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Title:

Acute Effect of Alternative Complex-Contrast Training Set Strategies on Vertical Jump Propulsive Impulse and Rate of Force Development.

Running head:

Effect of Alternative Complex-Contrast Training Sets on Vertical Jump Propulsion.

ABSTRACT

Complex-contrast training (CCT) is an advanced training method that aims to augment explosive force application through post-activation performance enhancement (PAPE). However, the intra-contrast rest periods (ICRP) required to observe PAPE are typically too long (5-12 minutes), making CCT impractical for most training scenarios. This study, therefore, aimed to assess whether combining CCT with rest redistribution (RR) strategies could reduce the total contrast rest period (TCRP) required to observe PAPE in vertical jump metrics. Fifteen male subjects completed ten experimental interventions across five data collection sessions in a counterbalanced cross-sectional design. Interventions consisted of two vertical jump variations (countermovement jump (CMJ) and squat jump (SJ)) and five TCRPs (TCRP; 60, 120, 180, 240, 300s), partitioned as 0, 60, 120, 180, 240s ICRP, respectively, and 60s of RR. Within interventions, participants performed a control condition consisting of one set of vertical jumps (BASELINE), the assigned ICRP, then a second set of jumps (PRE-BS). This was followed by an experimental condition consisting of 3RM back squats with 30s between repetitions, then the ICRP, and a final set of jumps (POST-BS). Vertical jump propulsive impulse (J_{PROP}) and related force-time components were assessed. A 5x2x2 (TCRP*CONDITION*TIME) repeated measures ANOVA assessed differences in force-time variables. Results showed no significant interaction of TCRP×CONDITION×TIME for J_{PROP}, indicating that, regardless of intervention, neither CMJ nor SJ J_{PROP} was enhanced. However, RR led to significant increases in both peak and average CMJ rate of force development (RFD) and reduced propulsion time (t_{PROP}) after TCRP180, TCRP240, and TCRP300, demonstrating a more explosive, but not higher, jump. For SJ, no meaningful changes in RFD or t_{PROP} were observed. Thus, RR may preserve J_{PROP} while augmenting explosive force application via enhanced eccentric-concentric coupling and stretch-shortening cycle efficiency, but PAPE remains insufficient to increase jump height in recreationally strong populations. Practically, RR may reduce the time required within CCT sets to observe PAPE through enhanced RFD. This combined approach may also be an effective tool for increasing training density by maintaining explosive capacity during power phases without impairing performance. However, longer rest may still be necessary when maximising impulse is the primary goal.

Keywords: force, strength, conditioning, rest redistribution

LIST OF ABBREVIATIONS

1RM	One-repetition maximum
3RM	Three-repetition maximum
5RM	Five-repetition maximum
ANOVA	Analysis of variance
BS	Back squat
CA	Conditioning activity
CCT	Complex-contrast training
CMJ	Countermovement jump
EA	Explosive activity
GRF	Ground reaction force
ICC	Intra-class correlation coefficient
ICRP	Intra-contrast rest period
J_{PROP}	Propulsive impulse
MF	Mean force
PAPE	Post-activation performance enhancement
PF	Peak force
RFD	Rate of force development
RR	Rest redistribution
SJ	Squat jump
SSC	Stretch-shortening cycle
SWC	Smallest worthwhile change
TCRP	Total contrast rest period
TE	Typical error
t_{PROP}	Propulsion time
v_{MEAN}	Mean velocity

INTRODUCTION

Strength and conditioning practitioners continually seek to refine and optimise training strategies to efficiently enhance neuromuscular force application and rate of force development (RFD). Complex-contrast training (CCT) is a popular and effective training method for this endeavour, characterised by alternating a high-intensity conditioning activity (CA) with a plyometric or explosive activity (EA) (Cormier et al., 2022). Typically, CCT pairs a high-load CA, such as a three-repetition maximum (3RM) back squat (BS), with a biomechanically similar, but velocity-dominant, EA, such as a vertical jump. High-load CAs augment the performance of the EA through the phenomenon of post-activation performance enhancement (PAPE), wherein neuromuscular contractile history temporarily potentiates subsequent explosive efforts through augmented rapid, synchronous high threshold motor unit recruitment, stretch-shortening cycle (SSC) efficiency, increased tendon stiffness and muscle temperature and muscle cell water content (Blazevich & Babault, 2019; Cormier et al., 2022). Post-activation performance enhancement is thought to manifest through increased RFD (Blazevich & Babault, 2019; Cormier et al., 2022; Tillin & Bishop, 2009). The combination of enhanced rate and synchrony of high-threshold motor unit recruitment and SSC efficiency results in more rapid force generation. Performance enhancement cannot manifest as increased peak force (PF) or peak contraction velocity, because the extremes of the force–velocity curve are reached only when neural drive and contractile capacity are already maximised through high-frequency stimulation (Sale, 2002; Tillin & Bishop, 2009). Thus, conceptually, PAPE results in a flattening of the force-velocity curve, with the middle of the curve shifting upward and to the right.

Complex-contrast training protocols inherently pose two problems. Firstly, alongside PAPE, high-load CAs elicit acute neuromuscular fatigue, thereby masking the benefits of PAPE. However, acute fatigue dissipates faster than PAPE and when adequate rest is provided post-CA, fatigue sufficiently attenuates, allowing PAPE to manifest as improved performance in subsequent activities (Cormier et al., 2022). Secondly, muscular contractions are affected by contractile history. Within CCT protocols, the characteristically slow contraction speed of high-load compound movements may elicit movement pattern interference, in which the EA's contraction speed is negatively affected by slow contraction rates (Blazevich & Babault, 2019;

Cormier et al., 2022; Tillin & Bishop, 2009). Thus, intra-contrast rest periods (ICRP) are prescribed to facilitate sufficient recovery and minimise interference with movement patterns that would prevent PAPE from manifesting. Athletes typically require 5-12 minutes ICRP to allow sufficient recovery of metabolic and neuromuscular function for enhanced performance to manifest (Crewther et al., 2011; Esformes & Bampouras, 2013; Kilduff et al., 2008; Lowery et al., 2012; Scott et al., 2017). These recommendations predominantly stem from CCT protocols that employ traditional set structures (i.e., repetitions are performed continuously until the prescribed numbers are completed, with ICRPs provided post-CA, prior to the EA) (Cormier et al., 2022; Seitz & Haff, 2016; Thapa et al., 2024). Conversely, shorter rest periods may result in fatigue accumulation, limited recovery and a diminished potentiation effect. This may be particularly detrimental in athletic training scenarios where training time is limited. Long ICRPs reduce training session efficiency, as training density and work completed within specified timeframes may decrease. Therefore, it is pertinent to identify and investigate strategies that may enhance the efficacy and practicality of CCT while balancing fatigue, potentiation, and training time.

Rest redistribution (RR) is an alternative set strategy that has recently gained popularity in the literature as an innovative approach to structuring rest within training sessions (Latella et al., 2019; Tufano et al., 2017). Unlike traditional set structures, where repetitions are completed continuously with longer inter-set rest intervals (Tufano et al., 2017), RR partitions the total inter-set rest into shorter, more frequent rest intervals between smaller groups of repetitions. This approach has been shown to maintain force application and velocity across repetitions and sets by attenuating fatigue accumulation compared to traditional sets (Boffey et al., 2021; Cuevas-Aburto et al., 2022; Jukic & Tufano, 2022; Tufano et al., 2017). For example, Tufano et al. (2017) demonstrated that RR preserved BS mean velocity (v_{MEAN}) and power compared to traditional sets, when total volume and total rest were equated. Furthermore, RR has been shown to reduce session RPE and increase intent, strongly correlating with increased explosiveness (Chae et al., 2023; Jukic & Tufano, 2022; Ho et al., 2021). Thus, RR may provide a practical method for maintaining within-CA performance by sufficiently limiting peripheral fatigue accumulation and movement pattern interference, thereby reducing the total contrast rest period (TCRP) required to observe enhanced explosive performance.

Despite promising evidence supporting the use of alternative set strategies as a tool to maintain within-set performance of the same movement (Latella et al., 2019; Tufano et al., 2017), the acute performance effect on subsequent movements remains largely unexplored. For example, Cuevas-Aburto et al. (2022) observed no difference in countermovement jump (CMJ) height after completing 18 BS repetitions, performed at 10RM, using different set prescriptions (traditional, three sets of six repetitions with three minutes inter-set rest; cluster sets, three sets of six repetitions, with 30 s additional intra-set rest after every two repetitions and three minutes inter-set rest; RR, nine sets of two repetitions, with 45 s inter-set rest). This study used 10RM, which equated to lower body relative strength ~1.0 x body mass, which may suggest that participants would not benefit from PAPE using continuous CA protocols (Seitz & Haff, 2016), due to an inability to recruit higher-order motor units effectively. This may have been compounded by the training prescriptions, as participants performed sets of up to six repetitions at 10RM intensity, which likely reduced the participants' proximity to failure and further limited the likelihood of higher-order motor unit recruitment and PAPE (Harmon et al., 2021; McManus et al., 2015). The combined effect of low relative strength and limited fatigue suggest it is unlikely that PAPE would be exhibited (Seitz & Haff, 2016) When stronger participants (relative strength, 1.5 x body mass) and higher intensities (5RM) were considered, Sirieiro et al. (2021) also observed no difference in CMJ height at any time point between 0- and 12-minute post-5RM BS when analysing sample means. However, analysis of individual peak performances (i.e., best CMJ performance, regardless of time point) indicated that continuous CA repetitions enhanced CMJ performance compared with protocols incorporating 30 s rest between repetitions. Despite heavier absolute and relative loads, PAPE was still not observed through sample means, limiting the generalisability of the results to wider populations. Consequently, the CA protocols used in these studies may not have been sufficiently intense enough to induce PAPE, fatigue, or movement pattern interference that would necessitate set structure manipulation in participants with low to moderate lower body strength. It therefore remains pertinent to assess the effect of RR within CCT prescriptions that use heavier CAs and stronger participants, who are more likely to benefit from PAPE.

Subsequently, a recent study examined the effect of RR within CCT sets on vertical jump performance using 1.66 x body mass, aiming to facilitate performance enhancement with less total training time (Houlton et al., Under review). This study assessed the effect of a 15 s RR between 3RM BS repetitions (CA) on vertical jump (EA) propulsive impulse (J_{PROP}) and related force-time characteristics, with up to 5 minutes of total rest prescribed. RR resulted in no meaningful change in J_{PROP} across conditions and, therefore, no change in overall jump height. Furthermore, the inclusion of 15 s RR resulted in changes in propulsion strategy, where similar jump performance was achieved less explosively through longer propulsion time (t_{PROP}) and adverse effects on RFD. We concluded that RR may sufficiently limit fatigue and movement pattern interference to maintain overall jumping performance with shorter TCRPs than those currently suggested, even if this requires altering force-generation strategies, which may be helpful to practitioners in time-limited scenarios and specific sport and rehabilitation contexts. However, the observed attenuation of RFD suggests that either PAPE was not present (i.e., the CA did not sufficiently recruit higher-threshold motor units) or that the combination of CCT and RR did not sufficiently diminish fatigue and movement pattern interference within five minutes for PAPE to manifest as expected via RFD enhancements. As the 15 s RR used may not have been sufficient to allow enough recovery of phosphocreatine stores (Harries et al., 1976) to maintain CA performance, and only one RR strategy was considered, it is pertinent to investigate the effect of other RR strategies within CCT sets on vertical jump force application.

This study, therefore, aimed to assess the effect of redistributing 30 s of rest between three-repetition maximum (3RM) BS repetitions, when one to five minutes of TCRP is prescribed, on subsequent CMJ and squat jump (SJ) J_{PROP} and associated force-time components. We hypothesised that there would be a significant increase in J_{PROP} and RFD between conditions for CMJ-dependent variables, but no difference for SJ-dependent variables. Additionally, it was anticipated that longer TCRPs would further augment performance, but that RR would mitigate the need for excessively long rest periods for PAPE to manifest. Findings from this study may contribute to refining CCT methodologies by providing practical strategies for strength and conditioning practitioners to maximise explosive performance outcomes through optimising rest in time-limited scenarios.

METHODS

Research Design

This study aimed to assess the effect of RR on explosive vertical jump force during lower-limb CCT sets. The BS was selected as the CA because it is commonly prescribed by practitioners to enhance lower limb strength and power, and is frequently used in CCT prescriptions due to its perceived biomechanical similarity to sprinting and jumping variants (Myer et al., 2014).

Participants attended the facility on seven separate occasions. Sessions were spaced one week apart and were consistently scheduled in the morning or afternoon, depending on individual schedules. The first session was used for familiarisation to ensure participants could perform the BS, CMJ and SJ safely and proficiently, adhering to the technical models described by Brewer and Favre (2022), Acero et al. (2011), and Arabatzi et al. (2014), respectively. A maximal-strength assessment was conducted during the second session to determine participants' 3RM BS. Sessions three to seven were used for data collection. Within these sessions, five TCRPs (of 60, 120, 180, 240 and 300 s duration; TCRP60, TCRP120, TCRP180, TCRP240 and TCRP300, respectively and two vertical jumps (CMJ and SJ) were assigned evenly in a counterbalanced, cross-sectional, repeated measures design to assess the effect of redistributing 30 s between 3RM BS repetitions (60 s in total) from the assigned TCRP, on vertical jump propulsive force application.

Participants completed two full interventions per session. Each intervention consisted of a control condition (CON), one set of five jumps (BASELINE), an ICRP, and another set of five vertical jumps (PRE-BS). A 10-minute rest period was provided to minimise fatigue accumulation between conditions, after which the experimental condition (EXP) was performed. EXP consisted of a CCT set; 3RM BS, with 30 s intra-set rest between repetitions one and two and repetitions two and three, followed by the same ICRP, then a final set of five jumps (POST-BS). The sum of total RR and ICRP corresponded to the assigned TCRP. The best-performed jump repetition at BASELINE, PRE-BS, and POST-BS, based on J_{PROP}, was selected for analysis. BASELINE served as a comparison to PRE-BS within CON and to POST-BS within EXP. Dependent variables (CMJ: J_{PROP}; PF; mean force, MF; peak RFD, RFD_{PEAK}; average RFD, RFD_{AVE}; RFD index, RFD_{INDEX}; $t_{PROP.}$ SJ: PF, MF, RFD_{AVE}, RFD over the first 50-, 100- and 150 ms, RFD_{50}, RFD_{100} and RFD_{150}, respectively; t_{PROP}) were calculated from force-time data. A 5 (TCRP; TCRP60, TCRP120, TCRP180, TCRP240 and TCRP300) x 2 (conditions; CON, EXP) x 2 (TIME; PRE (BASELINE), POST (PRE-BS or POST-BS accordingly)) repeated measures ANOVA was used to assess for differences.

Participants

Fifteen recreational male participants (age = 26.0 ± 2.6 years, stature = 1.75 ± 0.08 m, weight = 82.49 ± 5.32 kg, BS 3RM = 141.33 ± 13.64 kg, relative strength = 1.72 ± 0.15) were recruited for this study via convenience sampling from local strength and conditioning facilities, universities and amateur sports teams. Similar to previous studies that have used recreational samples, recreational participation in sport and exercise was defined as participating in resistance training or sport two to four times a week, with training not explicitly aligned with sports performance (Hendker & Elis, 2021; Jagim & Oliver, 2015). Participants were required to have had no history of musculoskeletal injury within the three months prior to the start of data collection, a minimum of 12 months of free-weight resistance training experience, and a lower-body relative strength >1.50 (measured as the ratio between 3RM strength and body mass). Initially, BS 3RM loads were self-reported before being formally assessed during the maximal strength assessment. Although the inclusion criteria did not specify that only males could participate, no females that could meet the criteria volunteered. As such, only male participants were recruited. Prior to data collection, participants received a comprehensive briefing on the expectations and requirements. They were also provided with a participant information sheet and made aware of their right to withdraw from the study at any time. Participants subsequently completed a health questionnaire and signed an informed consent form. Ethical approval for this study was provided by the Institutional Review Board at the BLINDED FOR REVIEW PURPOSES (Project reference: PGR-7607, approved on 18/05/2023).

Experimental Procedures

Anthropometrics

Stature and body mass data were collected for each participant prior to the 3RM assessment. Stature was measured with a calibrated stadiometer (Seca 217, Seca, UK), and body mass was measured with calibrated scales (Seca 899, Seca, UK).

Maximal Strength Assessment

Upon arrival at the testing facility for the maximal strength assessment, participants completed a dynamic warm-up consisting of static bike, walking lunges, inchworms, deadbugs, glute bridges, and bodyweight squats. Participants then completed a 3RM assessment following the guidelines for recreational or amateur athletes provided by Shephard and Triplett (2016, pp. 452-454). Briefly, participants initially self-reported their 3RM BS. Five warm-up sets that progressively increased in load by 10-20% up to 90% of each participant's 3RM were calculated based on their self-reported 3RM. After completing the final warm-up set, participants continued to perform sets at increasingly heavier loads until they were unable to complete all three repetitions with correct execution form. Three minutes of inter-set rest was provided between all warm-up sets and 3RM attempts. Participants took a median of 4 (interquartile range = 1) to establish 3RM BS. The heaviest completed set was recorded as participants' 3RM.

All BS repetitions during the maximal strength assessment and subsequent data collection were conducted using a 20 kg Olympic barbell, competition bumper plates, collars and a squat rack (Werk San, Ankara, Turkey, provided by TechnoGym, UK). All repetitions were monitored for correct execution by a United Kingdom Strength and Conditioning Association accredited strength and conditioning coach (L.J.H.). For repetitions to count, participants' hip axis had to pass below the knee axis and return to standing, with the feet remaining in full contact with the ground. Barbell v_{MEAN} was measured for all three repetitions of each attempt to ensure a true 3RM was achieved. The v_{MEAN} of the final repetition of a BS repetition maximum assessment is typically ≤0.30 $m \cdot s^{-1}$ (Mann, 2022). When this threshold is reached, it is unlikely participants will be able to complete another repetition, and thus the repetition maximum is reached. Thus, subsequent attempts were estimated based on the proximity of the final repetition to 0.30 $m \cdot s^{-1}$. Participants were permitted to continue to attempt heavier loads until they could no longer complete all three repetitions. However, if all repetitions at a particular load could not be completed, the heaviest set in which the final repetition was ≤0.30 $m \cdot s^{-1}$ was recorded as 3RM.

Mean velocity was measured using a Vitruve encoder (Vitruve Fit, Spain). Vitruve encoder reliability has been reported by Kilgallon et al. (2022). The coefficient of variation (CV) and intra-class correlation coefficient (ICC) for measuring v_{MEAN} at 90% of 1RM (a similar intensity to 3RM) were reported as 8.8% and 0.77, respectively.

Experimental Procedure

For data collection, participants were required to report to the testing facility two hours postprandial. They were instructed to refrain from caffeine intake for the six hours preceding data collection and from alcohol intake and rigorous exercise for 48 hours prior to data collection. Participants were also asked to confirm verbally that they had adhered to these instructions and that they remained injury-free and healthy enough to complete data collection.

Each session included two separate interventions (i.e. two different TCRPs and a jump type). Each intervention consisted of the CON and EXP conditions corresponding to the assigned TCRP and jump. Participants completed the same standardised dynamic warm-up as the maximal strength assessment session, followed by 10 minutes of rest. Subsequently, they performed 5 vertical jumps (BASELINE), with the type of jump (SJ or CMJ) randomly allocated, followed by a randomly allocated ICRP (i.e. 0, 60, 120, 180 or 240s, calculated as TCRP minus 60s RR) and another set of 5 jumps (PRE-BS). This completed the CON condition of the intervention. After a further 10-minute recovery, participants performed the EXP condition. EXP started with a specific BS warm-up consisting of 5 sets, up to 90% of their established 3RM. All warm-up sets were performed continuously and separated by 2 minutes. After the final warm-up set, a three-minute rest period was provided before initiation of the CCT set. The CCT set consisted of 3RM BS with 30s between repetitions (i.e. RR). Participants were instructed to complete BS repetitions maximally and, consistent with the maximal strength assessment, v_{MEAN} was assessed for all three repetitions. Upon completion of the third BS repetition, the barbell was racked, and the ICRP started. The sum of RR and ICRP equalled the TCRP. Immediately after the ICRP, participants completed the final set of 5 jumps (POST-BS). Finally, following another 10 minutes of rest, the experimental procedure was repeated for a second randomly allocated vertical jump and TCRP intervention. During all rest periods, participants were seated. A schematic overview of the session is presented in Figure 1, and the breakdown of rest period durations within each intervention are shown in Table 1. The independent variables (vertical jump (2) and TCRP (5)) were assigned in a randomised, counterbalanced design using a random number generator in Microsoft Excel (Microsoft, USA).

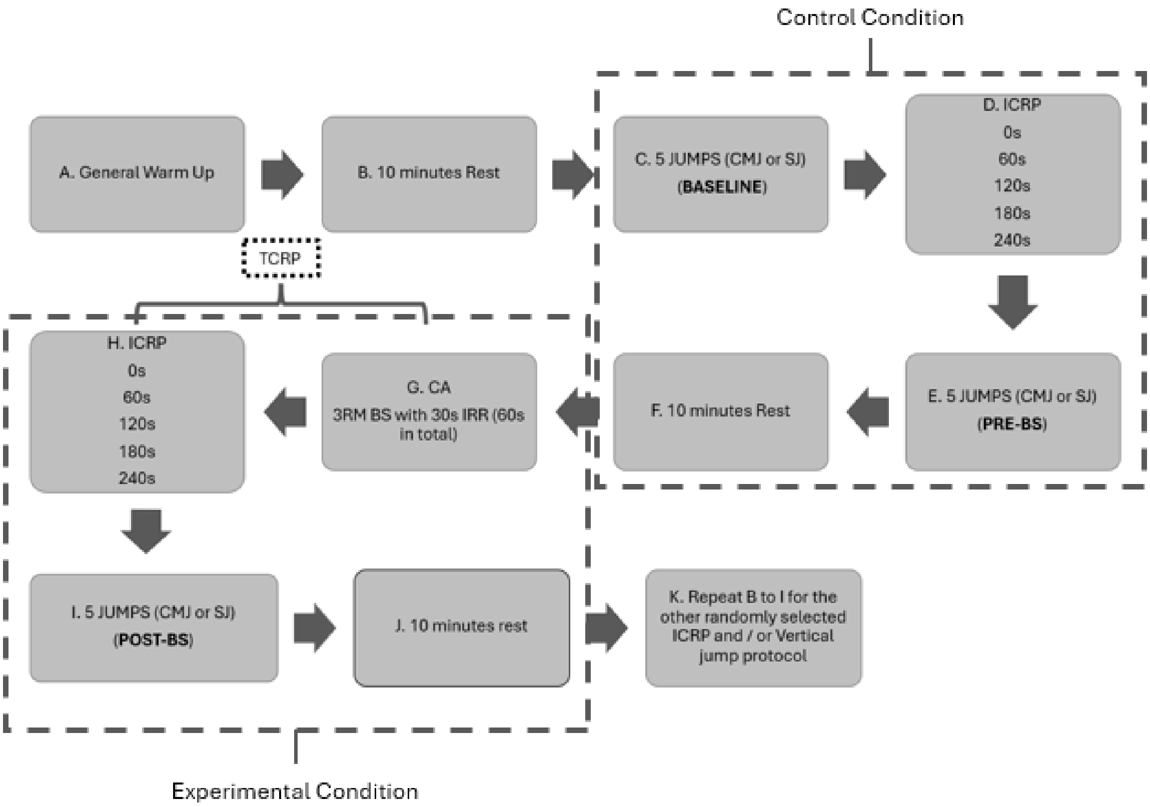


Figure 1. Schematic overview of the experimental procedure for a single session. Participants performed 5 jumps (BASELINE) of a randomly allocated vertical jump type (C). A randomly allocated ICRP is then used for rest (D), followed by another set of 5 jumps (PRE-BS) (E). After 10 minutes rest, the subjects performed a 3RM BS with 60s equally distributed between the repetitions (G), followed by the ICRP (H) and the final set of 5 jumps (POST-BS) (I). The sum of G and H times represents TCRP. C, D and E and F represent the CON condition. G, H and I and J represent the EXP condition. Following 10 minutes of rest, the above process was repeated with another randomly allocated vertical jump type and ICRP.

Table 1. Intra-contrast rest and rest redistribution duration within each total contrast rest period.

TCRP (s)	ICRP (s)	RR (s)
60	0	60
120	60	60
180	120	60
240	180	60
300	240	60

TCRP, total contrast rest period; ICRP, intra-contrast rest period; RR, rest redistribution.

Vertical jump ground reaction force (GRF) data were collected using dual force platforms (PS-2141, Pasco, Roseville, CA, USA) with a sampling rate of 1000 Hz and recorded using commercial software (Pasco Capstone 2.0, Pasco, Roseville, CA, USA). The GRF from both platforms were summed to calculate the total GRF (GRF_{TOTAL}). The raw force-time data were transferred to Microsoft Excel for processing and analysis.

Data Processing

Countermovement jump and SJ raw data were transferred to custom-made Microsoft Excel templates to extract dependent variables. Body weight was calculated as the mean of the first 2000 force data points of the weighing phase (McMahon et al., 2018). Body weight was subtracted from all subsequent GRF_{TOTAL} data points to obtain net GRF (GRF_{NET}) and, subsequently, impulse via force-time curve integration (Hansen et al., 2011; McBride et al., 2010).

Countermovement jump propulsion was considered to start at the instantaneous point where the negative centre of mass velocity ceased at the end of the unweighting phase, coinciding with the peak negative centre of mass displacement (McMahon et al., 2018). Squat jump propulsion was considered to have begun at the data point at which GRF_{NET} first exceeded 50 N (Perez-Castilla et al., 2021). For both jumps, propulsion was considered to have ceased when GRF_{TOTAL} returned to 0 N.

Dependent variables were subsequently calculated from the propulsive phase. Propulsive impulse was calculated as the sum of all instantaneous impulse data points in the propulsive phase. Peak force was calculated as the highest instantaneous GRF_{TOTAL} datapoint. The MF was calculated as the average of all GRF_{TOTAL} data points. Propulsion time was calculated as the difference between the time points corresponding to the instantaneous start and end of the propulsive phase.

Rate of force development variables were calculated by differentiating the force-time curve. For CMJ, RFD was calculated for CMJ repetitions using the equations described by Boullosa et al. (2018) and Perez-Castilla et al. (2019). RFD_{PEAK} was defined as the highest instantaneous RFD value during the propulsive phase. RFD_{AVE} was calculated as the difference between instantaneous PF and instantaneous GRF_{TOTAL} at the start of the propulsive phase, divided by the corresponding difference in time. RFD_{INDEX} was calculated as RFD_{PEAK} divided by the difference in time between RFD_{PEAK} and the start of the propulsive phase. For SJ, RFD_{AVE} was calculated similarly to CMJ (McLellan et al., 2011). RFD_{50}, RFD_{100} and RFD_{150} were calculated as the difference between the instantaneous GRF_{TOTAL} at 50, 100, and 150 ms and the instantaneous GRF_{TOTAL} at the start of the propulsive phase, divided by 50, 100 and 150 ms, respectively (Hansen et al., 2011; Torres Laett et al., 2021).

Statistical Analysis

To inform recruitment, an a priori sample size estimation was completed. A similar study using vertical jumps pre- and post-3RM BS reported J_{PROP} effect sizes (Cohen's *d*) of 0.53 and 0.62 for two BS variants. Converting these effect sizes to Cohen's f values and for a one-way within-subjects ANOVA, alpha = 0.05 and power = 80%, 14-19 subjects would be required (Faul et al., 2007).

Dependent variables were tested for normality and confirmed using the Shapiro-Wilks test and visual inspection of Q-Q plots of the residuals. Each variable was assessed with ICCs to estimate relative reliability and with typical error (TE) to estimate absolute reliability. Intra-class correlation coefficients were calculated between the first and second repetitions of BASELINE completed during the first data collection session (Table 2). 0.00–0.10, 0.10–0.30, 0.30–0.50, 0.50–0.70, 0.70–0.90, and 0.90–1.00 were classed as trivial, small, moderate, large, very large, and nearly perfect ICCs, respectively (Hopkins et al., 2009). Typical error was calculated as the standard deviation of the difference between the first and second repetitions of BASELINE divided by √2 (Swinton et al., 2018) using standard deviations and ICCs calculated between the same repetitions (Table 2). The smallest worthwhile change (SWC) was calculated as 0.35 times the standard deviation of the first BASELINE repetition, with 0.35 deemed a more appropriate smallest effect size for this population (Rhea, 2004). The relationship between TE and SWC was examined to assess the ability to detect true changes across timepoints or interventions (Pojskic et al., 2020). True changes were considered detectable when TE was smaller than SWC, indicating that observed differences exceeded measurement error and individual variability. Conversely, when TE exceeded SWC, true differences were deemed less detectable due to greater measurement noise.

The difference in 3RM BS v_{MEAN} between TCRP conditions was assessed using a repeated measures ANOVA. The difference in dependent variables between peak BASELINE, PRE-BS and POST-BS repetitions was examined across TCRP conditions using a 5x2x2 (TCRP*CONDITION*TIME) repeated-measures ANOVA. Sphericity was assessed, and ANOVA results are reported accordingly following the recommendations of Verma et al. (2015). Significant interactions and main effects were further examined, followed, where necessary, by pairwise comparisons corrected using Holm's Sequential Bonferroni stepwise adjustment, with corrected values reported. The overall effect size was calculated using partial eta-squared (η_p^2), where effect sizes of 0.01, 0.06, and 0.14 were considered small, medium, and large, respectively (Cohen, 1988). Bias-corrected pairwise effect sizes (Hedge's *g*) with 95% confidence intervals were also calculated when a significant difference between pairs was revealed. Based on a sample of recreationally trained participants, effect sizes were categorised as trivial (<0.35), small (0.35–0.80), moderate (0.81–1.50), and large (>1.50) (Rhea, 2004). All data are presented as mean ± SD unless otherwise stated. Significance was set at $p < 0.05$. All data were statistically analysed in IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, N.Y., USA).

RESULTS

Reliability

Intraclass correlation coefficients, TE and SWC are presented in Table 2. All metrics displayed very large or nearly perfect ICCs, except for RFD_{INDEX}, which showed a large ICC, demonstrating acceptable reliability similar to Perez-Castilla et al. (2019).

Table 2. Intra-class correlation coefficients, typical error and smallest worthwhile change with 95% confidence intervals. For both vertical jump types, propulsive impulse, peak and mean force, and propulsion time are reported. For countermovement jumps, peak, average and index RFD are reported. For squat jumps, average RFD, and RFD over the first 50, 100 and 150 ms of propulsion are reported.

Jump	Variable	ICC	TE	SWC
CMJ	Propulsive Impulse (N·s)	0.92 (0.84-1.00)	6.37 (1.81-10.92)	6.00 (-2.676-14.678)
	Peak Force (N)	0.94 (0.86-0.98)	77.48 (22.03-132.93)	63.43 (-28.28-155.15)
	Mean Force (N)	0.95 (0.85-0.98)	30.63 (8.71-52.55)	43.49 (-19.39-106.38)
	Peak RFD ($N \cdot s^{-1}$)	0.78 (0.47-0.92)	1242.61 (353.30-2131.92)	878.46 (-391.70-2148.62)
	Average RFD ($N \cdot s^{-1}$)	0.91 (0.75-0.97)	454.87 (129.33-780.41)	487.75 (-217.48-1192.97)
	RFD Index ($N \cdot s^{-2}$)	0.59 (0.14-0.84)	23445.89 (6666.19-40225.58)	12382.63 (-5521.29-30286.53)
	Propulsion Time (s)	0.98 (0.93-0.99)	0.01 (0.00-0.01)	0.01 (-0.01-0.03)
SJ	Propulsive Impulse (N·s)	0.98 (0.93-0.99)	5.57 (1.58-9.56)	11.52 (-5.14-28.19)
	Peak Force (N)	0.97 (0.92-0.99)	49.40 (14.05-84.75)	92.73 (-41.35-226.82)
	Mean Force (N)	0.94 (0.83-0.98)	28.20 (8.02-48.38)	36.88 (-16.44-90.20)
	Average RFD ($N \cdot s^{-1}$)	0.88 (0.68-0.96)	627.84 (178.51-1077.16)	587.48 (-261.95-1436.91)
	RFD 50 ms ($N \cdot s^{-1}$)	0.93 (0.81-0.98)	728.71 (207.19-1250.24)	908.27 (-404.98-2221.52)
	RFD 100 ms ($N \cdot s^{-1}$)	0.88 (0.68-0.96)	753.14 (214.13-1292.15)	704.91 (-314.31-1724.12)
	RFD 150 ms ($N \cdot s^{-1}$)	0.96 (0.90-0.99)	344.51 (97.95-591.07)	582.33 (-259.65-1424.32)
	Propulsion Time (s)	0.97 (0.92-0.99)	0.01 (0.00-0.02)	0.02 (-0.01-0.06)

CMJ, countermovement jump; SJ, squat jump; ICC, intraclass correlation coefficient; TE, typical error; SWC, smallest worthwhile change; RFD, rate of force development.

Back Squat Mean Velocity

The BS v_{MEAN} for the maximal strength assessment and all jump conditions is presented in Table 3. Repeated-measures ANOVA showed a significant main effect of CONDITION ($F_{6.229,\ 87.208} = 3.424$, $p < 0.001$, $\eta_p^2 = 0.197$). Post hoc analysis showed 3RM v_{MEAN} was significantly lower than all CMJ and SJ experimental BS v_{MEAN} (Table 3). Within CMJ experimental conditions, TCRP120 v_{MEAN} was significantly lower than TCRP300 ($t_{14} = -2.156$, $p = 0.049$, $g = -0.526$ (-1.034, -0.002)). Within SJ experimental conditions, TCRP120 v_{MEAN} was significantly lower than TCRP240 ($t_{14} = -2.256$, $p = 0.041$, $g = -0.551$ (-1.062, -0.023)), and TCRP240 was significantly higher than TCRP300 ($t_{14} = 2.199$, $p = 0.045$, $g = 0.537$ (0.011, 1.046)). No other significant differences were observed within the CMJ or SJ conditions.

Table 3. Back squat mean velocity, presented as individual repetitions and the average of the individual repetitions within the three-repetition maximum assessment and within each experimental condition. Hedge's *g* with 95% confidence intervals between 3RM and experimental condition back squat mean velocity are also presented.

JUMP	TCRP (s)	R1 ($m \cdot s^{-1}$)	R2 ($m \cdot s^{-1}$)	R3 ($m \cdot s^{-1}$)	Average ($m \cdot s^{-1}$)	***g***
-	3RM	0.37 ± 0.05	0.33 ± 0.03	0.28 ± 0.04	0.32 ± 0.05	-
	60	0.38 ± 0.08	0.37 ± 0.06	0.35 ± 0.07	0.36 ± 0.07[a]	0.762 (-1.306, -0.198)
	120	0.37 ± 0.07	0.36 ± 0.08	0.35 ± 0.08	0.36 ± 0.07[a]	0.505 (-1.010, -0.016)
CMJ	180	0.38 ± 0.08	0.37 ± 0.07	0.34 ± 0.09	0.36 ± 0.08[a]	0.624 (-1.145, -0.085)
	240	0.39 ± 0.08	0.38 ± 0.09	0.36 ± 0.08	0.38 ± 0.08[a]	0.805 (-1.356, -0.232)
	300	0.40 ± 0.07	0.38 ± 0.06	0.36 ± 0.07	0.38 ± 0.07[a]	1.088 (-1.699, -0.453)
	60	0.38 ± 0.07	0.37 ± 0.08	0.36 ± 0.07	0.37 ± 0.07[a]	0.862 (-1.425, -0.278)
	120	0.37 ± 0.08	0.38 ± 0.08	0.34 ± 0.08	0.36 ± 0.08[a]	0.627 (-1.148, -0.087)
SJ	180	0.38 ± 0.08	0.37 ± 0.07	0.34 ± 0.09	0.36 ± 0.08[a]	0.785 (-1.333, -0.216)
	240	0.39 ± 0.06	0.39 ± 0.06	0.37 ± 0.08	0.38 ± 0.06[a]	1.412 (-2.105, -0.696)
	300	0.38 ± 0.08	0.37 ± 0.07	0.33 ± 0.08	0.36 ± 0.08[a]	0.741 (-1.281, -0.180)

TCRP, total-contrast rest period; R1-3, repetition one, two and three; Average, mean of three repetitions; CMJ, countermovement jump; SJ, squat jump.

[a] significantly different to 3RM ($p < 0.05$).

Countermovement Jump

Countermovement jump descriptive statistics are reported in Table 4, and the repeated-measures ANOVA results are presented in Table 5.

Table 4. Countermovement jump dependent variable descriptive statistics, expressed as mean ± SD.

			Dependent Variable						
TCRP (s)	CONDITION	TIME	Propulsive Impulse (N·s)	Peak Force (N)	Mean Force (N)	Peak RFD ($N·s^{-1}$)	Average RFD ($N·s^{-1}$)	RFD Index ($N·s^{-2}$)	Propulsion Time (s)
60	CON	BASELINE	220.42 ± 20.34	1942.11 ± 187.38	1560.60 ± 115.69	5562.00 ± 1951.86	2061.51 ± 855.36	48253.80 ± 46294.84	0.28 ± 0.03
		PRE_BS	221.85 ± 22.59	1919.25 ± 185.77	1552.56 ± 98.72	5188.00 ± 2211.89	2145.80 ± 771.11	39300.33 ± 25448.11	0.30 ± 0.03
	EXP	BASELINE	220.42 ± 20.34	1942.11 ± 187.38	1560.60 ± 115.69	5562.00 ± 1951.86	2061.51 ± 855.36	48253.80 ± 46294.84	0.28 ± 0.03
		POST_BS	220.95 ± 20.58	1954.49 ± 155.29	1550.98 ± 102.09	5453.33 ± 1894.27	1992.91 ± 763.21	58776.03 ± 49575.70	0.32 ± 0.03
120	CON	BASELINE	222.21 ± 15.68	1942.34 ± 164.18	1573.21 ± 118.14	5124.00 ± 2321.85	2250.46 ± 953.14	46713.87 ± 30573.71	0.28 ± 0.03
		PRE_BS	223.52 ± 17.06	1985.34 ± 135.59	1581.47 ± 115.39	4902.67 ± 1911.92	2244.07 ± 677.01	57552.72 ± 44011.87	0.29 ± 0.03
	EXP	BASELINE	222.21 ± 15.68	1942.34 ± 164.18	1573.21 ± 118.14	5124.00 ± 2321.85	2250.46 ± 953.14	46713.87 ± 30573.71	0.28 ± 0.03
		POST_BS	228.10 ± 16.95	2013.21 ± 123.02	1581.80 ± 120.40	5118.00 ± 2017.71	2617.05 ± 873.51	49115.91 ± 34887.41	0.30 ± 0.03
180	CON	BASELINE	223.92 ± 20.77	1977.13 ± 123.65	1611.31 ± 125.58	4353.33 ± 1602.84	2126.80 ± 851.81	64083.53 ± 65461.10	0.29 ± 0.04
		PRE_BS	224.05 ± 22.20	2012.50 ± 130.55	1615.16 ± 107.70	4508.67 ± 1570.95	2240.75 ± 904.96	51341.44 ± 35534.71	0.28 ± 0.03
	EXP	BASELINE	223.92 ± 20.77	1977.13 ± 123.65	1611.31 ± 125.58	4353.33 ± 1602.84	2126.80 ± 851.81	64083.53 ± 65461.10	0.29 ± 0.04
		POST_BS	229.28 ± 18.60	1960.55 ± 130.00	1575.36 ± 117.46	4726.00 ± 1716.79	2540.18 ± 843.01	63418.42 ± 69293.28	0.27 ± 0.03
240	CON	BASELINE	224.29 ± 21.75	1945.93 ± 184.37	1563.35 ± 128.71	4727.33 ± 1625.14	2143.16 ± 945.63	34789.76 ± 19653.70	0.30 ± 0.03

TCRP (s)	CONDITION	TIME	Dependent Variable						
			Propulsive Impulse (N·s)	Peak Force (N)	Mean Force (N)	Peak RFD (N·s^{-1})	Average RFD (N·s^{-1})	RFD Index (N·s^{-2})	Propulsion Time (s)
	EXP	PRE_BS	224.15 ± 20.68	1944.17 ± 136.04	1570.62 ± 112.03	4218.53 ± 1920.80	2187.93 ± 875.81	37774.52 ± 45275.80	0.29 ± 0.03
		BASELINE	224.29 ± 21.75	1945.93 ± 184.37	1563.35 ± 128.71	4727.33 ± 1625.14	2143.16 ± 945.63	34789.76 ± 19653.70	0.30 ± 0.03
		POST_BS	230.07 ± 20.68	1942.01 ± 172.76	1546.12 ± 140.84	5453.33 ± 1919.59	2432.18 ± 945.84	33129.26 ± 14030.29	0.28 ± 0.03
300	CON	BASELINE	223.95 ± 16.87	1947.79 ± 136.18	1576.06 ± 127.00	4500.67 ± 1651.23	2210.73 ± 611.48	35655.98 ± 15576.11	0.29 ± 0.04
		PRE_BS	223.15 ± 18.63	1985.09 ± 133.63	1566.32 ± 152.46	4244.67 ± 1573.33	2159.06 ± 795.56	35409.65 ± 22109.02	0.29 ± 0.04
	EXP	BASELINE	223.95 ± 16.87	1947.79 ± 136.18	1576.06 ± 127.00	4500.67 ± 1651.23	2210.73 ± 611.48	35655.98 ± 15576.11	0.29 ± 0.04
		POST_BS	227.97 ± 17.50	1943.09 ± 148.35	1552.60 ± 138.81	5126.00 ± 1645.97	2459.67 ± 715.17	43841.84 ± 34862.16	0.28 ± 0.04

TCRP, total contrast rest period; CON, control condition; EXP, experimental condition; BASELINE, best performed repetition from the baseline set of jumps in the control condition; PRE-BS, best performed repetition from the post-ICRP set of jumps in the control condition; POST-BS, best performed repetition from the post-ICRP set of jumps in the experimental condition; RFD, rate of force development.

Table 5. Countermovement jump repeated measures ANOVA results. Significant interactions and main effects are shown in bold.

Effect	Dependent Variable Propulsive Impulse (N·s)	Peak Force (N)	Mean Force (N)	Peak RFD ($N·s^{-1}$)	Average RFD ($N·s^{-1}$)	RFD Index ($N·s^{-2}$)	Propulsion Time (s)
TCRP	$F_{4, 56}$ = 1.093 p = 0.371 η_p^2 = 0.072	$F_{4, 56}$ = 0.796 p = 0.515 η_p^2 = 0.054	$F_{4, 56}$ = 1.680 p = 0.185 η_p^2 = 0.107	**$F_{4, 56}$ = 3.153** **p = 0.021** **η_p^2 = 0.184**	$F_{4, 56}$ = 0.579 p = 0.679 η_p^2 = 0.040	$F_{2.040, 28.564}$ = 0.2366 p = 0.111 η_p^2 = 0.145	$F_{4, 56}$ = 1.536 p = 0.204 η_p^2 = 0.099
CONDITION	**$F_{1, 14}$ = 17.959** **p < 0.001** **η_p^2 = 0.562**	$F_{1, 14}$ = 0.538 p = 0.475 η_p^2 = 0.037	**$F_{1, 14}$ = 5.641** **p = 0.032** **η_p^2 = 0.287**	**$F_{1, 14}$ = 54.817** **p < 0.001** **η_p^2 = 0.797**	**$F_{1, 14}$ = 7.373** **p = 0.017** **η_p^2 = 0.345**	$F_{1, 14}$ = 1.372 p = 0.261 η_p^2 = 0.089	$F_{1, 14}$ = 0.545 p = 0.473 η_p^2 = 0.037
TIME	**$F_{1, 14}$ = 25.256** **p < 0.001** **η_p^2 = 0.656**	$F_{1, 14}$ = 1.802 p = 0.201 η_p^2 = 0.114	$F_{1, 14}$ = 1.417 p = 0.254 η_p^2 = 0.092	$F_{1, 14}$ = 0.364 p = 0.556 η_p^2 = 0.025	**$F_{1, 14}$ = 12.439** **p = 0.003** **η_p^2 = 0.470**	$F_{1, 14}$ = 0.046 p = 0.866 η_p^2 = 0.003	$F_{1, 14}$ = 2.288 p = 0.153 η_p^2 = 0.140
TCRP*CONDITION	$F_{4, 56}$ = 2.258 p = 0.090 η_p^2 = 0.139	$F_{4, 56}$ = 2.251 p = 0.077 η_p^2 = 0.139	$F_{4, 56}$ = 1.460 p = 0.238 η_p^2 = 0.094	**$F_{4, 56}$ = 4.052** **p = 0.006** **η_p^2 = 0.224**	**$F_{4, 56}$ = 12.439** **p = 0.003** **η_p^2 = 0.208**	$F_{2.196, 30.751}$ = 1.113 p = 0.346 η_p^2 = 0.074	**$F_{4, 56}$ = 12.950** **p < 0.001** **η_p^2 = 0.481**
TCRP*TIME	$F_{4, 56}$ = 0.530 p = 0.688 η_p^2 = 0.035	$F_{4, 56}$ = 0.990 p = 0.407 η_p^2 = 0.066	$F_{4, 56}$ = 0.503 p = 0.728 η_p^2 = 0.035	$F_{4, 56}$ = 2.034 p = 0.102 η_p^2 = 0.127	$F_{4, 56}$ = 0.736 p = 0.571 η_p^2 = 0.050	$F_{1.896, 26.550}$ = 0.168 p = 0.864 η_p^2 = 0.012	**$F_{4, 56}$ = 23.378** **p < 0.001** **η_p^2 = 0.625**
CONDITION*TIME	**$F_{1,14}$ = 17.959** **p < 0.001** **η_p^2 = 0.562**	$F_{1, 14}$ = 0.538 p = 0.475 η_p^2 = 0.037	**$F_{1, 14}$ = 5.641** **p = 0.032** **η_p^2 = 0.287**	**$F_{1, 14}$ = 54.817** **p < 0.001** **η_p^2 = 0.797**	**$F_{1, 14}$ = 7.373** **p = 0.017** **η_p^2 = 0.345**	$F_{1, 14}$ = 1.372 p = 0.261 η_p^2 = 0.089	$F_{1, 14}$ = 0.545 p = 0.473 η_p^2 = 0.037
TCRP*CONDITION*TIME	$F_{4, 56}$ = 2.258 p = 0.090 η_p^2 = 0.139	$F_{4, 56}$ = 2.251 p = 0.077 η_p^2 = 0.139	$F_{4, 56}$ = 1.460 p = 0.238 η_p^2 = 0.094	**$F_{4, 56}$ = 4.052** **p = 0.006** **η_p^2 = 0.224**	**$F_{4, 56}$ = 3.671** **p = 0.010** **η_p^2 = 0.208**	$F_{2.196, 30.751}$ = 1.113 p = 0.346 η_p^2 = 0.074	**$F_{4, 56}$ = 12.950** **p < 0.001** **η_p^2 = 0.481**

TCRP, total contrast rest period; CONDITION, control or experimental; TIME, pre-ICRP or post-ICRP.

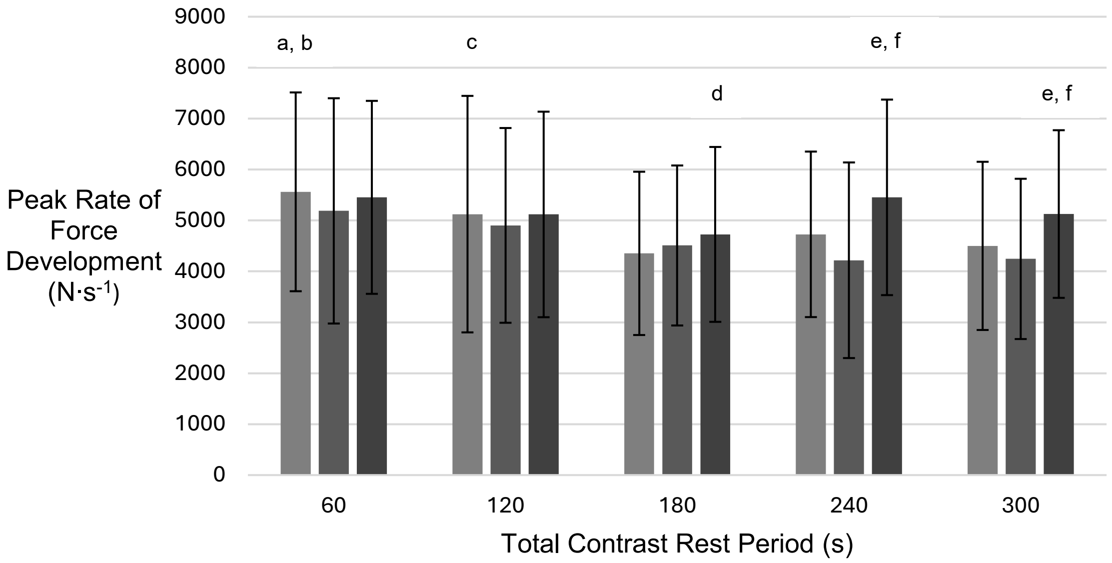
Analysis of JPROP revealed a significant interaction of CONDITION*TIME. Post hoc analysis showed that POST-BS was higher than PRE-BS and higher than BASELINE. There was no difference between PRE-BS and BASELINE (Table 6). There was a main effect of TIME, with POST-ICRP being higher than PRE-ICRP. There was a main effect of CONDITION with EXP being higher than CON. No other significant interactions or effects were observed for JPROP. No significant interactions or main effects were observed for PF. For MF, a significant interaction was found for CONDITION*TIME. Further analysis showed that POST-BS was lower than PRE-BS. There was no difference between POST-BS and BASELINE or PRE-BS and BASELINE (Table 6). There was a main effect of CONDITION, with CON being higher than EXP. No other significant interactions or effects were observed for MF.

Table 6. Countermovement jump CONDITION x TIME post hoc analysis. Pairwise significance and effect size between collapsed variables where a significant interaction was found. Effect size (g) is reported with 95% confidence intervals. Significant effect sizes are highlighted in bold.

Variable	Pairwise Comparison	*p*	*g*	CI
Propulsive Impulse (N·s)	POST-BS – PRE-BS	**<0.001**	**1.065**	**0.450, 1.681**
	POST-BS - BASELINE	**<0.001**	**1.702**	**0.895, 2.485**
	PRE-BS - BASELINE	0.570	0.146	-0.352, 0.639
Mean Force (N)	POST-BS – PRE-BS	**0.032**	**0.613**	**0.050, 1.158**
	POST-BS - BASELINE	0.063	0.507	-0.027, 1.026
	PRE-BS - BASELINE	0.481	0.012	-0.481, 0.504
Peak RFD ($N·s^{-1}$)	POST-BS – PRE-BS	**<0.001**	**1.860**	**1.008, 2.689**
	POST-BS - BASELINE	**<0.001**	**1.237**	**0.555, 1.894**
	PRE-BS - BASELINE	**0.015**	**0.694**	**0.130, 1.239**
Average RFD ($N·s^{-1}$)	POST-BS – PRE-BS	**0.017**	**0.682**	**0.120, 1.225**
	POST-BS - BASELINE	**<0.001**	**1.334**	**0.628, 2.016**
	PRE-BS - BASELINE	0.576	0.144	-0.354, 0.637

BASELINE, collapsed variable calculated as the mean of the best performed repetition from the baseline set of jumps in the control condition from each total contrast rest period (TCRP) intervention; PRE-BS, collapsed variable calculated as the mean of the best performed repetition from the post-ICRP set of jumps in the control condition from each TCRP intervention; POST-BS, collapsed variable calculated as the mean of the best performed repetition from the post-ICRP set of jumps in the experimental condition from each TCRP intervention; RFD, rate of force development.

Analysis of RFD_{PEAK} revealed a significant interaction for TCRP*CONDITION*TIME. Significant pairwise comparisons and effect sizes are reported in Figure 2. A significant interaction was found for CONDITION*TIME. Post hoc analysis showed that POST-BS was higher than PRE-BS and PRE-BS was lower than BASELINE (Table 6).



BASELINE, best performed repetition from the baseline set of jumps in the control condition; PRE-BS, best performed repetition from the post-ICRP set of jumps in the control condition; POST-BS, best performed repetition from the post-ICRP set of jumps in the experimental condition.

[a] Significant moderate effect with TCRP240_PRE-BS ($p < 0.05$, $g = 0.81\text{-}1.50$).
[b] Significant small effect with TCRP300_PRE-BS ($p < 0.05$, $g = 0.35\text{-}0.81$).
[c] Significant small effect with TCRP300_PRE-BS ($p < 0.05$, $g = 0.35\text{-}0.81$).
[d] Significant small effect with BASELINE ($p < 0.05$, $g = 0.35\text{-}0.81$).
[e] Significant moderate effect with BASELINE ($p < 0.05$, $g = 0.81\text{-}1.50$).
[f] Significant moderate effect with PRE-BS ($p < 0.05$, $g = 0.81\text{-}1.50$).

Figure 2. Countermovement jump peak rate of force development. Data is presented as mean ± SD. Pairwise significant differences and effect sizes between- and within-total contrast rest periods are represented with letters corresponding to footnote definitions.

A significant interaction was also found for TCRP*CONDITION. Post hoc analysis is shown in Table 7. Within-TCRP analysis showed that TCRP120_EXP was higher TCRP120_CON, TCRP180_EXP was higher than TCRP180_CON, TCRP240_EXP was higher than TCRP240_CON, and TCRP300_EXP was higher than TCRP300_CON. Between-TCRP analysis showed that TCRP60_CON was higher than TCRP180_CON, TCRP240_CON and TCRP300_CON. TCRP120_CON was higher than TCRP 240_CON. TCRP60_EXP was higher than TCRP180_EXP, and TCRP300_EXP. No other differences were observed. There was a significant effect of CONDITION, with EXP being higher than CON. There was a significant effect of TCRP. Pairwise comparisons showed TCRP60 was significantly higher than TCRP300 ($p = 0.010$). No other significant interactions or effects were observed for RFD_{PEAK}.

Table 7. Countermovement jump TCRP x CONDITION post hoc analysis. Pairwise significance and effect size between collapsed variables where a significant interaction was found. Effect size (g) is reported with 95% confidence intervals. Significant effect sizes are highlighted in bold.

Variable	Pairwise Comparison	*p*	*g*	CI
Peak RFD ($N \cdot s^{-1}$)	TCRP60_EXP vs TCRP60_CON	0.302	0.269	-0.237, 0.767
	TCRP120_EXP vs TCRP120_CON	**0.124**	**0.411**	**-0.111, 0.919**
	TCRP180_EXP vs TCRP180_CON	**0.232**	**0.314**	**-0.197, 0.814**
	TCRP240_EXP vs TCRP240_CON	**<0.001**	**0.992**	**0.369, 1.593**
	TCRP300_EXP vs TCRP300_CON	<0.001	1.107	0.457, 1.734
	TCRP60_CON vs TCRP120_CON	0.410	0.213	-0.289, 0.728
	TCRP60_CON vs TCRP180_CON	**0.020**	**0.659**	**0.101, 1.198**
	TCRP60_CON vs TCRP240_CON	**0.017**	**0.679**	**0.117, 1.221**
	TCRP60_CON vs TCRP300_CON	**0.001**	**1.106**	**0.456, 1.732**
	TCRP120_CON vs TCRP180_CON	0.088	0.460	-0.067, 0.974
	TCRP120_CON vs TCRP240_CON	**0.028**	**0.617**	**0.066, 1.150**
	TCRP120_CON vs TCRP300_CON	0.073	0.487	-0.044, 1.003
	TCRP180_CON vs TCRP240_CON	0.891	0.035	-0.458, 0.527
	TCRP180_CON vs TCRP300_CON	0.823	0.057	-0.437, 0.549
	TCRP240_CON vs TCRP300_CON	0.717	0.093	-0.402, 0.585
	TCRP60_EXP vs TCRP120_EXP	0.377	0.229	-0.274, 0.725

Variable	Pairwise Comparison	*p*	*g*	CI
	TCRP60_EXP vs TCRP180_EXP	**0.011**	**0.736**	**0.164, 1.287**
	TCRP60_EXP vs TCRP240_EXP	0.348	0.244	-0.260, 0.740
	TCRP60_EXP vs TCRP300_EXP	**0.007**	**0.800**	**0.216, 1.362**
	TCRP120_EXP vs TCRP180_EXP	0.085	0.465	-0.063, 0.979
	TCRP120_EXP vs TCRP240_EXP	0.909	0.029	-0.464, 0.521
	TCRP120_EXP vs TCRP300_EXP	0.362	0.237	-0.267, 0.733
	TCRP180_EXP vs TCRP240_EXP	0.122	0.413	-0.109, 0.921
	TCRP180_EXP vs TCRP300_EXP	0.374	0.231	-0.273, 0.726
	TCRP240_EXP vs TCRP300_EXP	0.322	0.258	-0.248, 0.755
Average RFD ($N \cdot s^{-1}$)	TCRP60_EXP vs TCRP60_CON	0.374	0.224	-0.265, 0.746
	TCRP120_EXP vs TCRP120_CON	**0.009**	**0.739**	**0.179, 1.279**
	TCRP180_EXP vs TCRP180_CON	**0.042**	**0.545**	**0.018, 1.055**
	TCRP240_EXP vs TCRP240_CON	**0.04**	**0.554**	**0.026, 1.065**
	TCRP300_EXP vs TCRP300_CON	**0.002**	**0.944**	**0.343, 1.524**
	TCRP60_CON vs TCRP120_CON	0.427	0.200	0.288, 0.680
	TCRP60_CON vs TCRP180_CON	0.731	0.076	-0.405, 0.554
	TCRP60_CON vs TCRP240_CON	0.782	0.069	-0.411, 0.547
	TCRP60_CON vs TCRP300_CON	0.598	0.132	-0.351, 0.610

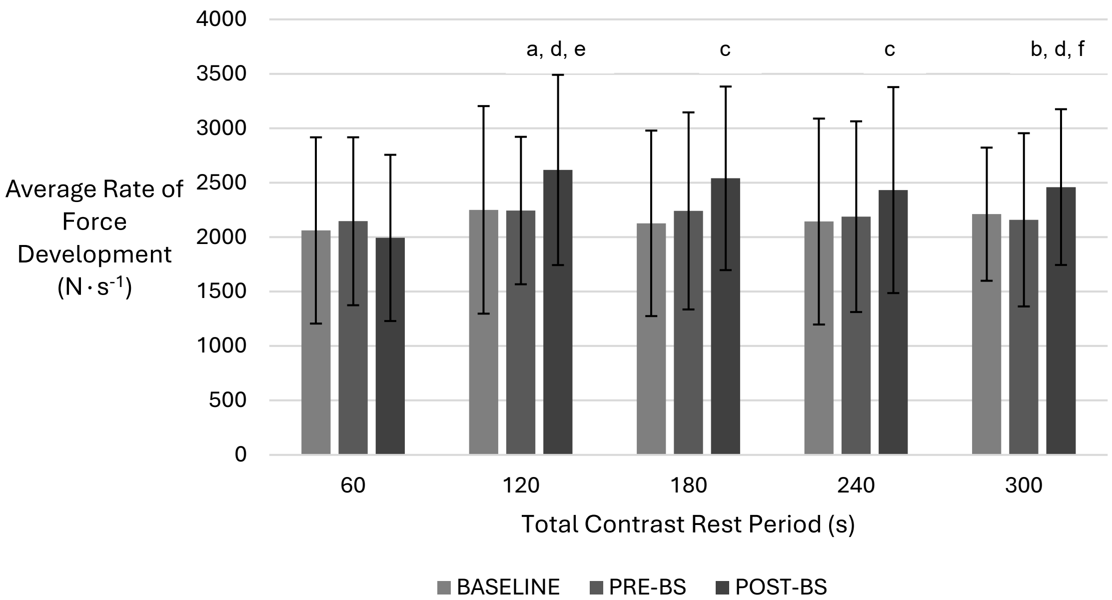
Variable	Pairwise Comparison	*p*	*g*	CI
	TCRP120_CON vs TCRP180_CON	0.690	0.099	-0.382, 0.578
	TCRP120_CON vs TCRP240_CON	0.581	0.138	0.345, 0.617
	TCRP120_CON vs TCRP300_CON	0.667	0.107	-0.375, 0.585
	TCRP180_CON vs TCRP240_CON	0.916	0.026	-0.453, 0.504
	TCRP180_CON vs TCRP300_CON	0.995	0.002	-0.477, 0.480
	TCRP240_CON vs TCRP300_CON	0.901	0.031	-0.448, 0.509
	TCRP60_EXP vs TCRP120_EXP	0.081	0.459	-0.056, 0.959
	TCRP60_EXP vs TCRP180_EXP	0.306	0.259	-0.233, 0.743
	TCRP60_EXP vs TCRP240_EXP	0.332	0.245	-0.246, 0.728
	TCRP60_EXP vs TCRP300_EXP	0.063	0.492	-0.027, 0.996
	TCRP120_EXP vs TCRP180_EXP	0.634	0.119	-0.364, 0.597
	TCRP120_EXP vs TCRP240_EXP	0.472	0.180	-0.306, 0.660
	TCRP120_EXP vs TCRP300_EXP	0.564	0.144	-0.340, 0.623
	TCRP180_EXP vs TCRP240_EXP	0.816	0.058	-0.422, 0.536
	TCRP180_EXP vs TCRP300_EXP	0.992	0.002	-0.476, 0.481
	TCRP240_EXP vs TCRP300_EXP	0.775	0.071	-0.409, 0.549
Propulsion Time (s)	TCRP60_EXP vs TCRP60_CON	**<0.001**	**1.181**	**0.513, 1.825**
	TCRP120_EXP vs TCRP120_CON	**0.042**	**0.562**	**0.019, 1.087**

Variable	Pairwise Comparison	*p*	*g*	CI
	TCRP180_EXP vs TCRP180_CON	**0.027**	**0.622**	**0.070, 1.156**
	TCRP240_EXP vs TCRP240_CON	**0.004**	**0.867**	**0.270, 1.442**
	TCRP300_EXP vs TCRP300_CON	**0.005**	**0.849**	**0.255, 1.421**
	TCRP60_CON vs TCRP120_CON	0.380	0.228	-0.276, 0.723
	TCRP60_CON vs TCRP180_CON	0.349	0.243	-0.261, 0.739
	TCRP60_CON vs TCRP240_CON	0.419	0.209	-0.293, 0.704
	TCRP60_CON vs TCRP300_CON	1.000	0.000	-0.492, 0.492
	TCRP120_CON vs TCRP180_CON	0.959	0.013	-0.479, 0.505
	TCRP120_CON vs TCRP240_CON	0.085	0.465	-0.063, 0.979
	TCRP120_CON vs TCRP300_CON	0.404	0.216	-0.286, 0.711
	TCRP180_CON vs TCRP240_CON	0.087	0.462	-0.066, 0.975
	TCRP180_CON vs TCRP300_CON	0.476	0.184	-0.316, 0.678
	TCRP240_CON vs TCRP300_CON	0.390	0.223	-0.280, 0.718
	TCRP60_EXP vs TCRP120_EXP	0.107	0.432	-0.092, 0.943
	TCRP60_EXP vs TCRP180_EXP	**<0.001**	**1.256**	**0.570, 1.918**
	TCRP60_EXP vs TCRP240_EXP	0.189	0.347	-0.168, 0.849
	TCRP60_EXP vs TCRP300_EXP	**0.005**	**0.839**	**0.248, 1.409**
	TCRP120_EXP vs TCRP180_EXP	0.065	0.502	-0.031, 1.020

Variable	Pairwise Comparison	*p*	*g*	CI
	TCRP120_EXP vs TCRP240_EXP	1.000	0.000	-0.492, 0.492
	TCRP120_EXP vs TCRP300_EXP	0.427	0.205	-0.296, 0.700
	TCRP180_EXP vs TCRP240_EXP	0.096	0.449	-0.077, 0.961
	TCRP180_EXP vs TCRP300_EXP	0.367	0.234	-0.270, 0.730
	TCRP240_EXP vs TCRP300_EXP	0.486	0.180	-0.320, 0.673

TCRP, total contrast rest period; CON, collapsed variable calculated as the mean of the pre-ICRP and post-ICRP measurement within the control condition; EXP, collapsed variable calculated as the mean of the pre-ICRP and post-ICRP measurement within the experimental condition; RFD, rate of force development.

Analysis of RFD_{AVE} showed a significant interaction was found for TCRP*CONDITION*TIME. Significant pairwise comparisons and effect sizes are reported in Figure 3. A significant interaction was found for CONDITION*TIME. Post hoc analysis is presented in Table 6. Further analysis showed that POST-BS was higher than PRE-BS and BASELINE. There was no difference between PRE-BS and BASELINE. A significant interaction was found for TCRP*CONDITION. Post hoc analysis is presented in Table 7. Within-TCRP analysis showed that for TCRP120, TCRP180, TCRP240 and TCRP300, EXP was higher than CON. No significant differences were observed between-TCRPs. There was a significant effect of TIME, with POST-ICRP being higher than PRE-ICRP. There was a significant effect of CONDITION, with EXP being higher than CON. No other significant interactions or effects were observed for RFD_{AVE}. No significant interactions or effects were observed for RFD_{INDEX}.

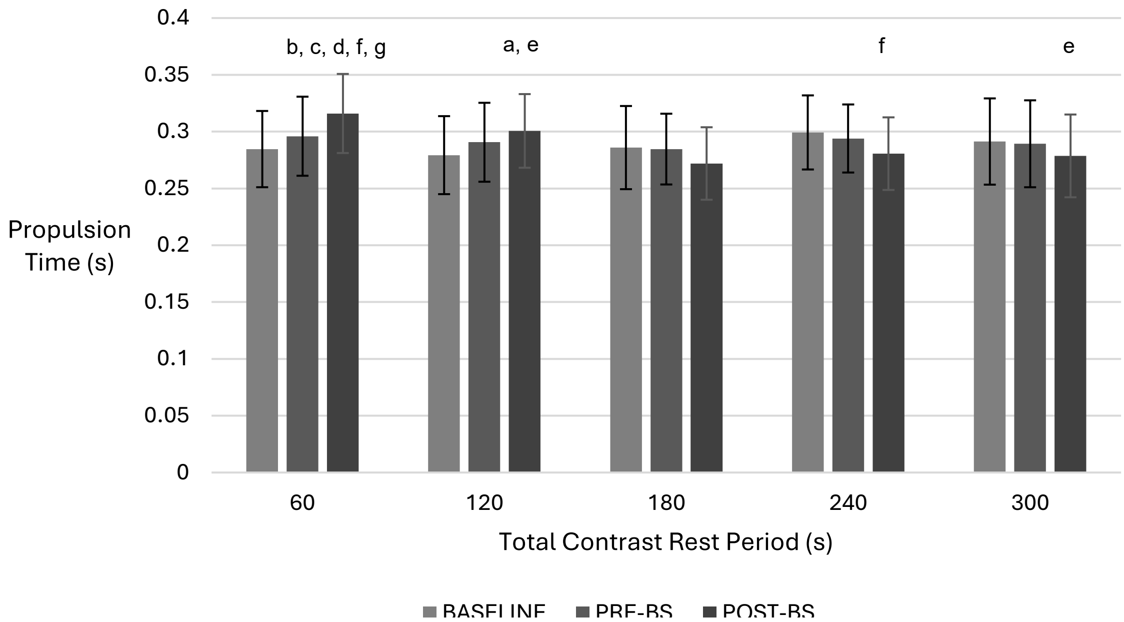


BASELINE, best performed repetition from the baseline set of jumps in the control condition; PRE-BS, best performed repetition from the post-ICRP set of jumps in the control condition; POST-BS, best performed repetition from the post-ICRP set of jumps in the experimental condition.

[a] Significant small effect with TCRP60_POST-BS ($p < 0.05$, $g = 0.35$-0.81).
[b] Significant moderate effect with TCRP60_POST-BS ($p < 0.05$, $g = 0.81$-1.50).
[c] Significant small effect with BASELINE ($p < 0.05$, $g = 0.35$-0.81).
[d] Significant moderate effect with BASELINE ($p < 0.05$, $g = 0.81$-1.50).
[e] Significant small effect with PRE-BS ($p < 0.05$, $g = 0.35$-0.81).
[f] Significant moderate effect with PRE-BS ($p < 0.05$, $g = 0.81$-1.50).

Figure 3. Countermovement jump average rate of force development. Data is presented as mean ± SD. Pairwise significant differences and effect sizes between- and within-total contrast rest periods are represented with letters corresponding to footnote definitions.

Analysis of t_{PROP} showed a significant interaction was found for TCRP*CONDITION*TIME. Significant pairwise comparisons and effect sizes are reported in Figure 4. A significant interaction was found for TCRP*CONDITION. Post hoc analysis is presented in Table 7. Within-TCRP analysis showed that TCRP60_EXP was higher than TCRP60_CON. TCRP120_EXP was higher than TCRP120_EXP, TCRP180_EXP was lower than TCRP180_CON, TCRP240_EXP was lower than TCRP240_CON, and TCRP300_EXP was lower than TCRP300_CON. Between-TCRP analysis showed TCRP180_EXP was lower than TCRP60_EXP and TCRP300_EXP. No other differences were found.



BASELINE, best performed repetition from the baseline set of jumps in the control condition; PRE-BS, best performed repetition from the post-ICRP set of jumps in the control condition; POST-BS, best performed repetition from the post-ICRP set of jumps in the experimental condition.

[a] Significant moderate effect with TCRP180_POST-BS ($p < 0.05$, $g = 0.81$-1.50).
[b] Significant moderate effect with TCRP240_POST-BS ($p < 0.05$, $g = 0.81$-1.50).
[c] Significant moderate effect with TCRP300_POST-BS ($p < 0.05$, $g = 0.81$-1.50).
[d] Significant large effect with TCRP180_POST-BS ($p < 0.05$, $g > 1.50$).
[e] Significant moderate effect with BASELINE ($p < 0.05$, $g = 0.81$-1.50).
[f] Significant large effect with BASELINE ($p < 0.05$, $g > 1.50$).
[g] Significant moderate effect with PRE-BS ($p < 0.05$, $g = 0.81$-1.50).

Figure 4. Countermovement jump propulsion time. Data is presented as mean ± SD. Pairwise significant differences and effect sizes between- and within-total contrast rest periods are represented with letters corresponding to footnote definitions.

There was a significant interaction of TCRP*TIME. Post hoc analysis is presented in Table 8. Within-TCRP analysis showed that TCRP60_POST was higher than TCRP60_PRE, TCRP120_POST was higher than TCRP120_PRE, TCRP240_POST was lower than TCRP240_PRE, TCRP300_POST was lower than TCRP300_PRE. Between-TCRP analysis revealed that TCRP180_POST was lower than TCRP60_POST, TCRP240_POST was lower than TCRP60_POST, TCRP300_POST was lower than TCRP60_POST and TCRP180_POST was lower than TCRP120_POST. No other significant differences were observed. No significant effects of TCRP, CONDITION or TIME were found.

Table 8. Countermovement jump TCRP x TIME post hoc analysis. Pairwise significance and effect size between collapsed variables where a significant interaction was found. Effect size (g) is reported with 95% confidence intervals. Significant effect sizes are highlighted in bold.

Variable	Pairwise Comparison	*p*	*g*	CI
Propulsion Time (s)	TCRP60_POST vs TCRP60_PRE	**<0.001**	**1.578**	**0.806, 2.325**
	TCRP120_POST vs TCRP120_PRE	**0.009**	**0.757**	**0.181, 1.312**
	TCRP180_POST vs TCRP180_PRE	0.073	0.486	-0.045, 1.002
	TCRP240_POST vs TCRP240_PRE	**<0.001**	**1.216**	**0.540, 1.869**
	TCRP300_POST vs TCRP300_PRE	**0.020**	**0.659**	**0.101, 1.198**
	TCRP60_PRE vs TCRP120_PRE	0.389	0.223	-0.280, 0.718
	TCRP60_PRE vs TCRP180_PRE	0.806	0.063	-0.431, 0.555
	TCRP60_PRE vs TCRP240_PRE	0.064	0.505	-0.029, 1.023
	TCRP60_PRE vs TCRP300_PRE	0.086	0.464	-0.064, 0.978
	TCRP120_PRE vs TCRP180_PRE	0.552	0.153	-0.345, 0.646
	TCRP120_PRE vs TCRP240_PRE	0.128	0.406	-0.115, 0.914
	TCRP120_PRE vs TCRP300_PRE	0.829	0.055	-0.438, 0.547
	TCRP180_PRE vs TCRP240_PRE	0.050	0.538	0.000, 1.060
	TCRP180_PRE vs TCRP300_PRE	0.461	0.191	-0.310, 0.685
	TCRP240_PRE vs TCRP300_PRE	0.309	0.265	-0.241, 0.763
	TCRP60_POST vs TCRP120_POST	0.133	0.400	-0.120, 0.908

TCRP60_POST vs TCRP180_POST	**<0.001**	**1.742**	**0.924, 2.537**
TCRP60_POST vs TCRP240_POST	**0.041**	**0.567**	**0.024, 1.093**
TCRP60_POST vs TCRP300_POST	**0.002**	**0.925**	**0.316, 1.512**
TCRP120_POST vs TCRP180_POST	**0.007**	**0.789**	**0.208, 1.350**
TCRP120_POST vs TCRP240_POST	0.241	0.307	-0.203, 0.807
TCRP120_POST vs TCRP300_POST	0.108	0.432	--0.093, 0.942
TCRP180_POST vs TCRP240_POST	0.197	0.340	-0.173, 0.843
TCRP180_POST vs TCRP300_POST	0.427	0.205	-0.296, 0.700
TCRP240_POST vs TCRP300_POST	0.628	0.125	-0.372, 0.617

TCRP, total contrast rest period; PRE, collapsed variable calculated as the mean of pre-intervention measurements from the experimental condition and control condition; POST, collapsed variable calculated as the mean of post-intervention measurements from the experimental and control condition.

Squat Jump

Squat jump descriptive statistics are reported in Table 9, and the repeated-measures ANOVA results are presented in Table 10.

Table 9. Squat jump dependent variable descriptive statistics, expressed as mean ± SD.

			Dependent Variable							
TCRP	PREDITION	TIME	Propulsive Impulse (N·s)	Peak Force (N)	Mean Force (N)	Average RFD ($N \cdot s^{-1}$)	RFD 50 ms ($N \cdot s^{-1}$)	RFD 100 ms ($N \cdot s^{-1}$)	RFD 150 ms ($N \cdot s^{-2}$)	Propulsion Time (s)
60	CON	BASELINE	227.90 ± 27.22	1928.93 ± 272.27	1380.29 ± 149.69	3817.37 ± 1776.97	3708.87 ± 2749.23	4394.63 ± 2513.07	4040.13 ± 1909.45	0.40 ± 0.08
		PRE_BS	227.37 ± 25.39	1922.91 ± 218.15	1372.22 ± 129.71	3910.49 ± 1797.65	4780.61 ± 2927.82	4839.56 ± 2183.01	4137.80 ± 1796.62	0.40 ± 0.09
	EXP	BASELINE	227.90 ± 27.22	1928.93 ± 272.27	1380.29 ± 149.69	3817.37 ± 1776.97	3708.87 ± 2749.23	4394.63 ± 2513.07	4040.13 ± 1909.45	0.40 ± 0.08
		POST_BS	225.67 ± 25.89	1908.96 ± 274.40	1363.70 ± 134.14	3753.84 ± 1603.22	4360.60 ± 2250.01	4735.29 ± 1839.52	4207.92 ± 1692.11	0.40 ± 0.08
120	CON	BASELINE	229.98 ± 28.78	1917.74 ± 270.26	1373.14 ± 109.14	3867.58 ± 1626.27	4026.03 ± 2215.20	4727.28 ± 1750.23	4069.21 ± 1491.38	0.40 ± 0.06
		PRE_BS	229.58 ± 24.88	1939.73 ± 305.70	1371.29 ± 123.15	3735.21 ± 1714.72	3804.81 ± 2436.35	4272.75 ± 2124.67	3929.14 ± 1720.99	0.40 ± 0.06
	EXP	BASELINE	229.98 ± 28.78	1917.74 ± 270.26	1373.14 ± 109.14	3867.58 ± 1626.27	4026.03 ± 2215.20	4727.28 ± 1750.23	4069.21 ± 1491.38	0.40 ± 0.06
		POST_BS	235.21 ± 26.04	1937.96 ± 264.08	1383.34 ± 125.70	3734.60 ± 1402.90	4195.21 ± 2627.88	4492.09 ± 1870.08	3865.76 ± 1394.04	0.40 ± 0.06
180	CON	BASELINE	229.24 ± 28.83	1929.00 ± 245.27	1376.40 ± 118.59	3836.87 ± 1409.62	4220.48 ± 2023.79	4622.71 ± 1802.73	4005.57 ± 1684.67	0.39 ± 0.06
		PRE_BS	228.78 ± 27.67	1903.53 ± 263.06	1378.39 ± 118.79	3690.17 ± 1340.23	4204.08 ± 2024.81	4689.72 ± 1575.56	4140.52 ± 1388.14	0.39 ± 0.06
	EXP	BASELINE	229.24 ± 28.83	1929.00 ± 245.27	1376.40 ± 118.59	3836.87 ± 1409.62	4220.48 ± 2023.79	4622.71 ± 1802.73	4005.57 ± 1684.67	0.39 ± 0.06
		POST_BS	239.07 ± 26.94	1879.32 ± 272.44	1359.41 ± 119.14	3531.58 ± 1364.58	4305.35 ± 2499.79	4587.99 ± 1897.86	3821.31 ± 1409.57	0.40 ± 0.07
240	CON	BASELINE	233.93 ± 22.21	1898.65 ± 220.06	1395.84 ± 94.59	3753.04 ± 1153.96	4898.07 ± 2123.51	5200.21 ± 1676.68	4300.86 ± 1457.88	0.38 ± 0.05

		PRE_BS	231.42 ± 24.89	1877.81 ± 211.05	1372.79 ± 62.74	3484.52 ± 889.94	4066.57 ± 1641.78	4635.99 ± 1295.75	4150.00 ± 808.89	0.40 ± 0.05
	EXP	BASELINE	233.93 ± 22.21	1898.65 ± 220.06	1395.84 ± 94.59	3753.04 ± 1153.96	4898.07 ± 2123.51	5200.21 ± 1678.68	4300.86 ± 1457.88	0.38 ± 0.05
		POST_BS	237.41 ± 26.85	1897.46 ± 220.62	1374.19 ± 89.59	3728.02 ± 1329.44	4755.61 ± 2733.66	4983.06 ± 1919.03	4144.70 ± 1567.73	0.39 ± 0.06
300	CON	BASELINE	233.30 ± 27.89	1905.57 ± 270.35	1362.00 ± 119.88	3692.49 ± 1414.99	4426.16 ± 2173.88	4778.28 ± 1842.18	4021.43 ± 1683.52	0.39 ± 0.06
		PRE_BS	230.73 ± 24.06	1871.43 ± 247.98	1352.99 ± 104.72	3750.69 ± 1613.17	4179.49 ± 2501.48	4443.39 ± 1863.25	3835.12 ± 1384.11	0.40 ± 0.06
	EXP	BASELINE	233.30 ± 27.89	1905.57 ± 270.35	1362.00 ± 119.88	3692.49 ± 1414.99	4426.16 ± 2173.88	4778.28 ± 1842.18	4021.43 ± 1683.52	0.39 ± 0.06
		POST_BS	239.60 ± 25.86	1879.02 ± 267.32	1331.88 ± 128.44	3638.15 ± 1568.38	3470.27 ± 2329.01	3917.78 ± 2085.60	3638.57 ± 1708.50	0.42 ± 0.08

TCRP, total contrast rest period; CON, control condition; EXP, experimental condition; BASELINE, best performed repetition from the baseline set of jumps in the control condition; PRE-BS, best performed repetition from the post-ICRP set of jumps in the control condition; POST-BS, best performed repetition from the post-ICRP set of jumps in the experimental condition; RFD, rate of force development.

Table 10. Squat jump repeated measures ANOVA results. Significant interactions and main effects are shown in bold.

	Dependent Variable							
Effect	Propulsive Impulse (N·s)	Peak Force (N)	Mean Force (N)	Average RFD ($N·s^{-1}$)	RFD 50 ms ($N·s^{-1}$)	RFD 100 ms ($N·s^{-1}$)	RFD 150 ms ($N·s^{-2}$)	Propulsion Time (s)
TCRP	$F_{4, 56}$ = 1.057 p = 0.386 η_p^2 = 0.070	$F_{4, 56}$ = 0.786 p = 0.539 η_p^2 = 0.053	$F_{2.178, 30.493}$ = 0.764 p = 0.485 η_p^2 = 0.052	$F_{4, 56}$ = 0.299 p = 0.877 η_p^2 = 0.021	$F_{4, 56}$ = 1.113 p = 0.357 η_p^2 = 0.074	$F_{4, 56}$ = 1.002 p = 0.414 η_p^2 = 0.067	$F_{4, 56}$ = 0.795 p = 0.502 η_p^2 = 0.054	$F_{4, 56}$ = 1.130 p = 0.352 η_p^2 = 0.075
CONDITION	**$F_{1, 14}$ = 20.243** **p < 0.001** **η_p^2 = 0.591**	$F_{1, 14}$ = 0.116 p = 0.738 η_p^2 = 0.008	$F_{1, 14}$ = 1.107 p = 0.311 η_p^2 = 0.073	$F_{1, 14}$ = 0.123 p = 0.731 η_p^2 = 0.009	$F_{1, 14}$ = 0.002 p = 0.965 η_p^2 = 0.000	$F_{1, 14}$ = 0.048 p = 0.829 η_p^2 = 0.003	$F_{1, 14}$ = 1.638 p = 0.221 η_p^2 = 0.105	$F_{1, 14}$ = 535 p = 0.476 η_p^2 = 0.037
TIME	$F_{1, 14}$ = 1.332 p = 0.268 η_p^2 = 0.087	$F_{1, 14}$ = 2.353 p = 0.147 η_p^2 = 0.144	$F_{1, 14}$ = 3.369 p = 0.088 η_p^2 = 0.194	$F_{1, 14}$ = 1.548 p = 0.234 η_p^2 = 0.100	$F_{1, 14}$ = 0.053 p = 0.822 η_p^2 = 0.004	$F_{1, 14}$ = 1.309 p = 0.272 η_p^2 = 0.086	$F_{1, 14}$ = 0.845 p = 0.374 η_p^2 = 0.057	$F_{1, 14}$ = 3.830 p = 0.071 η_p^2 = 0.215
TCRP*CONDITION	$F_{4, 56}$ = 1.454 p = 0.228 η_p^2 = 0.094	$F_{4, 56}$ = 0.523 p = 0.719 η_p^2 = 0.036	$F_{4, 56}$ = 0.868 p = 0.489 η_p^2 = 0.058	$F_{4, 56}$ = 0.632 p = 0.642 η_p^2 = 0.043	$F_{4, 56}$ = 1.571 p = 0.195 η_p^2 = 0.101	$F_{2.531, 35.427}$ = 0.890 p = 0.441 η_p^2 = 0.060	$F_{4, 56}$ = 0.488 p = 0.745 η_p^2 = 0.034	$F_{4, 56}$ = 1.401 p = 0.246 η_p^2 = 0.091
TCRP*TIME	$F_{4, 56}$ = 0.542 p = 0.663 η_p^2 = 0.037	$F_{4, 56}$ = 1.538 p = 0.204 η_p^2 = 0.099	$F_{4, 56}$ = 0.628 p = 0.644 η_p^2 = 0.043	$F_{2.379, 33.292}$ = 0.286 p = 0.789 η_p^2 = 0.020	$F_{2.436, 34.104}$ = 1.862 p = 0.164 η_p^2 = 0.117	$F_{4, 56}$ = 1.514 p = 0.211 η_p^2 = 0.098	$F_{4, 56}$ = 0.751 p = 0.562 η_p^2 = 0.051	$F_{4, 56}$ = 1.137 p = 0.349 η_p^2 = 0.075
CONDITION*TIME	**$F_{1,14}$ = 17.17.959** **p < 0.001** **η_p^2 = 0.591**	$F_{1, 14}$ = 0.116 p = 0.738 η_p^2 = 0.008	$F_{1, 14}$ = 1.107 p = 0.311 η_p^2 = 0.073	$F_{1, 14}$ = 0.123 p = 0.731 η_p^2 = 0.009	$F_{1, 14}$ = 0.002 p = 0.965 η_p^2 = 0.000	$F_{1, 14}$ = 0.048 p = 0.829 η_p^2 = 0.003	$F_{1, 14}$ = 1.638 p = 0.221 η_p^2 = 0.105	$F_{1, 14}$ = 0.535 p = 0.476 η_p^2 = 0.037
TCRP*CONDITION*TIME	$F_{4, 56}$ = 1.454 p = 0.228 η_p^2 = 0.094	$F_{4, 56}$ = 0.523 p = 0.719 η_p^2 = 0.036	$F_{4, 56}$ = 0.868 p = 0.489 η_p^2 = 0.058	$F_{4, 56}$ = 0.632 p = 0.642 η_p^2 = 0.043	$F_{4, 56}$ = 1.571 p = 0.195 η_p^2 = 0.101	$F_{2.531, 35.427}$ = 0.890 p = 0.441 η_p^2 = 0.060	$F_{4, 56}$ = 0.488 p = 0.745 η_p^2 = 0.034	$F_{4, 56}$ = 1.401 p = 0.246 η_p^2 = 0.091

TCRP, total contrast rest period; CONDITION, control or experimental; TIME, pre-ICRP or post-ICRP.

Analysis of JPROP revealed a significant interaction for CONDITION*TIME ($F_{1,14}$ = 17.959, p < 0.001, ηp^2 = 0.591). Post hoc analysis is presented in Table 11. POST-BS was higher than PRE-BS and BASELINE. There was no difference between PRE-BS and BASELINE. There was a main effect of CONDITION with EXP being higher than CON. No significant interactions or effects were revealed for any other variables.

Table 11. Squat jump CONDITION x TIME post hoc analysis. Pairwise significance and effect size between collapsed variables where a significant interaction was found. Effect size (g) is reported with 95% confidence intervals. Significant effect sizes are highlighted in bold.

Variable	Pairwise Comparison	*p*	*g*	CI
Propulsive Impulse (N·s)	POST-BS – PRE-BS	**<0.001**	**1.130**	**0.475, 1.762**
	POST-BS - BASELINE	**0.030**	**0.608**	**0.059, 1.140**
	PRE-BS - BASELINE	0.268	0.290	-0.219, 0.789

BASELINE, collapsed variable calculated as the mean of the best performed repetition from the baseline set of jumps in the control condition from each total contrast rest period (TCRP) intervention; PRE-BS, collapsed variable calculated as the mean of the best performed repetition from the post-ICRP set of jumps in the control condition from each TCRP intervention; POST-BS, collapsed variable calculated as the mean of the best performed repetition from the post-ICRP set of jumps in the experimental condition from each TCRP intervention; RFD, rate of force development.

DISCUSSION

This study assessed the effect of partial redistribution of the ICRP within CCT prescriptions on vertical jump propulsive force application. While we previously examined the impact of RR of different TCRPs (Houlton et al., Under review), this was the first study to explore redistributing larger proportions of rest, to reorganise CCT prescriptions to enhance the practical effectiveness of CCT by reducing CA-induced fatigue and movement pattern interference, thereby enabling earlier detection of PAPE compared to standard CCT prescriptions.

No significant interaction of TCRP*CONDITION*TIME was observed for JPROP (Tables 5 and 10), suggesting that CMJ and SJ height was unaffected by up to 5 minutes post-CA. However, significant CONDITION*TIME interactions indicate that JPROP was significantly greater at POST-BS than at PRE-BS and BASELINE for both jumps, independent of TCRP (Tables 6 and 11). In both cases, numerical mean differences between timepoints were similar to TE and SWC (Table 2), meaning it is unclear whether J_{PROP} was truly enhanced or the difference observed was the result of measurement ‘noise’.

Regarding the propulsion strategy, CMJ ANOVA revealed significant TCRP*CONDITION*TIME interactions for RFD_{PEAK}, RFD_{AVE}, and t_{PROP} (Table 5), whereas no further interactions were observed for SJ. Increases in RFD and decreases in t_{PROP} at POST-BS within- and between-TCRPs suggest that, while overall CMJ performance was unaffected, participants produced similar J_{PROP} more explosively after TCRP180, TCRP240 and TCRP300 interventions. No further interactions or effects were observed for SJ variables, suggesting the interventions did not affect jump performance or jumping strategy when the SSC and excitation-contraction coupling were minimised. These results suggest that reorganising CCT prescriptions using RR may have positive effects on RFD and explosive force application via enhanced coupling and SSC efficiency. Practitioners may consider alternative set strategies to enhance RFD during SSC-based vertical jump variants if RFD, rather than overall jump height, is the primary objective.

Despite significant CONDITION*TIME interactions and subsequent observed POST-BS increases in J_{PROP} compared to PRE-BS and BASELINE, the proximity of these differences to TE and SWC (Table 2) suggests it is unlikely that J_{PROP} was affected by any intervention for either CMJ or SJ when ≤300 s is prescribed. This is consistent with the current literature, which suggests that at least 300 s of rest is required to observe potentiated jump performance (Kilduff et al., 2008; Esformes & Bampouras, 2013; Seitz & Haff, 2016). For example, Esformes et al. (2013) and Kilduff et al. (2008) reported increased CMJ performance 5 minutes and 8 minutes post-ICRP, respectively, after completing variations of the BS as the CA. This may be explained by differences in relative strength. Participants in these studies were semi-professional and professional rugby players with relative strength of ~2.10 and ~1.97, respectively, compared to the recreational sample in the present study, which demonstrated lower relative strength (1.72 ± 0.15) (Esformes & Bampouras, 2013; Kilduff et al., 2008). This is consistent with the notion that enhanced CMJ performance is more likely to occur in stronger athletes (relative strength >1.75 (Seitz & Haff, 2016)), who typically recruit larger numbers of higher threshold motor units, required to produce higher J_{PROP}. Thus, redistribution of the TCRP may not reduce the total rest required within CCT sets to observe potentiation in overall jump performance. However, it should also be noted that combining RR with CCT did not hinder J_{PROP}, whereas previous studies have shown reductions in J_{PROP} or jump height at time points prior to observation of enhanced performance (Comyns et al., 2006; Crewther et al., 2011; Jenson & Ebben, 2003; Kilduff et al., 2008). This is noteworthy, as in time-constrained environments or in populations of moderately strong athletes, where there may be diminishing returns on time required to enhance lower body strength further. This approach may lead to increased training density and efficiency of combined strength and power training sessions without negatively affecting jump performance.

Regarding propulsion strategy, significant interactions of TCRP*CONDITION*TIME for RFD_{PEAK}, RFD_{AVE}, and t_{PROP} suggest that the CMJ propulsion strategy changed post-CA, depending on TCRP. TCRP180, TCRP240 and TCRTP300 interventions enhanced RFD_{PEAK} at POST-BS compared with other timepoints (Figure 2). Moderate effect sizes for TCRP240 and TCRP300 suggest that these rest periods enhanced RFD_{PEAK} more than TCRP180, for which a small effect was observed. Similarly, RFD_{AVE} increased at POST-BS compared to PRE-BS and BASELINE after TCRP120, TCRP180, TCRP240 and TCRTP300 interventions (Figure 3). Larger differences were observed between timepoints within TCRP300 than between timepoints within TCRP120, TCRP180, and TCRP240. However, increases in RFD did not enhance J_{PROP}. This may be explained by considering t_{PROP} results, where POST-BS at TCRP240 and TCRP300 was significantly lower than corresponding BASELINE values (Figure 4). Combined RFD and t_{PROP} results suggest propulsive force application was shorter and more explosive, but reduced t_{PROP} may have limited the total force applied during propulsion.

This observation may be explained by considering the effect RR may have on the potentiation-fatigue relationship and the relative strength of the sample. Conceptually, RR may limit the potentiation and fatigue effect of the CA. Completing the CA as single repetitions may facilitate recovery and maintain performance between repetitions (Tufano et al., 2017). However, this may limit the recruitment of higher threshold motor units (Carpentier et al., 2001), which would better contribute to increased total force application. Less total rest may be sufficient for recovery to observe enhanced RFD in lower-threshold motor units.

Regarding participants' strength, the lower relative strength of the present sample may suggest a limited ability to efficiently recruit high-threshold motor units to produce higher peak forces more rapidly than stronger populations. Despite significant post-CA increases, the potentiated RFD values reported in this study (Table 4) are lower than those typically reported for sprinters (Boullosa et al., 2018) and experienced strength-and-power-trained athletes (Earp et al., 2011), who more efficiently recruit high-threshold motor units. This may suggest that participants in the present study were either not sufficiently experienced or not sufficiently strong to recruit higher-order motor units effectively, and therefore may require longer t_{PROP} to produce more force.

Mechanistically, observed changes in RFD may be explained by considering the types of jump assessed in this study and the neuromuscular and metabolic effects of fatigue on explosive performance. The limited effect on SJ variables (Table 10) suggested that observed changes in CMJ propulsion may be attributed to enhanced eccentric-concentric coupling and SSC efficiency (Linthorne, 2001), rather than to concentric-only motor unit recruitment. Therefore, enhanced RFD may result from enhanced crossbridge formation during coupling and, subsequently, from enhanced contractile velocity (Fenwick et al., 2017). Enhanced crossbridge formation within lower-threshold motor units may also contribute to changes in muscle stiffness, with more efficient use of stored elastic energy within contractile units rather than through tendon recoil dynamics, which may be associated with stronger, more athletic populations (Arampatzis et al., 2007).

Regarding fatigue, lower-threshold motor units, while producing less force, recover from fatigue faster than higher-threshold motor units and may not readily exhibit twitch force decrements associated with contractile history (Farina et al., 2009). Furthermore, lower-threshold motor units are more likely to sustain contractile velocity for longer, resulting in less CA-induced interference with movement patterns. The combination of shorter TCRPs and RR between CA repetitions may have sufficiently limited CA-induced peripheral fatigue by facilitating partial recovery of phosphocreatine and adenosine triphosphate and partial reduction in intramuscular acidity between repetitions (Chae et al., 2023; Girman et al., 2014; Tufano et al., 2017). This may be inferred from the higher CA v_{MEAN} observed compared to 3RM (Table 3). Reductions in intramuscular pH and phosphocreatine are directly related to reduced SSC efficiency (Wilson & Flanagan, 2008) and inhibited motor unit recruitment

(Ortega-Auriol et al., 2018) as high-intensity exercise-induced fatigue results in longer amortisation phases due to slower eccentric-concentric coupling (Turner & Jeffreys, 2010). While incorporating RR may not have enhanced J_{PROP}, it may have reduced fatigue sufficiently to optimise the intramuscular environment and neuromuscular stimulus post-CA, enabling earlier observation of PAPE through RFD enhancement compared with traditional CCT sets (Kilduff et al., 2008).

The homogeneous sample may have limited the generalisability of the results to wider populations. It remains unclear how stronger populations with more training experience, who are more likely to benefit from PAPE, would respond to the alternative CCT set strategies implemented in this study. As no females volunteered, it is uncertain how females, who typically have more type I muscle fibres (Nuzzo, 2024), faster high-intensity exercise recovery (Davies et al., 2018), and more compliant jump propulsion strategies (Márquez et al., 2017), would respond to these protocols. Lastly, this study has considered the effect of one alternative set strategy (RR) on CCT explosive force application, while the effects of other RR strategies and alternative set strategies, such as cluster sets, remain unexplored. Therefore, future research should consider the effect of RR within CCT prescriptions on EA performance in stronger populations and the female population. Furthermore, longitudinal studies should be considered to elucidate the long-term effects of combined training methods on lower-limb explosive force.

CONCLUSION

The results of this study show that incorporating RR strategies within CCT sets may minimise CA-induced fatigue, enabling PAPE to be observed earlier than in traditional CCT sets. Enhanced RFD variables and decreased t_{PROP} after TCRP180, TCRP240 and TCRP300 suggest that RR may augment CMJ propulsive force application via enhanced coupling and SSC efficiency. However, it remains unclear whether the enhanced propulsion strategy increased J_{PROP} and, therefore, jump height. While not augmented, RR sufficiently limited fatigue to maintain J_{PROP}. This is an important observation that shows RR strategies may be applied in time-constrained environments to improve training density when strength and power training are prescribed using CCT. Practitioners are recommended to consider the training objective. If the goal is to enhance J_{PROP}, then longer ICRPs may still be required for

PAPE to manifest in this way. If enhanced RFD is the primary aim, then RR strategies may reduce the training time required to observe enhanced performance. These results may also inform programming decisions during specific phases of training. For example, during strength phases, traditional CCT may be used with longer ICRPs to maximise neuromuscular adaptations in the CA and prioritise EA impulse. However, during power phases, RR may be incorporated to prioritise RFD of the EA and enhance propulsion strategies. Lastly, based on reliability metrics, experimentation at the individual level is recommended to optimise CCT prescriptions using alternative set strategies.

ACKNOWLEDGEMENTS

The authors thank the participants who volunteered for our study. Without them, this work would not have been possible. They would also like to thank the Ministry of Defence for facilitating the use of the force platforms used for data collection in this study. The authors declare they have no conflicts of interest.

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