

Delayed effects of post-activation performance enhancement using flywheel resistance versus traditional free weight protocols on countermovement jump and 10-m sprint performance

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Abstract:

This study examined the delayed effects of two post-activation performance enhancement (PAPE) protocols—traditional free-weight squats (TR) and flywheel isoinertial squats (FW)—on performance changes measured 48 h after intervention. Fourteen resistance-trained male athletes (age: 23.0 ± 1.5 years; height: 180.4 ± 6.6 cm; weight: 77.1 ± 6.9 kg) from five different sports completed both protocols in a non-synchronous crossover design. Each protocol involved 3 sets of 6 maximal squat repetitions. The TR protocol was performed at each participant's individual power maximum (mean load: $114.3 \pm \text{kg}$; Pmax: $957.7 \pm \text{W}$), while the FW protocol used isoinertial loading with a mean inertia of $0.117 \pm \text{kg} \cdot \text{m}^2$ (Pmax: $1060.6 \pm \text{W}$). Performance outcomes were assessed through 10-meter sprint and countermovement jump (CMJ) tests conducted at baseline and 48 hours after each intervention. The TR protocol led to a statistically significant improvement in 10-meter sprint time ($p = 0.022$, $d = 0.667$), whereas the FW protocol did not show significant changes ($p = 0.126$, $d = 0.420$). CMJ height significantly improved after both TR ($p = 0.001$, $d = 1.052$) and FW ($p = 0.004$, $d = 0.902$) protocols. No significant differences were found between protocols in either sprint or CMJ performance changes. Traditional resistance squats may elicit a delayed improvement in sprint acceleration 48 hours post-exercise, while both TR and FW protocols appear effective in enhancing vertical jump performance after the same recovery period. These findings suggest that properly structured PAPE interventions can lead to meaningful performance gains even beyond the typical acute window, highlighting their practical relevance for mid-term athletic planning.

Key Words: strength training, isoinertial resistance, activation, abilities

Introduction

Maximizing short-term and delayed neuromuscular performance is of central importance in competitive sport, where even small improvements may determine success. Beyond immediate warm-up effects, athletes and coaches seek strategies that can be deliberately scheduled to align with training microcycles or multi-day competitions. Therefore, understanding how preparatory interventions influence both acute and delayed performance has strong applied relevance. While warm-up protocols have long been recognized for their physiological and psychological benefits, more specific techniques such as Post-Activation Performance Enhancement (PAPE) have garnered growing attention for their ability to acutely enhance explosive output following high-intensity conditioning activities (Blazevich & Babault, 2019; Sale, 2002). PAPE is typically defined as the temporary increase in voluntary muscular performance following near-maximal or maximal voluntary contractions. Unlike the classical concept of Post-Activation Potentiation (PAP), which is measured via electrically evoked twitch responses, PAPE is assessed through performance-based outcomes such as jumps, sprints, or throws (Cuenca-Fernández et al., 2017; Tillin & Bishop, 2009).

Traditionally, the window for exploiting PAPE has been considered narrow—most studies report peak effects within 3 to 10 minutes after the conditioning activity (Trybulski et al., 2022; Vargas-Molina et al., 2021). However, emerging research challenges this short-term framework. In support of a prolonged PAPE effect, several studies have demonstrated that neuromuscular performance improvements may persist well beyond the typical acute window. For instance, Cook et al. (2014) and Sáez de Villarreal et al. (2007) reported significant increases in vertical jump height six hours after traditional free-weight resistance training. Similarly, Tsoukos et al. (2018) observed delayed potentiation effects in CMJ performance at both 24 and 48 hours following low-volume, high-intensity strength training (5×4 repetitions at 40% 1RM). Raastad and Hallén (2000) found improved jump performance 33 hours post-exercise using moderate loads (70% 1RM), suggesting that the delayed effects of PAPE are load-dependent and can extend beyond a full day. In contrast, high-volume protocols appear to induce fatigue that outweighs potentiation benefits. Ishida et al. (2023) reported decreased squat jump performance at 24 and 48 hours following a high-volume protocol (5×10 reps at 60% 1RM), highlighting how excessive training load can inhibit performance in the short term. Interestingly, Souza et al.

(2023) demonstrated that plyometric training (5×6 drop jumps from 52 cm with external load equal to 20% body mass) enhanced CMJ performance 24 to 48 hours post-intervention. In contrast, recent findings by Smoliga et al. (2025) indicate that although both traditional resistance and flywheel-based protocols significantly enhanced CMJ height within minutes after the intervention, these effects did not persist 24 hours later. This reinforces the notion that while acute potentiation is well established, its translation into delayed performance benefits is inconsistent and may strongly depend on protocol design.

Although the mechanisms behind these delayed effects remain unclear, hypotheses include long-lasting neural adaptations (Nuzzo et al., 2016), favorable muscle-tendon stiffness changes (Kubo et al., 2007), and residual metabolic upregulation, such as sustained elevations in intracellular calcium or enzyme activity (Docherty & Hodgson, 2007; Rassier & MacIntosh, 2000). This uncertainty reflects a key problem: despite promising evidence, knowledge about the time course of potentiation beyond the acute phase is fragmented and inconsistent. From a practical standpoint, this makes it difficult for coaches to plan training loads or competition tapering when delayed potentiation may interact with fatigue.

This line of inquiry raises important questions: could PAPE protocols be utilized not only for immediate competition preparation, but also strategically scheduled days in advance to align with competition peaks? And how does fatigue, which can linger for 24 to 72 hours following intense loading, interact with or obscure these delayed potentiation effects (T. C. Chen et al., 2007). Understanding the interplay between potentiation and fatigue is crucial for the practical application of PAPE. The timing of performance assessments relative to the conditioning activity is pivotal—if the interval is too short, fatigue may outweigh potentiation, whereas an appropriately longer recovery period appears to maximize performance benefits (Y. Chen et al., 2023). Moreover, the balance between potentiation and fatigue is influenced by individual characteristics such as strength level, training status, and the nature of the conditioning activity, which complicates the establishment of universal recommendations (Formiglio et al., 2024; Seitz et al., 2014; Sun et al., 2024).

Different modalities have been proposed to induce PAPE, including traditional resistance exercises and more novel methods such as flywheel-based isoinertial training. These approaches vary in their neuromechanical and metabolic demands, which could affect the timing and duration of the potentiation response (Beato & Dello Iacono, 2020). Some evidence even suggests that flywheel exercises may produce more sustained effects due to their eccentric overload component, although findings are mixed and highly context-dependent (Boullosa et al., 2020; Sun et al., 2024).

Taken together, the literature shows that while delayed potentiation is possible, its occurrence, magnitude, and practical utility remain poorly defined—particularly for explosive performance tasks. This gap in evidence is especially important for sports where athletes compete repeatedly within a short time frame, or where tapering strategies seek to maximize performance on a specific day. Despite growing interest, the literature lacks empirical data examining performance outcomes 48 hours after a CA, particularly in explosive tasks like sprinting and jumping.

To address this problem, the present study investigates the effects of two distinct CAs—traditional barbell back squats and flywheel squats—on vertical jump and sprint performance assessed 48 hours post-intervention. By directly comparing these modalities, the study aims to determine whether meaningful performance enhancements can be observed long after the CA. This approach not only expands the theoretical understanding of PAPE, but also provides applied insights for coaches seeking to integrate delayed potentiation into structured training and competition planning.

Material & methods

To examine the effects of two different resistance training protocols on neuromuscular performance, participants completed both a traditional resistance (TR) protocol using free weights and a flywheel resistance (FW) protocol involving iso-inertial loading. Prior to the main experimental sessions, all participants underwent a familiarization phase specific to the flywheel training. This phase consisted of three separate sessions (Sabido et al., 2018) each comprising 4 sets of 10 repetitions at a standardized inertial load of $0.079 \text{ kg} \cdot \text{m}^2$ (Smoliga et al., 2025). These familiarization sessions ensured technical proficiency and minimized any potential learning effect during testing. Only those who completed all three sessions were included in the subsequent analysis.

During the experimental phase, both protocols consisted of three sets of six maximal repetitions (3×6 ; 2 minutes rest between sets), which aligns with previous literature investigating post-activation performance enhancement (PAPE) protocols (Beato, de Keijzer, et al., 2021; Beato et al., 2019; Beato, Stiff, et al., 2021; McErlain Naylor & Beato, 2021; Timon et al., 2019). For FW protocol, we added 2 repetitions at half range and speed to ensure maximum power and speed output during the main 6 repetitions ($2 + 6$ repetitions per set) (Beato et al., 2023; Fu et al., 2023; Hall et al., 2024; Smoliga et al., 2025). The traditional resistance protocol involved a mean external load of $114.3 \pm 14.4 \text{ kg}$ and resulted in a mean peak power output (P_{max}) of $957.7 \pm 161.7 \text{ W}$. The flywheel protocol used a mean inertia of $0.117 \pm 0.013 \text{ kg} \cdot \text{m}^2$, with a corresponding mean P_{max} of $1060.6 \pm 188.1 \text{ W}$. Peak power was continuously recorded using a FITROdyne Premium (FiTRONiC s.r.o.) linear encoder, which provided real-time data and ensured load precision and maximal concentric effort across all repetitions. To evaluate the potential delayed effects of the two protocols on athletic performance, participants completed countermovement jump (CMJ) and 10-meter sprint tests 48 hours after completing each protocol.

This testing window was selected to explore residual performance changes commonly associated with PAPE, extending beyond the immediate acute response and offering practical relevance for athletic preparation.

Participants

Fourteen physically active male university students ($N = 14$) enrolled in a faculty of sports sciences participated in this study. Participants represented five distinct sport specializations: football ($n = 6$), ice hockey ($n = 2$), floorball ($n = 2$), calisthenics ($n = 2$), and cycling ($n = 2$). All participants met the inclusion criteria, which required the ability to perform a back squat with at least 1.5 times their body weight, a minimum of six months free from injury, and ongoing engagement in structured or competitive training within their respective sports. Prior to data collection, all participants were informed about the potential risks and benefits of the study, and each signed a written informed consent form in accordance with institutional ethical guidelines.

Procedure

Anthropometric data including body height (cm) and body mass (kg) were measured using a calibrated stadiometer (BSN170) and a precision scale (KERN MPI 200K-1S05). The knee joint angle for all squat repetitions was standardized at 90° , confirmed using a manual goniometer. To ensure consistent depth during the TR condition, a stable platform constructed from weightlifting boxes was used as a physical reference point in the bottom squat position. In the FW condition, a horizontal elastic expander was positioned at an individually adjusted height to assist in controlling the depth and eccentric phase without abrupt mechanical contact. Each testing session began with a dynamic warm-up consisting of 1 minute of jumping jacks, 1 minute of forward and backward jumps, followed by mobility and activation exercises: 5 bodyweight lunges per leg, 10 bilateral squats, 5 vertical countermovement jumps (without arm swing), and 5 unilateral forward bends targeting the hamstrings. The total warm-up duration was approximately 4 minutes, followed by a 2-minute passive recovery period before baseline testing. Participants then performed one of two conditioning protocols (TR or FW), each comprising 3 sets of 6 maximal squat repetitions with 2 minutes of rest between sets. The TR load was individualized to each participant's peak power output (P_{max}), while the FW protocol was set at an inertial level corresponding to the highest concentric velocity relative to P_{max} (Beato et al., 2019; Sañudo et al., 2020; Smoliga et al., 2025; Timon et al., 2019). Performance was assessed using a 10-meter sprint and countermovement jump (CMJ), both measured at baseline and 48 hours post-intervention. No additional testing occurred before the 48-hour timepoint. Participants were instructed to abstain from any physical activity during the 48-hour period to minimize confounding effects on neuromuscular performance outcomes.

Test protocol

Performance testing was conducted at two time points: baseline (pre-intervention) and 48 hours following each loading protocol (TR and FW). This design allowed for the evaluation of delayed neuromuscular responses potentially linked to post-activation performance enhancement (PAPE).

Countermovement jump (CMJ)

Height of CMJ was assessed using the OptoJump Next device (version 1.12.23). Participants were instructed to perform each jump with their hands placed on the hips to eliminate arm swing and standardize execution. Each participant completed three maximal-effort CMJs, separated by 30 seconds of passive rest. The average value of the three trials was calculated and used for statistical analysis. ICC was high (0,921; 95 % CI: 0,781-0,973).

10 meters sprint (10m)

Sprint performance was evaluated using a 10-meter linear sprint test, measured with dual-beam photocells Fitro Light Gates (FiTRONiC s.r.o.) to ensure high temporal accuracy. Participants started from a static upright position and were instructed to avoid any preparatory countermovement. Each participant completed three maximal-effort sprints, with 45 seconds of rest between trials. The mean sprint time across the three attempts was used for comparison. ICC was high (0,912; 95 % CI: 0,759-0,970).

Data collection and analysis

Testing procedures were conducted under standardized laboratory conditions to minimize variability. Prior to each session, participants completed a general warm-up followed by specific warm-up sets relevant to the upcoming protocol. During both the traditional resistance (TR) and flywheel resistance (FW) protocols, concentric peak power output (P_{max}) was recorded for every repetition using the linear encoder (FITROdyne Premium). The encoder was securely attached to the barbell during TR sessions and integrated with the flywheel axis during FW trials, ensuring accurate measurement of velocity and power output throughout the concentric phase of movement. Every participant performed 2 repetitions at each resistance throughout diagnostic series.

The resistance increased when peak power was higher comparing to previous repetition. If the peak power decreased, P_{max} was pointed on previous repetition, where peak power output was the highest from the resistance in diagnostic series (P_{max}). Data were exported and reviewed immediately following each session to ensure signal quality and identify any artifacts or outliers. The highest power output from each set was selected, and the average of the three peak values was used for statistical comparison. In both protocols, load parameters (kg for TR; $\text{kg}\cdot\text{m}^2$ for FW) and corresponding P_{max} values were collected. In addition to performance metrics obtained during the training protocols, countermovement jump (CMJ) height and 10-meter sprint time were recorded 48 hours post-intervention using dual-beam photocells (Fitro light Gates) and standardized procedures. This 48-hour window was chosen to assess any residual PAPE effects, rather than short-term fatigue-related fluctuations.

Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics (Version 27). Descriptive statistics were calculated for all variables, including mean and standard deviation. Prior to inferential testing, data normality was assessed using the Shapiro-Wilk test. Differences in peak power output between TR and FW protocols were analyzed using a paired-sample t-test, as each participant completed both conditions. Effect sizes (Cohen's *d*) were also calculated to determine the magnitude of differences between protocols. Additionally, performance outcomes in CMJ height and 10-meter sprint time were compared using paired t-tests to examine whether either intervention produced delayed performance improvements. Statistical significance was set at $p < 0.05$.

Results

Descriptive statistics and paired-sample analyses were used to examine the effect of the two resistance training protocols—flywheel isoinertial (FW) and traditional resistance (TR)—on sprint and jump performance measured 48 hours post-intervention.

Mean sprint time improved from 1.711 s to 1.691 s after 48 hours in the FW condition ($\Delta = 0.021$ s), and from 1.713 s to 1.681 s in the TR condition ($\Delta = 0.032$ s) (Table 1). The paired t-test indicated no statistically significant improvement in sprint performance in the FW protocol ($p = 0.126$), whereas the TR protocol showed a statistically significant improvement ($p = 0.022$) (Figure 1). Effect size analysis revealed a small effect for FW ($d = 0.420$) and a moderate effect for TR ($d = 0.667$). However, no statistically significant difference was observed when comparing the sprint differences between FW and TR ($p = 0.495$, $d = 0.181$) (Figure 1).

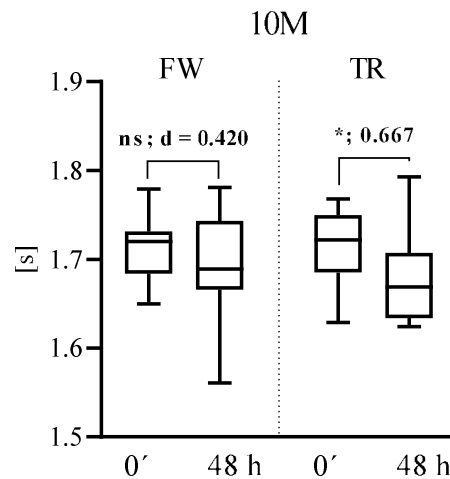


Figure 1 – 10-meter sprint performance; mean differences comparing between baseline and 48 hours post-PAPE protocol of FW or TR

The smallest worthwhile change (SWC) for sprint time was calculated as 0.008 s, and the standard error of measurement (SEM) was 0.013 s for both protocols. The mean change observed after TR protocol (0.032 s) exceeded the SWC, suggesting practical relevance (Table 1).

Table 1 – 10-meter sprint performance

Protocol	Baseline [s]	48 hours [s]	Δ Mean [s]	<i>p</i>	<i>d</i>	SWC [s]	SEM [s]
Flywheel (FW)	1.711 $\pm$ 0.04	1.691 $\pm$ 0.06	0.021 $\pm$ 0.05	0.126	0.420	0.008	0.013
Traditional Resistance (TR)	1.713 $\pm$ 0.04	1.681 $\pm$ 0.05 *	0.032 $\pm$ 0.05	0.022	0.667	0.008	0.013

In the FW protocol, mean CMJ height improved from 49.83 cm to 51.81 cm ($\Delta = 1.98$ cm), while in the TR protocol it increased from 50.20 cm to 51.86 cm ($\Delta = 1.66$ cm) (Table 2). Both changes were statistically significant in FW ($p = 0.004$) and TR ($p = 0.001$) (Figure 2).

Effect sizes indicated a large effect for both protocols (FW: $d = 0.902$; TR: $d = 1.052$). Despite similar improvements in jump height, no significant difference was found between the protocols in their effect on CMJ ($p = 0.828$, $d = 0.059$) (Figure 2).

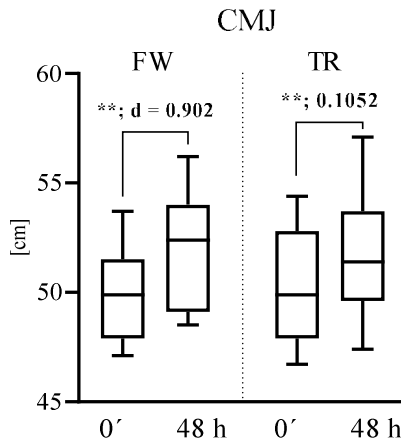


Figure 2 – Countermovement jump; mean differences comparing between baseline and 48 hours post-PAPE protocol of FW or TR

The calculated SWC was 0.44 cm for FW and 0.52 cm for TR, while the SEM values were 0.70 cm and 0.82 cm respectively. The observed mean changes in both protocols clearly exceeded the SWC, indicating meaningful practical improvements in vertical jump performance (Table 2).

Table 2 – Countermovement jump

Protocol	Baseline [cm]	48 hours [cm]	Δ Mean [cm]	p	d	SWC [cm]	SEM [cm]
Flywheel (FW)	49.83 $\pm$ 2.20	51.81 $\pm$ 2.52 **	1.98 $\pm$ 2.20	0.004	0.902	0.44	0.70
Traditional Resistance (TR)	50.20 $\pm$ 2.60	51.86 $\pm$ 2.74 **	1.66 $\pm$ 1.58	0.001	1.052	0.52	0.82

Dicussion

The present study investigated the delayed effects (48 hours post-intervention) of two different PAPE protocols: flywheel isoinertial squats (FW) and traditional free-weight squats (TR) on sprint and jump performance. The results showed that both protocols led to significant improvements in countermovement jump (CMJ) height, with slightly greater effect sizes observed in the TR group. For 10-meter sprint performance, only the TR protocol yielded statistically significant improvements, whereas changes following the FW protocol did not reach significance. Despite these differences, no significant interaction effects were found when directly comparing the two protocols. These findings suggest that while both methods can enhance jumping performance after 48 hours, traditional resistance training may offer a slight advantage in short-distance sprinting tasks.

Delayed potentiation in sprint performance enhancement may be associated with accumulated fatigue and slower neuromuscular recovery (Pareja-Blanco et al., 2020). Findings by Tsoukos et al. (2018) and Goulart et al. (2020) support this in relation to both jump and sprint performance under different resistance volumes. Goulart et al. (2020), using the same number of sets and repetitions (but different resistance) compared to our study, did not observe significant improvements in 10- or 20-meter sprint performance after 24 or 48 hours. The practical effects were trivial to small ($ES = 0.18 - 0.26$). In our study, conducted 48 hours after the intervention, we did not observe statistically significant improvements in 10-meter sprint performance after FW. The changes were small and nonsignificant for FW (-0.021 s; -1.23%). After TR protocol we observed statistically significant changes after 48 hours with little bigger changes (TR: -0.032 s; -1.87%) comparing to FW. Effect sizes were small for FW ($d = 0.42$) and medium for TR ($d = 0.67$). Similar results were reported by Öhrner (2021), who found no significant performance improvements in female soccer players ($n = 31$) 24 hours after performing six sets of four trap bar vertical jumps. No significant changes were found in CMJ, 10-meter sprint, or 20-meter sprint performance ($p = 0.69$; $d = 0.14$; $p = 0.58$; $d = 0.19$; $p = 0.61$; $d = 0.17$). Panteli et al. (2024) also found no significant improvements in 20-meter sprint or CMJ height. Their study examined a group of footballers divided into weaker and stronger subgroups, performing two protocols: ballistic loading (BP) and resisted sprinting (RS). Changes were tracked in 20-meter sprint, agility T-test, and CMJ. Interestingly, significant improvements were observed in agility (T-test) performance after both RS ($p = 0.005$; $2.51 \pm 2.28\%$) and BP ($p = 0.02$; $1.91 \pm 2.30\%$) compared to a control group. Notably, stronger individuals showed significantly greater agility improvements when comparing RS and BP to the control group (RS vs. CON: $p = 0.016$; $3.02 \pm 2.96\%$; BP vs. CON: $p = 0.02$; $2.64 \pm 2.76\%$). In the study by Pino-Mulero et al. (2025),

performance improvements in football players were assessed using 20-meter sprint and CMJ height. The day before a match, participants performed resisted sprints using sleds (EXP) and were compared with a control group (CON) who performed traditional unloaded sprints. Testing occurred again 24 hours later. The resisted sprints were performed at 100% body mass resistance over 15 meters in two sets of two repetitions. Significant improvements were found in 20-meter sprint time at the 1% level with a large effect size ($p = 0.001$; $d = 1.24$; average difference = -0.08 s) in the EXP group. The difference between groups was also significant ($p = 0.001$; $d = 1.41$; average difference = 0.08 s).

Delayed PAPE effects on explosive performance had so far been predominantly studied using traditional free-weight resistance. The most commonly reported timeframes include 6 hours (Cook et al., 2014; Saez Saez de Villarreal et al., 2007), and 24 to 48 hours post-training (Smoliga et al., 2025; Tseng et al., 2021; Tsoukos et al., 2018; Weakley et al., 2017). Continuing with findings by authors Pino-Mulero et al. (2025) as they found significant enhancements in sprint performance, similar improvements were observed in CMJ height after EXP ($p = 0.003$; $d = 1.01$; $+1.8$ cm) and in comparing to CON ($p = 0.001$; $d = 1.11$; $+1.8$ cm). In our study, performance improvements were confirmed only in countermovement jump (CMJ) height at 48 hours post-intervention. The FW group improved by 1.98 ± 2.20 cm ($+3.97\%$) and the TR group by 1.66 ± 1.58 cm ($+3.31\%$), both statistically significant (FW: $p = 0.002$; TR: $p = 0.001$) and with large effect sizes (FW: $d = -0.90$; TR: $d = -1.05$). Despite the absence of sprint enhancement, these results highlight a potentiating effect on vertical jump performance after 48 hours, possibly linked to reduced task complexity and more favorable neuromuscular recruitment patterns in CMJ compared to sprinting. Weakley et al. (2017) assessed both acute and delayed effects following three types of resistance training: traditional (TRA), superset (SS), and tri-set (TRI) protocols.

While all three produced an immediate drop in CMJ height post-exercise, only the TRA group returned to baseline after 24 hours; performance remained suppressed in SS and TRI. Tsoukos et al. (2018) observed a $5.1 \pm 1.0\%$ improvement using resistance at 40% of 1RM. In our study, the TR protocol used resistance corresponding to Pmax (Beato et al., 2019; Smoliga et al., 2025; Timon et al., 2019). While prior reports indicate that Pmax-based loading may produce favorable neuromuscular responses, our findings suggest this may not translate into significant short-distance sprint improvements at 48 hours post-activation. However, the observed improvements in CMJ align with studies suggesting that potentiation effects are more evident in tasks with lower coordinative complexity. The variability in response, particularly in sprint performance, may also be explained by the high inter-individual variability and fatigue accumulation. Our findings differ from those of Tseng et al. (2021), who examined delayed effects of an accentuated eccentric loading (AEL) protocol (105 % of 1RM). They found no improvement in CMJ height; instead, jump height decreased by ~ 1 cm at 24 hours and >3 cm at 48 hours. In contrast, our Pmax-based protocols (FW and TR) produced significant gains at 48 hours. While both AEL and FW loading involve eccentric overload, our results suggest that the lower volume and moderate intensity used in our study may be more suitable for potentiation, avoiding excessive fatigue. Ishida et al. (2023) also demonstrated a CMJ decline after high-volume protocols (5 sets of 10 reps at 60 % 1RM), supporting the notion that training volume is a key determinant of potentiation outcomes. The lower volume used in our study likely mitigated fatigue and allowed recovery sufficient for CMJ enhancement after 48 hours.

Conclusions

Our study demonstrated delayed (48 hours) PAPE effects using two different protocols: flywheel isoinertial resistance (FW) and traditional free weight resistance (TR) on 10-meter sprint (10m) performance and countermovement jump (CMJ) height. Our results showed that only the TR protocol was significantly effective in enhancing sprint performance, while both FW and TR significantly improved CMJ performance, with no statistical difference between the protocols. These findings indicate that delayed potentiation is task-specific: CMJ, as a less coordinatively complex explosive task, appears more responsive to both protocols, whereas sprinting performance benefits require the use of traditional resistance training.

From a theoretical perspective, this work adds evidence to the growing but inconsistent body of literature on delayed PAPE. While previous studies have reported mixed outcomes at 24–48 hours, our results support the idea that moderate-volume, Pmax-based loading may provide sufficient stimulus for potentiation without excessive fatigue, at least in vertical jump performance. This highlights the importance of training load and exercise modality when interpreting delayed potentiation effects. From a practical standpoint, the study suggests that coaches can consider traditional resistance exercises not only for acute potentiation but also for enhancing sprint performance when planned 48 hours before competition. Both TR and FW protocols appear equally effective for improving jump performance in this delayed window, which may have implications for sports requiring repeated explosive actions. The possibility of scheduling conditioning activities days before competition opens opportunities for more flexible periodization strategies.

Despite the promising results, the absence of sprint improvements after FW indicates that not all modalities are interchangeable. Practitioners should be aware that exercise selection must be matched to the performance outcome of interest. This task-specific nature of delayed potentiation is a key insight for applied practice. Future research should expand on these findings by examining larger, sport-specific cohorts, testing different recovery intervals beyond 48 hours, and including additional performance metrics (e.g., agility,

repeated sprint ability, or match-related skills). Studies should also further evaluate the reliability of flywheel devices for inducing eccentric overload and their comparative role against free weights in producing sustainable potentiation.

Study limitations

Our study had some limitations. Our study included only 14 participants from various sports disciplines, which may limit the generalizability of our findings. We recommend that future research focuses on a single, specific sport discipline to better understand protocol-specific effects. Additionally, we only assessed performance outcomes 48 hours post-intervention, and did not monitor any other time points. This limited timeframe, along with the narrow scope of measured variables (only CMJ and 10-meter sprint), may have overlooked other relevant performance or recovery changes. Although participants were verbally instructed not to engage in any high-intensity physical activity 48 hours prior to and following the intervention, we did not objectively monitor their compliance, which may have introduced uncontrolled variability into the results. Another limitation lies in the equipment used for the interventions — its reliability and actual ability to generate eccentric overload have not been independently verified. We recommend further research to validate whether the device functions as claimed by the manufacturer and is truly suitable for inducing eccentric loading.

Conflicts of interest

The authors declare no conflicts of interest.

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Ethical Approval

This study was approved by the Ethics Committee of Faculty of Physical Education and Sport under protocol number 21/2024, in accordance with the Declaration of Helsinki.

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