

Title: My coach says: The effects of accelerated eccentric and landing cues to elicit change in countermovement jump propulsive and landing performance.

Short Title: The effects of accelerated eccentrics on countermovement jump land performance.

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ABSTRACT

The study aimed to determine if an accelerated eccentric (AE) cue during a countermovement jump (CMJ) produces distinct kinetic outputs. Eighteen strength-trained males (mean $\pm$ standard deviation $\pm$ SD: age = 25.9 ± 4.5 years; body mass = 87.1 ± 12.2 kg; stature = 181.7 ± 6.2 cm) completed a jump cue ("jump as high and fast as possible" (NORM) or AE ("fast downward, max braking, and jump as high and fast as possible") with two types of landing cues: deceleration eccentric (DC) ("decelerate as fast as possible once landed") and dissipating eccentric (DP) ("stop in your own time"). The Hawkin Dynamics Cloud system was used for jump analysis, including additional landing metrics. Participants performed 4 repetitions of AEDC, AEDP, NORMDC, and NORMDP in a randomized order on two separate occasions. When compared to the NORM conditions, the AE conditions had significantly greater peak and mean braking velocity (effect size (ES) = -0.77 to -0.89 and -0.60 to -0.83, respectively), mean braking power (ES = -0.56 to -0.59, mean braking force (ES = 0.40 to 0.46), braking impulse (ES = 0.35 to 0.41), force at minimal displacement (ES = 0.26 to 0.32), and peak propulsion force (ES = 0.24 to 0.26), with a reduced braking phase time (ES = 0.59 to 1.14). Only landing impulse showed acceptable reliability for landing metrics, with no significant differences between groups. Findings highlight AE's enhance braking (eccentric) metrics and overall CMJ performance. Future research should explore AE in strength-based exercises and further investigate CMJ landing phase metrics.

Key words: Braking strategy, braking, eccentric training, braking force, fast eccentrics.

53 INTRODUCTION

54 Strength and conditioning coaches frequently use specific commands and cues to instruct
55 athletes with the intent to enhance specific aspects of movement phases (29). The effect of both
56 internal and external focus of attention cues has been extensively investigated (25,29,34,36).
57 Internal cues direct attention to specific joints or body areas, whereas external cues focus on
58 external objects like jumping as high as possible (34). Internal cues draw specific attention to
59 an area which would cause enhanced performance at that one area, they tend to lead to a
60 reduction in exercise performance as attention of focus is subjected to a specific area rather
61 than the performance of the exercise itself (7,34,36,60). Whereas external cues typically cause
62 greater movement accuracy and efficiency (60). This highlights the significant influence of
63 specific cues on movement performance

64 Specific commands to perform exercises have been tested, resulting in changes in kinetics,
65 kinematics variables, and the intended physiological changes (34,41). The most commonly
66 used coaching instruction in eccentric training is tempo lifting (21,40), which involves
67 specifying a temporal framework for either a movement or specific phase (e.g., the downward
68 phase) (58). As described by Wilk et al. (59), commands can be more explicit than timeframes,
69 encompassing both fast (2-4.9 s) and slow (10-14.9 s) durations. Verkhoshansky and Siff (52)
70 introduced accelerated eccentrics (AE) which aim to increase eccentric velocity during the
71 eccentric phase through verbal cue, often accomplished by offering specific instructions like
72 pulling a barbell down during the eccentric phase or maximising eccentric speed in the
73 downward phase (e.g., during a back squat) (20). Specific commands could elicit distinct
74 responses, offering athletes greater clarity in exercise execution or potentially enhancing the
75 physical stimulus, as demonstrated by external cues (34).

Building upon the exploration of specific commands and coaching instructions in eccentric training, it's noteworthy that cues can promote changes during the eccentric phase, expressed through the impulse strategy applied to a moving mass, such as a barbell or the athlete (19). When a body travels at a higher velocity, its momentum increases (Equation 1) and that a change in momentum is proportional to the impulse applied to an object (37). Consequently, a larger impulse strategy is required to decelerate and bring the body to a stop (eccentric braking) (19,20) an object that is in motion. This concept is known as the impulse-momentum relationship (19,38), and it involves applying either a greater force over a shorter duration (highly impulsive) or less force over a longer period. Implying force production can be enhanced by an object having a greater velocity.

$$\text{Equation 1: } \mathbf{p} = \mathbf{m} \times \mathbf{v}$$

Equation 1: Momentum equation where $\mathbf{p}$ = momentum, $\mathbf{m}$ = mass and $\mathbf{v}$ = velocity.

Various eccentric training methods exist, with eccentric tempo training at the forefront, which provides individuals with a specific duration to execute each phase of an exercise (19). For example, Wilk et al. (57) demonstrated a 2 s eccentric tempo led to larger increases in both peak and mean concentric power than a 6 s eccentric tempo. Eccentric coaching commands like eccentric tempo training exemplify a simpler method than when compared to supramaximal accentuated eccentric loading (AEL) or flywheel training which is reliant upon additional (specialised) equipment (20,22,42). Krzyzskowski et al. (29) examined an unloading and braking strategy, including unweighting and eccentric methods, to improve countermovement jump (CMJ) performance. They found that a stronger focus on eccentric braking resulted in increased eccentric force production, rapid force development, and a shorter time to take-off compared to the control trial. Biomechanical insights, along with the findings from Wilk et al. (57), Krzyzskowski et al. (29) and Handford et al. (19) demonstrate that

increasing downward velocity can lead to a larger braking force in a shorter time adhering to a larger braking impulse strategy. This would simulate sporting motions such as deceleration and change of direction (COD) tasks (14,37) and has the potential to enhance concentric performance (19). This suggests that exercise execution, including coaching cues discussed by Handford et al. (19,20) could enable greater physical performance such as increasing braking rate of force development (RFD) or enhancing stretch shortening cycle performance during sporting motions.

The braking phase of a CMJ involves a significant eccentric stimulus similar to the landing phase, yet research on landing, especially the CMJ landing phase, is less extensive, despite the critical role of eccentric force in decelerating and stopping motion (24). Harry et al. (25) investigated the effects of an internal and external cue on landing strategy during a maximal CMJ. In male participants, they found that an external cue reduced landing duration and increased peak landing force. Since both the braking phase (centre of mass (COM) deceleration during descent) and landing phase (impact and stabilization) involve eccentric muscle actions to decelerate the COM, it is plausible that specific external cues might alter kinetic values or landing technique, either enhancing adaptation through greater exposure or mitigating injury risk. Handford et al. (20) clarifies this by presenting various proposed eccentric motions within a training method, highlighting the potential for specific changes through accurate cueing.

The aim of this study was to analyze the effects of AE commands in comparison to a control command to determine if metrics such as impulse and velocity were altered during a CMJ and landing. It was hypothesized that the AE cues would achieve greater force production and peak braking velocity compared to the control condition. It was expected that a greater braking impulse strategy would be employed, characterised by applying a larger force in less time than the control group.

METHODS

Experimental approach to problem

To assess both jumping and landing phase metrics of a CMJ following differing AE cues, a sample of eighteen strength-trained males were recruited. Using a randomized cross-over, within-subject study design each participant underwent testing on two separate occasions, ranging from ≥ 1 to 48 hours post testing session 1. Participants were instructed not to engage in any resistance-based training during the interval between testing sessions. The two testing sessions were conducted to evaluate the between-session reliability of the measurements. Though, the study aimed to assess landing phase metrics, reliability testing identified that only landing impulse was an acceptable metric. However, presented in the current study is the peak and mean landing forces to provide information to the reader into forces that can be experienced to an athlete during a landing task.

Subjects

Eighteen strength trained males (mean $\pm$ standard deviation (SD): age = 25.9 ± 4.5 years; mass = 87.1 ± 12.2 kg; stature = 181.7 ± 6.2 cm, >2 years strength training experience (5.8 ± 2.9 yrs) were included in this study. An a priori power analysis was conducted using G*Power (Version 3.1.9.7), with an effect size of 0.3 (Cohen's d), an alpha level of 0.05, and a desired power of 0.80, indicating that a total sample size of 17 participants was required to detect significant differences between conditions. The effect size of 0.3 was selected based on similar cueing methodologies and kinetic outcomes reported by Barillas et al. (3) in a study investigating jump kinetics under external focus cues (3,11). Participants were eligible for inclusion in the study if they were competent in performing the CMJ and had been free from any injuries for at least six months prior to the study. In the 24 hours prior to testing session one participants were advised not to drink alcohol or perform physical exercise, and as such refrain from resistance

training. Additionally, on testing days, participants were required to avoid caffeine intake and any form of resistance-based training until after completing the experiment. This research was approved by the Institutional Ethics Committee, and all participants provided written, informed consent before participating in the study.

Procedure

Familiarization

Participants were requested to attend a familiarization session at least 1 day before testing session whereby age, height and informed consent was obtained for the study. Participants were familiarized with the testing protocol and the exercise cues that would be used for the experiment prior to data collection. Participants were introduced to the CMJ cues and landing cues, this consisted of 3 submaximal attempts on each condition. Participants were advised not to conduct resistance training 1 day before the familiarization session.

Testing session 1

On the first testing session participants were briefed with the protocol, they then performed a 5-minute warm up on a Wattbike Nucleus (2000 W United Kingdom) at 60 RPM, level 2. After completing this they undertook 3 submaximal efforts of CMJs using the jump landing cues. After 5 minutes of rest, they commenced the testing protocol. During the testing session participants performed 4 CMJs using a specific jump landing cue which were performed in a randomized order (Figure 1). The jump landing cues consisted of either “jump as high and fast as possible” (NORM) with a specific landing cue, the other jump cue was to perform a “fast downward phase, maximum braking and then jump high and fast” (AE) with a specific landing cue (Table 2). Landing cues consisted of deceleration (DC) and dissipating eccentric landing (DP) (Table 1) (20). Between conditions participants were given 2 minutes recovery. Once

participants had completed all conditions, they completed testing session 1. In total participants completed 16 CMJs per session (4 CMJs per condition) (Figure 1).

All CMJs were performed on a force plate (Bertec 5060-06, Columbus, Ohio) and sampled at 1000 Hz. Before each CMJ the participant was instructed to descend to as close to the same depth as the first recorded CMJ as possible and provided with the specific jump land cue. After this, the force plate was zeroed, participants were then asked to step on the force plate with hips and knees fully extended, with hands on hips (39). Participants were instructed to remain stationary for a 3, 2, 1, countdown, this was completed to provide at least 1 s to calculate participant's weight (weighing phase) (39). After the countdown was complete participants were cued to go (3, 2, 1, Go). Upon completing the landing phase participants were advised to hold the bottom position for 1 s and then to slowly stand back up. Once the allotted time was complete participants would step off the force plate and the process was repeated. The Hawkin Dynamics Cloud system, which enabled instantaneous feedback of jumping metrics, was used to assess CMJ depth displacement, if participants went greater or less than 5 cm then their first CMJ depth they were asked to repeat the jump (35,45). No participant completed more than 5 CMJs for each protocol. Between trials, participants were provided 30 - 45 s rest.

Testing session 2

After an allotted time between sessions, participants repeated the same protocol as in session 1 (Figure 1). Before testing, participants were reminded of their depth displacement from the previous session and were asked to execute as close to the same displacement as possible for all jump conditions again. Participants either performed the testing sessions on the same day where they had no less than 1 hour between testing sessions or performed the second session 24 or 48 hours apart. This was performed to reduce participant burden and allowed the research

team to assess the test-retest reliability across different time gaps, ensuring that the time between sessions did not affect the outcomes.

Jump landing cues.

For each condition a specific jump landing cue was performed. These consisted of AEDC, AEDP, NORMDC and NORMDP. During the AEDC cue participants were instructed to perform “fast downward phase with a maximum braking and then jump high and fast” (Table 1) and “upon landing to decelerate and stop as quickly as possible” (Table 2). During the NORMDP cue participants were instructed to “jump as high and fast as possible” and upon landing to “decelerate and stop in their own time”. For the AEDP and NORMDC the specific jump landing cue was provided using the right combination of the aforementioned commands. If participants struggled to interpret the commands during the familiarization session, additional coaching cues which attempted to achieve the same response were provided instead, which are also shown in Table 1 and 2. This method was employed as this is a phenomenon that would occur in practice from strength and conditioning coaches if certain athletes could not interpret the intended cue.

****INSERT FIGURE 1 HERE****

216 *****INSERT TABLE 1 HERE*****

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223 *Data analysis*

224 The force plate was linked to the Hawkin Dynamics mobile app, where jumps were recorded,
225 and then data was presented via the Hawkin Dynamics software using a Tablet (Nokia T10
226 Android 12 4G) and all jump data were subsequently saved to the Hawkin Dynamics Cloud
227 system. Most metrics in the current study were calculated by the Cloud system, therefore, these
228 data points were transported from the Cloud system to a Microsoft Excel spreadsheet (version
229 2012, Microsoft Corp., Redmond, WA, USA). All metric calculations can be found via the
230 Hawkin Dynamics Metric Database ([Hawkin Metric Database \(hawkindynamics.com\)](http://hawkindynamics.com))).

231 In addition to the metrics that were pre-calculated via the Hawkin Dynamics system, further
232 landing metrics were calculated that are not currently available from the Hawkin Dynamics
233 system. A raw text file containing vertical force values of the CMJ was taken from the Cloud
234 system and subsequently imported into a customised Microsoft Excel spreadsheet where means
235 SD were calculated. From this spreadsheet specific values were calculated, and these values
236 were then transferred to another spreadsheet where mean and SD were calculated using the
237 following methods.

238 Take-off and touchdown were identified when vertical ground reaction force (vGRF) fell below
239 or above a threshold equal to $5 \times \text{SD}$ of the flight phase (Figure 2). The SD of the flight phase
240 residual force was calculated across the middle 50% of the flight phase duration when the force
241 plate was unloaded (8). The landing phase metrics were identified as beginning at the point of
242 touchdown (when force exceeded the take-off threshold) to the point centre of mass (COM)
243 velocity reached $0 \text{ m} \cdot \text{s}^{-1}$ (the point of stabilization) (31,44) which coincided with peak negative
244 landing displacement. Peak and mean landing force were calculated as the highest and average
245 value during the landing phase. Landing phase time was calculated as the time from the point
246 of touchdown to the point of stabilization. Mean net landing force was calculated as participants
247 mean force value minus their body weight from the point of touchdown to stabilization.
248 Landing impulse was calculated by integrating net force (force minus weight) with respect to
249 time using the trapezoid rule. Displacement was obtained by integrating velocity with respect
250 to time using the trapezoid rule and landing displacement value was recorded as the
251 displacement value that coincided with $0 \text{ m} \cdot \text{s}^{-1}$ COM (stabilization phase) (31,39). For analysis
252 the average of the 4 CMJs was used in the current study.

253 *Statistical analysis*

254 *Between session reliability*

255 All relevant data were transferred from the Hawkin Dynamics Cloud system to Microsoft Excel
256 where means and SD were established for each performance measure, then data was imported
257 into SPSS software (version 24.0, SPSS Inc., Chicago, IL, USA). All data satisfied parametric
258 assumptions, as determined through Shapiro-Wilks test excluding the unweighting phase.
259 metric. Paired sample t-tests were used to determine whether there were significant differences
260 between the sessions mean and A Mann-Whitney U test was used to establish between session
261 differences for the unweighting phase metric. A two-way mixed-effects model interclass
262 correlation (ICC) was used to determine the relative between-trial reliability of each
263 performance measure. The ICC values were interpreted as scores ranging from <0.500 poor,
264 0.500 - 0.750 moderate, 0.750 - 0.900 good and >0.900 excellent reliability (28). The typical
265 error (TE) was calculated as the SD of the differences between trials divided by the square root
266 of 2 (1,8), 95% coefficient of variation (CV) was determined using the calculation of the root
267 mean square method ($\sqrt{SD/mean^2 \times 100}$) (8,26), Magnitude of CV was based on the following
268 parameters: poor (>10%), moderate (5–10%), or good (<5%) (2). For each finding a 95% upper
269 and lower bound confidence interval (CI) was calculated to create upper and lower control
270 limits and recognise non-overlapping areas for ICC and CV.

271 *Comparing conditions*

272 All measures passed parametric assumptions through a Shapiro-Wilks test; therefore, a one-
273 way repeated measures ANOVA was used to determine differences between conditions and a
274 post hoc test with Bonferroni adjustment, when necessary, with the alpha level set $p = 0.05$. If
275 the assumption of sphericity was violated, Greenhouse-Geisser adjusted values were reported.
276 The magnitude of Hedge's g effect size (ES) results were interpreted as trivial (<0.19), small

277 (0.20–0.49), moderate (0.50–0.79), and large (>0.80) and 95% upper and lower bound CI were
278 established (10).

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RESULTS

Prior to comparison between conditions reliability testing established metrics showing poor reliability and be excluded from analysis. All metrics presented in the current study achieved acceptable reliability levels, through ICC scores > 0.8 , CV% $< 10\%$ and no significant difference between testing sessions. Metrics not reaching acceptable reliability levels were braking RFD landing phase time and landing displacement. Both peak and mean net landing force were significantly different between sessions and poor CV. Time to stabilization had poor CV ($> 10\%$) and ICC (< 0.5) and landing phase time had poor CV ($> 10\%$), ICC (< 0.5) and significantly different between trials. Unweighting phase highlighted $> 10\%$ CV% and not all conditions passed parametric assumptions, thus not allow comparisons between conditions. These findings warranted their exclusion from the between condition study.

****INSERT TABLE 3 HERE****

System weight and jump height identified no difference between conditions with trivial ES (Table 3). No significant difference between AEDC and NORMDC and trivial ES for depth displacement. Although, there was a significant difference for AEDC compared with the AEDP and NORMDP achieving small ES, however, this did not exceed the TE value (Table 3). Braking phase both AEDC and AEDP achieved significantly shorter times than NORM conditions. AEDC reduced greater than the TE for NORMDP and NORMDC, while AEDP only did for compared to NORMDP condition (Table 3). For time to take-off, the AEDC was

significantly less than the NORM conditions, although not surpassing the NORMDC TE score but did exceed the NORMDP value. AEDP achieved a significant difference compared to NORMDP but not when compared to NORMDC. For propulsion phase the AEDC condition exhibited a significant decrease in time, surpassing the TE values set by the NORM conditions with small and moderate ES changes. Moreover, both AE conditions had greater improvements than the NORM conditions for reactive stretch index modified (RSImod), surpassing the TE values with small to moderate ES changes (Table 3).

****INSERT FIGURE 2 HERE****

Peak braking force (TE = 75.90 N) the AEDC (2329.95 ± 424.36 N) was significantly greater than the NORMDC (2188.49 ± 391.74 N; $p < 0.01$; ES = 0.34 (-0.28, 0.96) and NORMDP (2200.36 ± 409.84 N; $p < 0.01$; ES = 0.30 (-0.32, 0.93). Similarly, the AEDP (2319.74 ± 417.75 N) was significantly greater than both NORMDC ($p = < 0.01$, ES = 0.32 (-0.31, 0.94) and NORMDP ($p = < 0.01$, ES = 0.28 (-0.34, 0.91). Both AEDC and AEDP conditions exceeded the TE value, there was no significant difference between AE protocols ($p \geq 0.05$, ES = 0.02 (-0.60, 0.64) and NORM protocols ($p \geq 0.05$, ES = -0.03 (-0.65, 0.59)) (Figure 2).

****INSERT FIGURE 3 HERE****

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328 For mean braking force (TE = 70.22 N), findings indicated both AEDC (1843.35 ± 322.25 N)
329 and AEDP (1826.84 ± 308.46 N) were significantly greater than NORMDC (1701.45 ± 305.37
330 N, $p \leq 0.01$, ES = 0.44 (-0.18, 1.07), $p \leq 0.01$, ES = 0.40 (-0.23, 1.03), respectively) and
331 NORMDP (1695.81 ± 309.21 N) ($p \leq 0.01$, ES = 0.46 (-0.17, 1.09, $p \leq 0.01$, ES = 0.42 (-0.21,
332 1.04), respectively), and exceeding TE scores. No significant difference was observed between
333 the AE ($p > 0.50$, ES = 0.05 (-0.57, 0.67) and NORM ($p > 0.50$, ES = 0.02 (-0.60, 0.64)
334 conditions (Figure 3).

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AE conditions resulted in significantly greater impulse and peak braking velocity, surpassing the TE scores with (Table 4), impulse achieved small – moderate ES and peak velocity scored moderate – large ES changes. Mean braking velocity, the AE conditions were significantly greater than NORMDC and NORDP, surpassing the TE and moderate – large ES. For force at minimal displacement AE conditions were significantly greater than NORM, with small ES. Landing impulse had no significant difference and trivial ES for all conditions. Both AE conditions had a significant increase in peak propulsion force than NORM conditions with small ES, surpassing the TE values. The AEDC has a significant increase in mean propulsion force compared to all other conditions with trivial ES, however, the AEDC to not surpass the AEDP TE score. Findings in Table 4 showcase that when presented as an average an instructed DC strategy creates greater peak and mean landing forces during a CMJ landing.

The AE protocols had significantly greater mean and peak braking power as well as mean propulsion power (Table 5) than the NORM conditions where mean and peak braking power had moderate ES changes and mean propulsion power had trivial ES. However, no significant difference was found between the groups in terms of peak propulsion power.

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DISCUSSION

This study compared AE and controlled landing cues outlined by Handford et al. (20) to assess whether AE cues generate a greater eccentric stimulus. It was hypothesized that AE cues would result in greater peak braking velocity, leading to increased braking force in reduced time (larger braking impulse) than the NORM conditions. Results confirmed the hypothesis, showing significant increases in both peak and mean braking force and a significant reduction in braking phase time during the AE conditions. It's worth noting the AEDC condition exhibited significantly less depth displacement compared to AEDP and NORMDP. Increased depth displacement in a CMJ can contribute to a greater propulsion impulse and, consequently, higher jump heights (47,48). Moreover, displacement depth can influence variables like time to take-off, as greater displacement typically increases contact time (30). However, it's important to acknowledge the AEDC did not exceed the TE value of AEDP and NORMDP conditions (Table 3) and jump height was the same for all conditions. Therefore, while these conditions can be compared, readers should exercise caution when interpreting certain results.

Braking (eccentric) actions typically involve greater forces than propulsion (concentric) actions (16,46). This physiological phenomenon is harnessed in training methods like flywheel training or AEL to achieve more significant improvements such as strength and hypertrophy compared to isoinertial training (50). These methods require specialised equipment (20,54). Our results exhibit greater braking force can be simply achieved by providing specific cues and is in line with the work of Verkhoshansky and Siff (52), who commented that, as dictated by the impulse-momentum relationship, greater downward momentum requires larger braking forces (or more time) to decelerate and stop a body in motion (19,20). This theory is substantiated by the findings in the current study, where the increase in peak braking velocity, indicates negative acceleration (5,6,12). This relationship suggests that greater unweighting results in a larger downward momentum (12,30). Superior downward momentum necessitates larger braking

forces if braking phase time is the same, as demonstrated by both peak and mean braking forces (Figure 2 and 3). Though there were some differences between depth displacement between the DC and DP conditions, participants were required to generate more force within a shorter time frame (Figure 2 and 3 and Table 3). The AE conditions significantly reduced the braking phase time compared to the NORM condition, findings supported by Krzyszkowski et al. (29). The AE cues utilised a larger impulse that consisted of larger forces over shorter durations, which replicates the demands of sporting motions better than traditional tempo methods as discussed in (23). Consequently, this approach aligns with deceleration tasks that demand rapid braking force development within short time frames (23,37). It can be concluded that AE cues successfully generate this effect, thereby affirming the concepts of Verkhoshanky and Siff (52) and Handford et al. (19,20).

The application of larger braking forces in AE trials resulted in a significant increase in force at minimal displacement (Table 4). This greater force, in turn, led to significantly higher peak propulsion force in the AE trials compared to the NORM trials, as well as greater mean propulsion force in the AEDC condition compared to the other conditions. These findings are consistent with previous AEL research (32,42,53), which could impact other exercises such as a back squat or bench press. AE methods have the potential to enhance both eccentric and concentric forces, resulting in increased concentric velocity and, subsequently, power (Table 5) (12,19). The observed increase in force at minimal displacement indicates a greater SSC (12). This occurrence is likely attributed to the recruitment of type IIx muscle fibres or enhanced neural drive. Notably, larger eccentric forces can be generated by muscles compared to isometric and concentric actions, and this study demonstrates this can be achieved without external equipment. Research on antagonist conditioning has shown that performing actions within a 1 - 2 s timeframe results in greater RFD, although EMG maximum output remains unchanged when compared to slower tempos (5-10 s) (27). This effect is further supported by

previous research (18) and is thought to stem from increased neural activation of motor discharge rate (17).

The significant reduction in propulsion phase time during the AE conditions compared to the NORM conditions aligns with the greater RFD observed (Table 6) during the propulsion phase, with both peak and mean force values being higher (Figure 2 and 3). The higher peak and mean braking velocity in the AE condition is consistent with IKD research and discussions in (19) which suggest that eccentric forces increase with velocity. Another potential mechanism is neural intent (33) as described by Cronin et al. (13), where the intent to move explosively positively impacts velocity values (12). The current cue of maximal braking could correlate with this, as participants are instructed to decelerate and stop maximally, in agreement with observations by Bright et al. (9), where flywheel training also emphasises a maximal braking strategy to increase eccentric force output. These findings further support the notion of antagonist conditioning leading to greater agonist faster force production and its connection to SSC research, indicating the need for further investigation in this area.

The AE conditions significantly reduced time to take-off, resulting in small to moderate ES. However, it is worth noting the AE conditions did not surpass the NORMDC TE score. These results suggest that enhanced braking and propulsion forces can be achieved in significantly less time, aligning with the demands of sporting actions, as reflected in the RSImod scores (Table 3). This indicates the successful implementation of a more pronounced impulse strategy where greater braking forces in AE conditions leads to quicker deceleration rates, in line with a higher braking RFD than compared to the NORM conditions (33). These findings are consistent with the work of Oliveira et al. (43) who found that fast eccentric actions resulted in greater increases in early (< 100 ms) eccentric RFD. It is essential to highlight that AE methods exhibit shorter braking phases compared to traditional tempo research, as discussed by Handford et al. (20) where AE lengthens the unweighting phase time to increase downward

momentum (19). This observation emphasises that performing the downward phase does not necessarily mean an eccentric (braking) muscle action is occurring but rather muscle lengthening with in active braking (20) but rather muscle lengthening with no deceleration can also occur.

It is worth noting the control cue (NORM) in athletic performance testing, places constraints on jumping as high and fast as possible. This study hypothesizes if the current AE cue were compared to temporal timeframes such as 1 – 3 s durations commonly used in practice (21) and studied (15,51,55), we might observe even more substantial responses than those found in the current study. Handford et al. (19) emphasised that eccentric tempos of 1 s vs 3 s led to greater concentric velocity possibly due to a heightened SSC response. The current study's findings may further support this notion, given the increased range of motion and system mass (including body mass and additional mass like barbells). Moreover, research by Wilk et al. (55,56) demonstrated that higher 1RM were achieved with 2 s and voluntary tempos against a 4 and 6 s tempo (19) suggesting AE might align with this concept in exercises such as bench press or back squat. This agrees with speculation by Douglas et al. (15) that faster eccentric actions could yield more significant responses with areas such as strength and force production (19,20).

The current study further aimed to evaluate the impact of landing cues discussed by Handford et al. (20), specifically focusing on deceleration and dissipating eccentrics. Reliability testing identified the only acceptable landing metric was landing impulse, which is to be expected. The same impulse strategy required for propelling a mass is also necessary for deceleration during the landing phase (49), as supported by Lake et al. (31). These results raise questions about the reliability of incorporating landing metrics. Deceleration and dissipating eccentric actions lead to variations in subsequent landing force (Table 6) It is important for readers to note that while utilising deceleration and dissipating eccentric actions outlined by Handford et

al. (20), can lead to changes in subsequent landing metrics, the results can exhibit unreliable findings and as such caution must be taken when interpreting information.

The limitation of this study were that the AE protocol was not compared to tempo durations, such as 3 s eccentric tempo instead of the NORM cue, which may have been more suitable for CMJ testing. However, the results in the current study may yield different outcomes when compared to the 3 s tempo, as the longer tempo duration allows for more time during the braking phase or if adding additional load causes any differences in performance. Furthermore, another limitation was that participants performed repeated testing sessions at various time difference from ≥ 1 to 48 hours which could result in less confidence within the reliability results.

In addition to the formulated discussion, Table 6 highlights the metrics used in the current study and how these correlate with other metrics that can either be certified by past research or basic biomechanical understanding. This is an attempt to tell the story of the jump through a reduced number of metrics. Subsequently, if there is a decrease or increase in one metric others would likely alter. Therefore, there is no need to analyze this metric, i.e. an increase in peak braking velocity results in a longer unweighting phase (5,6). Future research should investigate the effects of AE cues in exercises like back squats and bench press to determine if similar outcomes can be observed. Additionally, it is crucial to conduct chronic training studies to assess the specific impact of AE cues on metrics such as braking RFD. Coaches can utilise AE techniques to enhance metrics like braking RFD and implement a larger braking impulse strategy during strength.

****INSERT TABLE 6 HERE****

PRACTICAL APPLICATIONS

These findings are valuable for strength and conditioning coaches aiming to improve athletes' rapid deceleration and COD ability. Incorporating AE cues during plyometric exercises like CMJs may boost braking force during the eccentric phase. Cues such as “brake hard” or “focus on stopping quickly” could help athletes generate more force in less time, enhancing COD and acceleration (19, 23). AE cues could be introduced during the specific preparation phase of a periodized training plan, targeting deceleration and COD skills. As athletes progress, the cues can be adapted for more advanced drills, such as depth jumps. A typical session might start with unloaded drop jumps using AE cues, progressing to loaded variations (e.g., weight vests) to increase the braking challenge under fatigue. Practitioners can measure improvement by tracking the time to take off via video analysis or force plates, aiming for reduced ground contact time and increased peak braking forces, which indicate successful adaptation to AE cue training.

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Figure 1

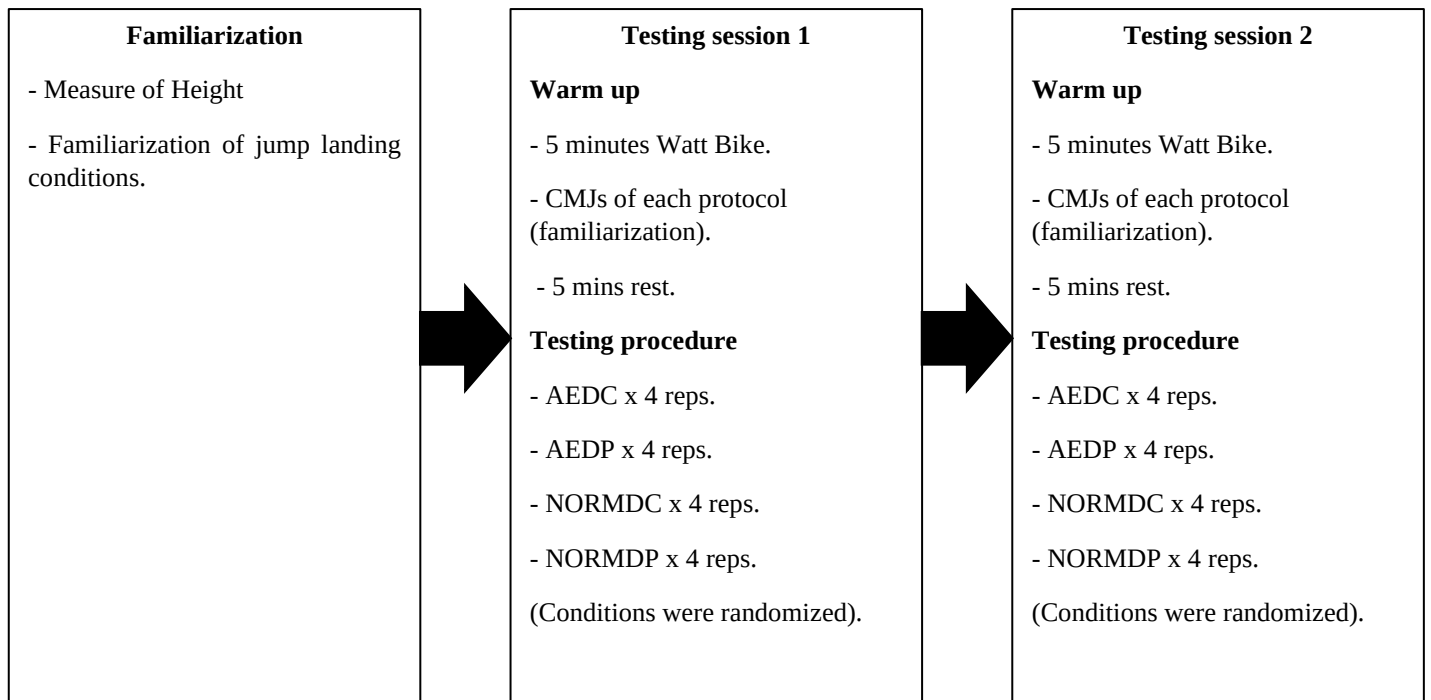


Figure 1: Testing procedure of the experimental study, **Key:** **AEDC:** Accelerated eccentric deceleration eccentric, **AEDP:** Accelerated eccentric dissipating eccentric, **CMJ:** Countermovement jump, **NORMMDC:** Normal deceleration eccentric, **NORMDP:** Normal dissipating eccentric.

Figure 2

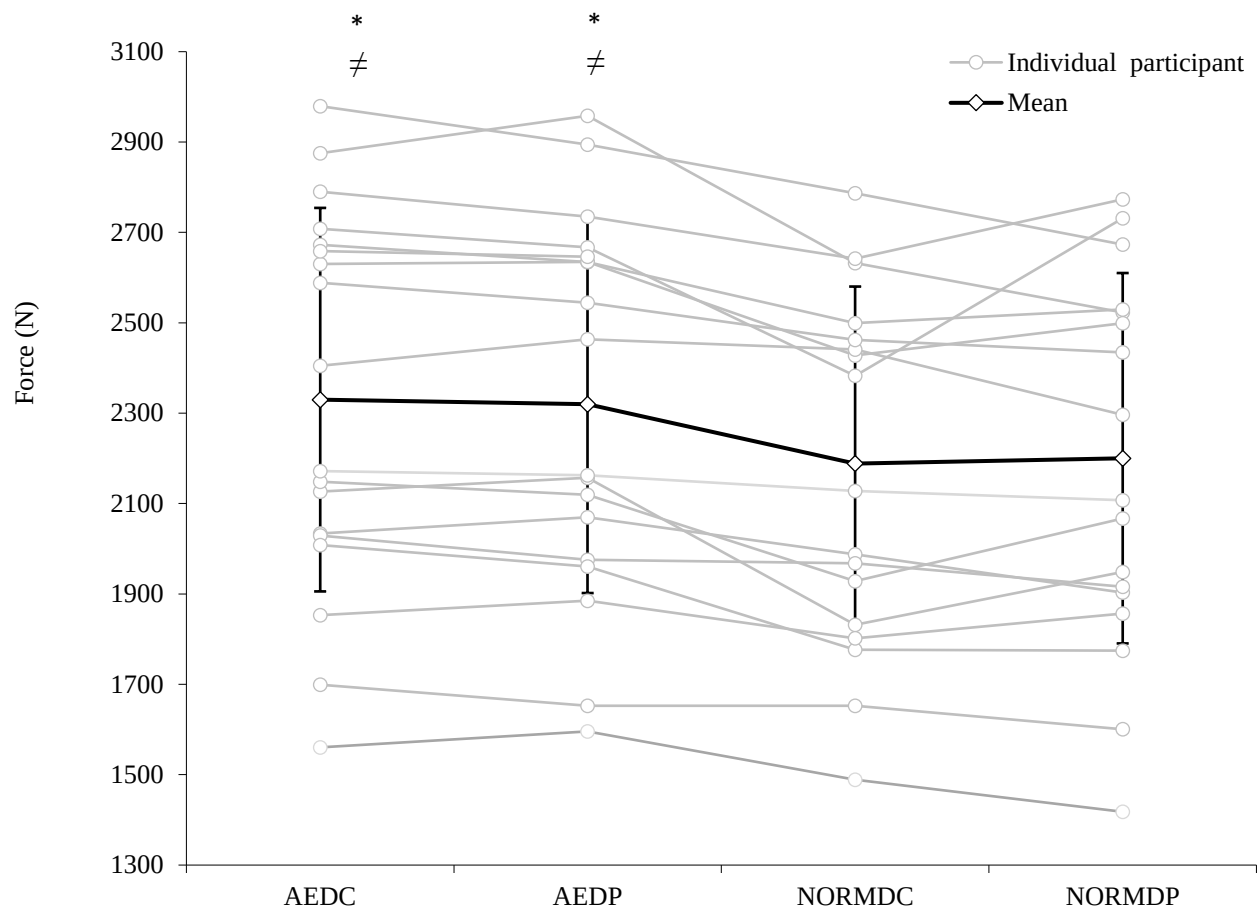


Figure 2: Shows the peak braking force during all conditions. *: $p < 0.05$ than NORMDC, ≠: $p < 0.05$ than NORMDP.

Figure 3

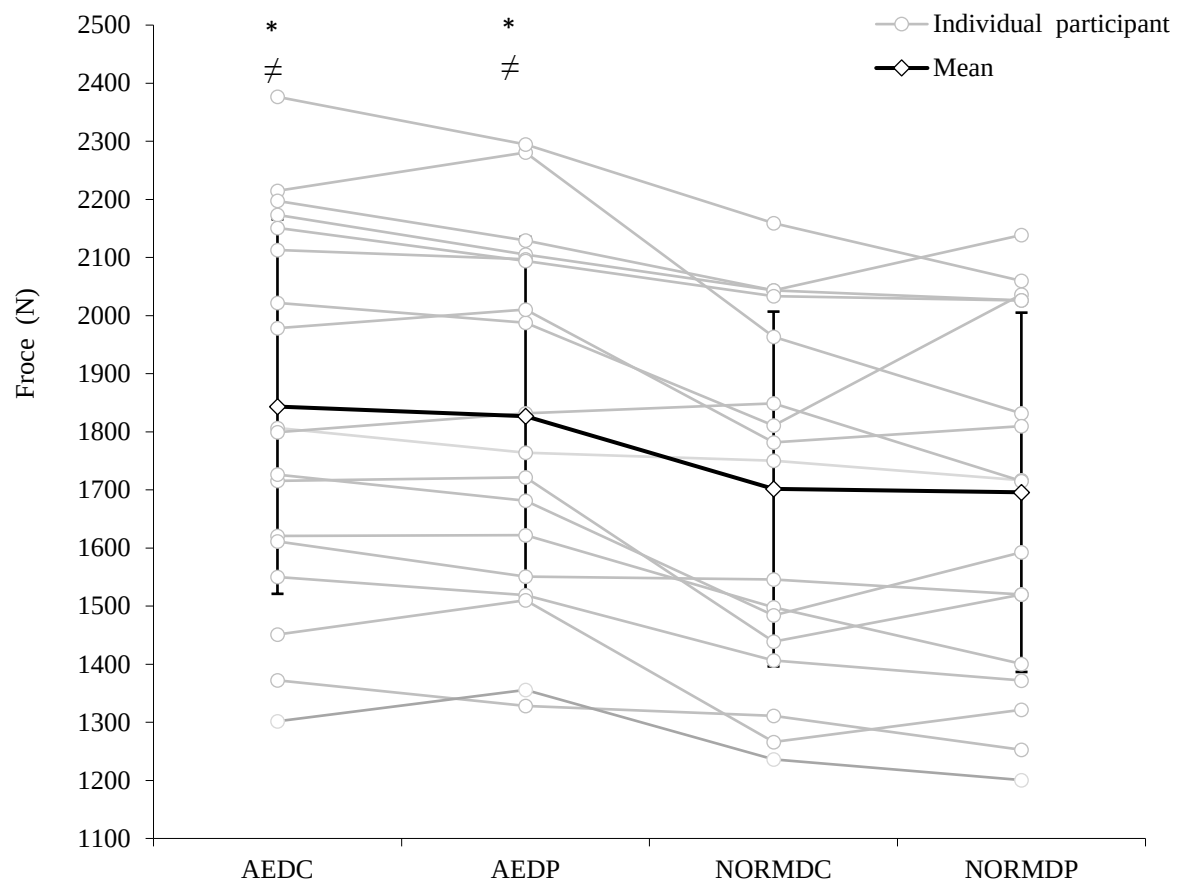


Figure 3: Shows the mean braking force during all conditions. *: $p < 0.05$ than NORMDC, ≠: $p < 0.05$ than NORMDP.

Table 1

Table 1: Accelerated eccentric jumping cues used in study.

Conditions	Coach to athlete cue	Coach to coach cue	Explanation
AEDC	“Fast downward phase	The aim is unloaded	The aim of this cue is to perform the
AEDP	with a maximum braking and then decelerate downward phase as quickly as and then jump high and as quickly and possible, however, an intent to fast” “Drop, Stop and Jump as high and fast as possible”. “Downward phase as quickly as possible, hit the brakes hard and jump high and fast”	forcibly as possible. Then to jump as high and fast as possible.	decelerate as quickly as possible and do this with maximum effort. Once a person has decelerated, they perform a maximum jump. This is all performed in one motion.

Key: **AEDC**: Accelerated eccentric deceleration eccentric landing, **AEDP**: Accelerated eccentric dissipating eccentric.

Table 2

Table 2: Landing strategies descriptions.

Condition	Coach to athlete cue	Coach to coach cue	Explanation
AEDC	“Upon landing	Land stiff and aim to	Deceleration eccentrics: dictates an impact
NORMDC	decelerate as quickly as possible”. “Stick the landing” “Hard landing”	decelerate your body as quickly as possible. Aim to have as minimal flexion of the knee and hip joint as possible.	where the aim is to decelerate and stop the mass in motion as quickly as possible performing a stiff landing (minimal knee and hip displacement).
AEDP	“Upon landing	Perform a soft landing	Dissipating eccentrics dictates an impact
NORMDP	decelerate and stop when you want”. “Absorb the floor” “Soft land”	and have flexion at the knee and hip joint.	whereby the aim to perform a soft landing (increased knee and hip displacement) where the individual aims to decelerate and stop on a voluntary basis.

Key: **AEDC**: Accelerated eccentric deceleration eccentric landing, **AEDP**: Accelerated eccentric dissipating eccentric, **NORMDC**: Normal deceleration eccentric landing, **NORMDP**: Normal dissipating eccentric landing.

Table 3

Table 3: Mean values and statistical data of jump height, system weight, depth displacement, phase time and RSImod between conditions.

Metric	Condition	Mean (SD)	TE	P			ES (CI ₉₅)		
				vs AEDP	vs NORMDC	vs NORMDP	vs AEDP	vs NORMDC	vs NORMDP
Jump height (m)	AEDC	0.383 (0.060)	0.01	> 0.05	> 0.05	> 0.05	-0.05 (-0.67, 0.57) Trivial (Mod-Mod)	-0.12 (-0.74, 0.50) Trivial (Mod-Mod)	-0.05 (-0.67, 0.57) Trivial (Mod-Mod)
	AEDP	0.380 (0.057)	0.01		> 0.05	> 0.05		-0.07 (-0.69, 0.55) Trivial (Mod-Mod)	0.00 (-0.62, 0.62) Trivial (Mod – Mod)
	NORMDC	0.375 (0.057)	0.01			> 0.05			0.07 (-0.55, 0.69) Trivial (Mod-Mod)
	NORMDP	0.380 (0.057)	0.01						
System weight (N)	AEDC	853.66 (120.07)	3.14	> 0.05	> 0.05	> 0.05	0.00 (-0.62, 0.62) TI (Mod-Mod)	0.00 (-0.62, 0.62) Trivial (Mod-Mod)	0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	AEDP	853.90 (120.10)	2.99		> 0.05	> 0.05		0.00 (-0.62, 0.62) Trivial (Mod-Mod)	0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDC	853.85 (120.06)	3.18			> 0.05			0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDP	854.86 (120.19)	6.43						
Depth displacement (m)	AEDC	-0.34 (0.03)	0.01	< 0.05	> 0.05	< 0.05	0.33 (-0.30, 0.95) Small (Small-Large)	0.00 (-0.62, 0.62) Trivial (Mod-Mod)	0.33 (-0.30, 0.95) Small (Small-Large)
	AEDP	-0.35 (0.03)	0.01		> 0.05	> 0.05		-0.28 (-0.90, 0.35) Small (Small-Large)	0.00 (-0.62, 0.62) Trivial (Mod-Mod)
	NORMDC	-0.34 (0.04)	0.01			> 0.05			0.28 (-0.35, 0.90)

									Small (Large-Small)
	NORMDP	-0.35 (0.03)	0.01						
Braking phase (s)	AEDC	0.143 (0.011)	0.005	> 0.05	< 0.01	< 0.01	0.30 (-0.33, 0.92) Small (Small-Large)	0.92 (0.27, 1.57) Large (Small-Large)	1.14 (0.47, 1.81) Large (Small-Large)
	AEDP	0.147 (0.015)	0.007		< 0.01	< 0.01		0.59 (-0.04, 1.23) Mod (Small-Large)	0.76 (0.12, 1.40) Mod (Trivial-Large)
	NORMDC	0.157 (0.018)	0.010			> 0.05			0.12 (-0.51, 0.74) Trivial (Mod-Mod)
	NORMDP	0.159 (0.016)	0.009						
Time to take-off (s)	AEDC	0.722 (0.056)	0.032	> 0.05	< 0.01	< 0.01	0.08 (-0.54, 0.70) Trivial (Mod-Mod)	0.47 (-0.16, 1.10) Smal (Trivial- Large)	0.71 (0.07, 1.35) Mod (Trivial-Large)
	AEDP	0.727 (0.060)	0.040		< 0.05	< 0.01		0.38 (-0.25, 1.00) Small (Small-Large)	0.62 (-0.01, 1.26) Mod (Trivial-Large)
	NORMDC	0.751 (0.065)	0.032			> 0.05			0.26 (-0.37, 0.88) Small (Small-Small)
	NORMDP	0.769 (0.072)	0.041						
Propulsion phase (s)	AEDC	0.257 (0.020)	0.005	< 0.01	< 0.01	< 0.01	0.27 (-0.35, 0.90) (Small (Small- Large)	0.40 (-0.23, 1.03) Small (Small-Large)	0.55 (-0.08, 1.18) Mod (Trivial-Large)
	AEDP	0.263 (0.023)	0.009		> 0.05	< 0.01		0.13 (-0.50, 0.75) Trivial (Mod-Mod)	0.28 (-0.34, 0.90) Small (Small-Large)
	NORMDC	0.266 (0.024)	0.008			> 0.05			0.16 (-0.46, 0.78) Trivial (Small-Mod)

	NORMDP	0.270 (0.026)	0.012						
	AEDC	0.54 (0.09)	0.02	> 0.05	< 0.01	< 0.05	-0.11 (-0.73, 0.51) Trivial (Mod-Mod)	-0.46 (-1.09, 0.17) Small (Large-Trivial)	-0.44 (-1.06, 0.19) Mod (Large-Trivial)
RSImod	AEDP	0.53 (0.09)	0.03		< 0.05	> 0.05		-0.35 (-0.97, 0.28) Small (Large-Trivial)	-0.33 (-0.95, 0.30) Small (Large-Trivial)
	NORMDC	0.50 (0.08)	0.02			> 0.05			0.00 (-0.62, 0.62) Trivial (Mod-Mod)
	NORMDP	0.50 (0.09)	0.03						

Key: **AEDC**: Accelerated eccentric deceleration eccentric landing, **AEDP**: Accelerated eccentric dissipating eccentric landing, **ES**: Effect size, **m**: meters, **Mod**: Moderate, **N**: Newtons, **NORMDC**: Normal deceleration eccentric landing, **NORDP**: Normal dissipating eccentric landing, **P**: P-value, **RSImod**: Reactive strength index, **s**: Seconds, **SD**: Standard deviation, **TE**: Typical error.

Table 4

Table 4: Mean values and statistical data of both impulse, velocity and force findings between conditions.

Metric	Condition	Mean (SD)	TE	P			ES (CI ₉₅)		
				vs AEDP	vs NORMDC	vs NORMDP	vs AEDP	vs NORMDC	vs NORMDP
Braking net impulse (N.s)	AEDC	139.33 (24.13)	4.18	> 0.05	< 0.01	< 0.01	-0.01 (-0.63, 0.60) Trivial) Mod-Mod)	0.38 (-0.24, 1.01) Small (Small-Large)	0.35 (-0.27, 0.98) Small (Small-Large)
	AEDP	139.69 (22.94)	3.73		< 0.01	< 0.01		0.41 (-0.22, 1.03) Small (Small-Large)	0.38 (-0.25, 1.00) Small (Small-Large)
	NORMDC	129.84 (24.58)	5.68			> 0.05			-0.03 (-0.65, 0.59) Trivial) Mod-Mod)
	NORMDP	130.63 (24.28)	6.06						
Peak braking velocity (m·s ⁻¹)	AEDC	-1.60 (0.10)	0.05	> 0.05	< 0.01	< 0.01	0.10 (-0.52, 0.72) Trivial (Mod-Mod)	-0.77 (-1.41, -0.13) Mod (Large-Small)	-0.81 (-1.45, -0.16) Large (Large-Small)
	AEDP	-1.61 (0.10)	0.04		< 0.01	< 0.01		-0.85 (-1.49, -0.20) Large (Large-Small)	-0.89 (-1.54, -0.24) Large (Large-Small)
	NORMDC	-1.50 (0.15)	0.07			> 0.05			0.00 (-0.62, 0.62) Trivial (Mod-Mod)
	NORMDP	-1.50 (0.14)	0.07						
Mean braking velocity (m·s ⁻¹)	AEDC	-1.00 (0.06)	0.02	> 0.05	< 0.01	< 0.01	0.16 (-0.46, 0.78) Trivial (Mod-Mod)	-0.69 (-1.33, -0.05) Mod (Large-Small)	-0.60 (-1.24, 0.03) Mod (Large-Trivial)
	AEDP	-1.01 (0.06)	0.03		< 0.01	< 0.01		-0.83 (-1.48, -0.18) Large (Large-Trivial)	-0.75 (-1.39, -0.11) Mod (Large-Trivial)

	NORMDC	-0.95 (0.08)	0.04			> 0.05			0.13 (-0.49, 0.75) Trivial (Mod-Mod)
	NORMDP	-0.96 (0.07)	0.04						
Force at minimal displacement (N)	AEDC	2309.33 (428.42)	45.89	> 0.05	< 0.01	< 0.01	0.02 (-0.60, 0.64) Trivial (Mod-Mod)	0.32 (-0.30, 0.95) Small (Mod-Mod)	0.29 (-0.34, 0.91) Small (Mod-Mod)
	AEDP	2298.91 (421.64)	56.45		< 0.01	< 0.01		0.30 (-0.32, 0.92) Small (Mod-Mod)	0.26 (-0.36, 0.89) Small (Mod-Mod)
	NORMDC	2174.30 (394.44)	71.62			> 0.05			-0.03 (-0.65, 0.59) Trivial (Mod-Mod)
	NORMDP	2187.00 (408.61)	66.84						
Peak propulsion force (N)	AEDC	2311.69 (429.90)	45.11	> 0.05	< 0.01	< 0.01	0.02 (-0.60, 0.64) Trivial (Mod- Mod)	0.26 (-0.36, 0.88) Small (Mod-Mod)	0.26 (-0.36, 0.88) Small (Mod-Mod)
	AEDP	2301.91 (423.96)	55.68		< 0.01	< 0.01		0.24 (-0.38, 0.86) Small (Mod-Mod)	0.24 (-0.38, 0.86) Small (Mod-Mod)
	NORMDC	2201.49 (394.25)	62.28			> 0.05			0.00 (-0.62, 0.62) Trivial (Mod-Mod)
	NORMDP	2200.89 (410.36)	63.96						
Mean propulsion force (N)	AEDC	1792.48 (315.74)	20.18	< 0.05	< 0.01	< 0.01	0.06 (-0.56, 0.68) Trivial (Mod-Mod)	0.12 (-0.50, 0.75) Trivial (Mod-Mod)	0.15 (-0.48, 0.77) Trivial (Mod-Mod)
	AEDP	1772.00 (311.37)	29.97		> 0.05	> 0.05		0.06 (-0.56, 0.68) Trivial (Mod-Mod)	0.08 (-0.54, 0.70) Trivial (Mod-Mod)
	NORMDC	1753.27 (301.00)	21.37			> 0.05			0.02 (-0.60, 0.64) Trivial (Mod-Mod)

	NORMDP	1746.53 (303.18)	42.42						
	AEDC	247.57 (43.07)	4.35	> 0.05	> 0.05	> 0.05	0.01 (-0.61, 0.63) Trivial (Mod-Mod)	0.01 (-0.61, 0.63) Trivial (Mod-Mod)	0.01 (-0.61, 0.63) Trivial (Mod-Mod)
Landing impulse (N.s)	AEDP	245.56 (41.67)	3.49		> 0.05	> 0.05		0.01 (-0.60, 0.63) Trivial (Mod-Mod)	0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDC	244.93 (41.13)	4.82			> 0.05			-0.01 (-0.63, 0.61) Trivial (Mod-Mod)
	NORMDP	245.33 (40.32)	3.84						
	AEDC	5417.72 (1706.65)							
Peak landing force (N)	AEDP	4396.77 (1732.52)							
	NORMDC	5373.85 (1732.52)							
	NORMDP	4525.72 (1185.10)							
	AEDC	2042.45 (417.49)							
Mean landing force (N)	AEDP	1627.60 (243.61)							
	NORMDC	1985.13 (378.83)							
	NORMDP	1651.34 (232.52)							

Key: **AEDC**: Accelerated eccentric deceleration eccentric landing, **AEDP**: Accelerated eccentric dissipating eccentric landing, **ES**: Effect size, **m·s⁻¹**: Meters per seconds, **N**: Newtons, **NORMDC**: Normal deceleration eccentric landing, **NORMDP**: Normal dissipating eccentric landing, **N**: Newtons, **N.s**: Newton seconds, **P**: P-value, **SD**: Standard deviation, **TE**: Typical error.

Table 5

Table 5: Mean values and statistical data of mean and peak braking and propulsion power between conditions.

Metric	Condition	Mean (SD)	TE	P			ES (CI ₉₅)		
				vs AEDP	vs NORMDC	vs NORMDP	vs AEDP	vs NORMDC	vs NORMDP
Mean braking power (W)	AEDC	-1659.17 (339.35)	71.26	> 0.05	< 0.01	< 0.01	-0.02 (-0.64, 0.60) Trivial (Mod-Mod)	-0.59 (-1.23, 0.04) Mod (Trivial – Large)	-0.57 (-1.21, 0.06) Mod (Trivial-Large)
	AEDP	-1651.67 (326.48)	76.72		< 0.01	< 0.01		-0.58 (-1.22, 0.05) Mod (Trivial – Large)	-0.56 (-1.20, 0.07) Mod (Trivial-Large)
	NORMDC	-1457.70 (326.48)	99.34			> 0.05			0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDP	-1462.35 (332.17)	106.05						
Peak braking power (W)	AEDC	-2378.21 (517.02)	155.81	> 0.05	< 0.01	< 0.01	-0.07 (-0.69, 0.55) Trivial (Mod-Mod)	-0.69 (-1.33, -0.05) Mod (Trivial–Large)	0.69 (-1.33, -0.05) Mod (Trivial-Large)
	AEDP	-2344.81 (468.50)	130.83		< 0.01	< 0.01		-0.66 (-1.30, -0.02) Mod (Trivial–Large)	-0.66 (-1.29, -0.02) Mod (Trivial-Large)
	NORMDC	-2021.54 (491.52)	161.30			> 0.05			0.00 (-0.62, 0.62) Trivial (Mod-Mod)
	NORMDP	-2023.31 (491.22)	174.22						
Mean propulsion power (W)	AEDC	2754.22 (601.55)	47.33	> 0.05	< 0.01	< 0.01	0.07 (-0.55, 0.69) Trivial (Mod-Mod)	0.18 (-0.44, 0.80) Trivial (Mod- Large)	0.16 (-0.46, 0.78) Trivial (Mod-Mod)
	AEDP	2713.70 (579.94)	72.17		< 0.01	> 0.05		0.11 (-0.51, 0.73) Trivial (Mod-Mod)	0.10 (-0.52, 0.72) Trivial (Mod-Mod)

Peak propulsion power (W)	NORMDC	2648.33 (545.85)	60.03			> 0.05			0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDP	2656.72 (566.78)	89.46						
	AEDC	4711.44 (1052.87)	89.45	> 0.05	> 0.05	> 0.05	0.04 (-0.58, 0.66) Trivial (Mod-Mod)	0.04 (-0.58, 0.66) Trivial (Mod-Mod)	0.05 (-0.57, 0.67) Trivial (Mod-Mod)
	AEDP	4670.41 (1013.89)	75.17		> 0.05	> 0.05		0.00 (-0.62, 0.62) Trivial (Mod-Mod)	0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDC	4669.67 (993.47)	110.81			> 0.05			0.01 (-0.61, 0.63) Trivial (Mod-Mod)
	NORMDP	4658.64 (984.98)	116.69						

Key: **AEDC**: Accelerated eccentric deceleration eccentric landing, **AEDP**: Accelerated eccentric dissipating eccentric landing, **ES**: Effect size, **NORMDC**: Normal deceleration eccentric landing, **NORMDP**: Normal dissipating eccentric landing, **P**: P-value, **SD**: Standard deviation, **TE**: Typical error, **W**: Watts.

Table 6

Table 6: Correlation of CMJ metrics that have a subsequent effect on surrogate metrics.

Combined metrics	Subsequent result
Increase in force and velocity values	There will be an increase in power, as power is calculated as a product of force and velocity.
Jump height and time to take-off	An increase of both or with no change in one and an increase in the other will lead to a greater RSI _{mod} value.
Increase in depth displacement	Irrespective of time if depth displacement is greater between groups, then duration will also likely be increased.
Increase in peak braking velocity	If there is an increase in peak braking velocity, this is indicative of a greater unweighting phase. As unweighting if force below BW this represents negative acceleration (no deceleration) thus peak velocity will be higher as a person is not decelerating the COM velocity.
Braking net impulse	Unweighting impulse: the more someone unloads the greater their acceleration meaning the greater the braking force must be. Peak braking velocity: A larger braking impulse would stem from a greater unweighting impulse (faster and greater unloading), meaning a greater peak braking velocity.
Increase in force at minimal displacement	An increase in force at minimal displacement is indicative of a greater SSC response and enhances propulsion force.

Key: **BW**: Bodyweight, **COM**: Centre of mass, **RSI_{mod}**: Reactive strength index modified, **SSC**: Stretch shortening cycle,