0.636 to 0.547	0.101	-0.494 to 0.692	-0.48	-1.277 to 0.327	-0.598	-1.400 to 0.216

Note: ES = effect size; CI = confidence interval; 1RM = one repetition maxmium

Table 6: Reliability analysis of peak and mean velocity and power across tested relative loads

	45% 1RM	55% 1RM	65% 1RM	75% 1RM	85% 1RM	95% 1RM
Peak Velocity (m·s-1)						
Trial 1	1.07 ± 0.17	0.93 ± 0.16	0.78 ± 0.11	0.61 ± 0.10	0.47 ± 0.09	0.40 ± 0.09
Trial 2	1.10 ± 0.17	0.92 ± 0.12	0.74 ± 0.10	0.6 ± 0.10	0.49 ± 0.09	0.46 ± 0.19
ICC	0.84 (0.67 to 0.93)	0.87 (0.73 to 0.94)	0.68 (0.39 to 0.84)	0.90 (0.78 to 0.95)	0.89 (0.77 to 0.95)	0.45 (0.08 to 0.72)
CV	4.6 (3.3 to 5.9)	3.7 (2.7 to 4.7)	5.3 (3.8 to 6.8)	4.4 (3.2 to 5.6)	4.6 (3.3 to 5.9)	11.2 (8.1 to 14.3)
Peak Power (W)						
Trial 1	526.5 ± 243.4	505.0 ± 236.7	484.2 ± 212.5	432.9 ± 207.2	377.3 ± 180.6	349.5 ± 170.7
Trial 2	530.7 ± 245.2	500.5 ± 227.3	459.4 ± 201.7	428.9 ± 193.7	384.5 ± 186.8	358.9 ± 178.8
ICC	0.98 (0.94 to 0.99)	0.99 (0.98 to 1.00)	0.97 (0.92 to 0.99)	0.99 (0.97 to 0.99)	0.99 (0.98 to 1.00)	0.98 (0.95 to 0.99)
CV	5.1 (3.7 to 6.5)	4.3 (3.1 to 5.5)	5.3 (3.8 to 6.8)	4.5 (3.3 to 5.7)	4.4 (3.2 to 5.6)	5.9 (4.3 to 7.5)
Mean Velocity (m·s-1)						
Trial 1	0.74 ± 0.12	0.66 ± 0.11	0.56 ± 0.09	0.46 ± 0.07	0.33 ± 0.06	0.22 ± 0.05
Trial 2	0.75 ± 0.11	0.65 ± 0.11	0.54 ± 0.08	0.45 ± 0.08	0.33 ± 0.07	0.23 ± 0.07
ICC	0.91 (0.80 to 0.96)	0.85 (0.70 to 0.93)	0.79 (0.59 to 0.90)	0.90 (0.78 to 0.95)	0.95 (0.88 to 0.98)	0.48 (0.11 to 0.73)
CV	3.4 (2.5 to 4.3)	4.3 (3.1 to 5.5)	4.5 (3.3 to 5.7)	4.5 (3.3 to 5.7)	3.9 (2.8 to 5.0)	9.9 (7.2 to 12.6)
Mean Power (W)						
Trial 1	299.8 ± 139.8	318.5 ± 146.7	318.0 ± 142.0	295.3 ± 128.7	248.1 ± 109.3	183.1 ± 86.3
Trial 2	300.7 ± 132.9	317.0 ± 138.1	313.5 ± 137.5	293.0 ± 128.7	244.7 ± 108.3	174.2 ± 63.2
ICC	0.93 (0.86 to 0.97)	0.99 (0.98 to 1.00)	1.00 (0.99 to 1.00)	0.99 (0.97 to 0.99)	0.98 (0.95 to 0.99)	0.87 (0.73 to 0.94)
CV	6.4 (4.6 to 8.2)	4.2 (3.0 to 5.4)	3.1 (2.2 to 4.0)	3.9 (2.8 to 5.0)	4.6 (3.3 to 5.9)	10.3 (7.4 to 13.2)

Note: ICC=intraclass correlation coefficient; CV= coefficient of variation; W=Watts; Data are presented as Mean ± SD