The Effects of Plyometric Conditioning on Acute Sprint Performance: A Comparative Study of Single versus Multiple Sets of Tuck Jumps

by

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This study investigated the effects of post activation performance enhancement induced by different sets of plyometric tuck jumps as a conditioning activity on sprint performance. Twenty-two male athletes performed either a single set (1 x 10) or three sets (3 x 10) of tuck jumps in randomised order followed by a 30-m sprint in the 15th s and the 2nd, the 4th, the 8th, the 12th, and the 16th min post activation. The 30-m sprint was performed with 10-m split times and 10-m, flying 10-m, 20-m, flying 20-m and 30-m times were determined. The comparisons were performed using two-way analysis of variance (ANOVA) and Bonferroni adjustment. In addition, smallest real differences were calculated to determine the individual effects of different sets of tuck jumps on sprint performance. For all running distances significant time effect was found ($p < 0.05$) with fatigue compared to baseline in most cases, except for 10-m and 20-m running distance in which no significant effect was observed ($p > 0.05$). Baseline flying 10-m running speed was faster than 15th s and 8th and 12th min running speed. Baseline flying 20-m running speed was faster than running speed at all-time points ($p < 0.05$). Baseline 30-m running speed was faster than 15th s running speed. In addition, no significant set effect and set x time interaction was found in all sprint distances ($p > 0.05$). It was found that the majority of participants had neutral responses to all sprint distances. The results of this study showed that different sets of plyometric conditioning activity did not cause any changes in 30-m sprint performance.

***Keywords**: conditioning activity; male athletes; post activation performance enhancement*

Introduction

Post-activation performance enhancement (PAPE), a condition that occurs as a result of voluntary contraction applied at maximal or near-maximal intensity, has been observed to enhance the peak force and the rate of force development during subsequent contractions (Blazevich and Babault, 2019; Cuenca-Fernández et al., 2017). Increases in muscle temperature and water content, as well as an increase in the neural drive and high threshold motor unit activation, may all be linked to PAPE (Blazevich and Babault, 2019; Hodgson et al., 2005). Nonetheless, the mechanisms responsible for these effects are still unclear.

The potentiation effect appears to be influenced by a number of variables, including the type of conditioning activity (CA), the number of sets, the intensity of the CA, and the rest period following the CA (Cormier et al., 2022; Garbisu and Santos, 2021; Seitz and Haff, 2016). In addition,

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PAPE is also influenced by participants' resistance training history; those who have been resistance training for at least two years show a greater PAPE effect than those who have done so for less than two years (Seitz and Haff, 2016).

Furthermore, it seems that the PAPE response caused by varying numbers of CA sets is mediated by the individual's strength level (Seitz and Haff, 2016; Wilson et al., 2013). Weaker individuals are less likely to demonstrate high levels of PAPE after multiple sets of the CA since they experience more fatigue (Seitz and Haff, 2016; Wilson et al., 2013). Extensive research advocates using a CA to improve performance in jumping, sprinting, throwing, and upper-body ballistic movements (Till and Cooke, 2009). Highlighting this, Poulos et al. (2018) investigated the effects of 10 sets of back squats on jump performance in 15 elite volleyball players using a strength-power potentiation complex training protocol which combined a CA with strength and power exercises, involving maximal or near-maximal muscle contractions (3–5 repetitions at ≥ 85% of 1RM). An increase in jump height was observed in the countermovement jump performed after three repetitions of back squats, regardless of the squat intensity (65% or 87% of 1-RM) and this effect was found to be more pronounced in participants with higher relative strength.

Plyometric exercises, such as high-intensity depth jumps, drop jumps, tuck jumps, or alternate leg bounding, are in fact activities that require maximal effort. A meta-analysis showed that plyometric conditioning exercises provide more effective results than other conditioning exercises (Wilson et al., 2013). Plyometric exercises primarily activate type II (fast-twitch) motor units, which are responsible for producing high torque and facilitating rapid, powerful contractions (Seitz and Haff, 2016). These units play a crucial role in strength- and power-dependent movements, especially explosive actions such as acceleration and jumping. Since plyometrics involves quick muscle elongation and contractions, it stimulates these fibres and increases motor unit recruitment, potentially boosting performance and explosive power output (Byrne et al., 2020). Compared to loaded conventional resistance training, a plyometric CA may cause less fatigue, allowing for a shorter time to reach peak PAPE effects (Seitz and Haff, 2016; Wilson et al., 2013). These exercises seem to improve explosiveness and reactiveness of the involved muscles (Kümmel et al., 2016; Mcbride et al., 2005). For example, acceleration performance in 10-m and 20-m sprints tended to improve after 3 sets of 10 alternating leg bounds against a resistance of 10% of body mass, performed with a weighted vest (Ruben et al., 2010).

In sports that involve sprinting, plyometric workouts are essential because they reduce ground contact time and promote the rapid production of eccentric force (Morin et al., 2011). In humans, high-speed running performance is closely related to mechanical and neuromuscular variables, particularly the ability to generate high levels of vertical ground reaction force relative to body mass and to apply this force effectively within a limited ground contact time (Colyer et al., 2018; Morin et al., 2012). Coaches and trainers can enhance athletes' explosive abilities, such as sprinting, by adding single and multiple sets of plyometrics as a CA. However, very few studies have evaluated the effects of single and multiple sets of plyometric CAs. The acute effects of plyometric exercise conditioning on jumping performance have been extensively studied (Byrne et al., 2020; Kümmel et al., 2016; Mcbride et al., 2005; Ruben et al., 2010), but relatively little is known about the PAPE effects of plyometric exercise applied in multiple sets on sprint speed. Thus, the purpose of this study was to examine whether single and multiple sets of a plyometric CA would affect sprint performance by creating PAPE.

Methods

Participants

Twenty-two male athletes from a variety of team and individual sports, aged between 18 and 28 years, volunteered to participate in this study (age: 21.63 ± 3.07 years, body mass: 75.2 ± 5.28 kg, body height: 176.09 ± 3.90 cm, body fat content: 16.42 ± 2.84%, fat mass: 12.34 ± 2.97 kg, lean body mass: 59.19 ± 4.51 kg, training experience: 7.09 ± 3.62 years, strength training experience: 6.50 ± 3.86 years) (Table 1). The sample size for this study was calculated a priori using G*power software (version 3.1.9.7) (Faul et al., 2009). The alpha value (α) was set at 0.05 and the power (1-β error probability) was set at 0.90. Sample size was estimated as 22 to be sufficient for this study. Being injury-free for the previous six months and having at least two years of strength training and plyometric training experience were the inclusion criteria. The study was conducted in accordance with the 2013 Helsinki Declaration and received ethical approval from the Institutional Review Board of the Hacettepe University, Ankara, Turkey (protocol code: 2019/20-48; approval date: 03 September 2019).

Procedures

A crossover-randomised design with one familiarization and two experimental sessions was applied in this study (Figure 1). The experimental protocols included single and three sets of 10 tuck jumps as a CA. Participants were instructed to avoid exercising the day before the test, to avoid caffeine and alcohol for 24 hours before each session, and to attend each testing session well-hydrated. Each participant was tested at the same time of the day in order to minimise the circadian rhythm effect (Poulos et al., 2018).

Initially, participants attended a familiarization session where the study protocol was explained, and they were instructed on how to perform tuck jumps accurately. Then, anthropometric measurements were obtained, and at least 10 tuck jumps, and two 30-m sprints were performed as familiarisation. In the experimental phase, participants initially underwent a 5-min jog session followed by a 5-min dynamic warm-up (involving dynamic stretching, submaximal sprints and jumps) for the lower extremities. Following a 2-min rest interval, participants performed two preliminary 30-m sprints with again 2-min rest intervals to determine baseline 30-m sprint times. The best sprint times determined in the baseline run were accepted as the control reference value for the comparison with post-CA values. After 10 min of passive rest in a standing position, participants performed the CA which consisted of ten tuck jumps in either a single set or three sets with 30-s rest intervals between sets. Following the CA, participants performed 30-m sprints with 10-m intervals in the 15 s, the 2nd, the 4th, the 8th, the 12th, and the 16th min post activation. The sprint times for 10-, flying 10-, 20-, flying 20-, and 30-m distances were recorded (Turner et al., 2015).

Anthropometric and Body Composition Measurements

A Holtain stadiometer (Holtain, England) with accuracy of ±1 mm was used to measure the participants' body height, and an electronic scale (Tanita TBF 401A, Japan) with accuracy of ±100 g was used to determine their body mass. Dual energy x-ray absorptiometry (DXA, Lunar Prodigy Narrow Fan Beam (4.5), GE Health Care, Madison, Wisconsin, USA) was used to measure body composition using standardized techniques.

30-m Sprint Measurements

Telemetric timing gates (Fusion Sport, Australia) placed at the start, 10-, 20-, and 30-m marks were used to measure 30-m sprint times. Starting from a standing position, participants were instructed to run as fast as they could and they were provided verbal encouragement during the 30-m sprint. Participants also ran 30-m sprints in the 15th s and the 2nd, the 4th, the 8th, the 12th, and the 16th min following the CA.

CA Application

In both single (1 x 10) and three sets (3 x 10), participants performed tuck jumps as a CA, with a 30-s rest interval between subsequent sets (Turner et al., 2015). They were instructed to minimise the amount of time their feet made contact with the ground and to maximize their vertical push when performing tuck jumps with their hands on their waists and their feet shoulder-width apart. Additionally, they were instructed to stay in the catch zone and land in the same area after every jump (Nascimento et al., 2022).

Statistical Analysis

For every measure, descriptive analyses were conducted, and the Kolmogorov-Smirnov test was used to verify that the data were normal. For all variables deviation from the normal distribution was non-significant ($p > 0.05$). A two-way analysis of variance with repeated measures was applied (2 x 7 within-participant factors: time [baseline, 15th s, 2nd, 4th, 8th, 12th and 16th min] x set [single set, three sets]). To identify the differences, Bonferroni's post-hoc tests were applied. Additionally, the Mauchly's test was performed, and when the sphericity requirements were not met, Greenhouse-Geisser correction was used. PAPE protocols were also evaluated on an individual basis, where the smallest real difference (SRD) within the 95% confidence interval was calculated using the following formula (Hunter et al., 2004):

SRD = Standard Error of Measurement × 1.96 × √2

When individual sprint time difference before and after the preload stimulus was positive and higher than the calculated SRD, it was considered positive response (potentiation effect), while a negative response (fatigue effect) was when it was negative and below the calculated SRD. Lastly, no potentiation effect (neutral) was when differences in individual sprint times equalled the calculated SRD (Hunter et al., 2004). SPSS (ver. 21) was used to analyse the data, with a level of significance set at $p < 0.05$.

Results

The sprint times after the single-set and three-set CA exercises at all distances are shown in Table 2.

Ten-meter running speed was not affected by the set (F (2. 42) = 0.110; p = 0.744, η2 = 0.005), time (F (2.42) = 2.224; p = 0.082, η2 = 0.096) and set x time interaction (F (2.42) = 1.887; p = 0.122, η2 = 0.082). Neutral response was observed after a single set and three sets of tuck jumps for 10-m running speed for most of the participants, whereas a fatigue effect was found for two participants after single set activity. In flying 10-m running speed a set effect (F (2.42) = 0.094; p = 0.762, η2 = 0.004) and set x time interaction (F (2.42) = 0.974; p = 0.392, η2 = 0.044) were not evident, whereas a time effect was significant (F (2.42) = 7.359; p = 0.001, η2 = 0.260). Flying 10-m running speed was significantly impaired in the 15th s as well as the 8th and 12th min compared to baseline (p < 0.05) and did not change in the 2nd, the 4th and the 16th min (p > 0.05) (Figure 2). Neutral response was observed after a single set and three sets of tuck jumps for flying 10-m running speed for most participants; however, the fatigue effect was found only in one participant after a single set CA.

Running speed over 20-m was not influenced by the set (F (2.42) = 0.001; p = 0.970, η2 = 0.000) and there was no significant set x time interaction (F (2,42) = 1.442; p = 0.226, η2 = 0.064). On the other hand, the time effect was significant (F (2.42) = 3.289; p = 0.022, η2 = 0.135), although when Bonferroni correction was made, this effect lost its significance (p > 0.05). Neutral response was observed after a single set of tuck jumps for 20-m running speed for most of the participants, while the fatigue effect was found for one participant after a single set CA. In flying 20-m running speed, the set effect (F (2.42) = 0.016; p = 0.900, η2 = 0.001) and the set x time interaction (F (2.42) = 0.553; p = 0.630, η2 = 0.026) were not evident, whereas the time effect was significant (F (2.42) = 2.649; p = 0.069, η2 = 0.112). Bonferroni post-hoc tests revealed that this difference was due to the impaired running speed at the 15th s, the 2nd, the 4th, the 8th, the 12th and the 16th min when compared to baseline (p < 0.05) (Figure3). Neutral response was observed after a single set and three sets of tuck jumps for flying 20-m running speed for most participants, while in one participant the fatigue effect was found after three sets of the CA.

Finally, 30-m running speed was not influenced by the set (F (2.42) = 0.030; p = 0.864, η2 = 0.001) or set x time interaction (F (2.42) = 1.145; p = 0.341, η2 = 0.052), while, the time effect was significant (F (2.42) = 3.420; p = 0.019, η2 = 0.140) and this difference was due to impaired running speed at the 15th s compared to baseline. No difference was found between the baseline and the sprint times at the 2nd, the 4th, the 8th, the 12th and the 16th min (p > 0.05) (Figure 4). The effect of a single set and three sets of tuck jumps on 30-m sprint performance was neutral for most participants during all time conditions.

Discussion

The aim of this study was to examine the effects of different sets of a plyometric CA in eliciting PAPE on sprint performance. Our study's primary findings were that there was no PAPE effect of single-set or three-set tuck jump exercises on sprint performance for the 10-, flying 10-, 20- flying 20-, and 30-m distances. Furthermore, analysis of individual responses revealed that most individuals responded '*neutral*' at all sprint distances.

According to research, when compared to traditional weightlifting exercises, plyometric activities may have a higher biomechanical relevance to sprinting, with ground contact times comparable to the acceleration phase (de Villarreal et al., 2012). Only a limited amount of research, however, has examined how a plyometric CA—such as depth jumps, tuck jumps, drop jumps, and alternate leg bounds—affects sprint performance. In a study by Turner et al. (2015), an enhanced sprint performance in the 4th and 8th min was found after 3 sets of 10 repetitions of the leg bound exercise with weighted vests (10% of the body weight) when compared to protocols where only body weight was used. As the leg bound exercise is a single-leg movement and takes place in the horizontal plane, it might have a larger effect on acceleration in a short distance sprint (such as a 10-m sprint) compared to a movement that takes place in the vertical plane with an imposed load on both legs (like tuck jumps) (Turner et al., 2015). Byrne et al. (2020) examined the acute potentiation effect of drop jumps on 20-m sprint time, and the results revealed a potentiation effect following a 1-min rest interval after the CA. In another study, where a dynamic warm-up and depth jumps were performed together as a CA, there was a 2.93% improvement in 20-m sprint performance (DeRenne, 2010). Also improvement in 50-m sprint performance was noted after two maximal repetitions of the drop-jump activity in a study of Healy and Comyns (2017). As demonstrated in previous research, the absence of a PAPE effect in our study may be attributed to a biomechanical mismatch between the tuck jump and sprinting. The tuck jump is a bilateral, vertically oriented movement that is less specific to sprinting demands (Till and Cooke, 2009). In contrast, exercises such as leg bounds and drop jumps are more biomechanically aligned with sprinting, particularly during the acceleration phase (Byrne et al., 2020; Turner et al., 2015). Leg bounds, performed unilaterally in the horizontal plane, enhance horizontal propulsive force and reactive strength, both of which are critical in early sprinting (Morin et al., 2011; Turner et al., 2015). Similarly, drop jumps—with their shorter ground contact times and greater utilization of elastic energy—more effectively activate the stretch-shortening cycle and the neuromuscular system, improving force output relevant to sprint mechanics (Byrne et al., 2020). In contrast, the tuck jump's vertical force orientation, longer ground contact time, and reduced elastic energy contribution may limit its effectiveness in enhancing sprint performance.

Table 1. Demographic and physical activity characteristics of participants included in the study.

Variables	Mean	SD
Age (years)	21.63	3.07
Body height (cm)	176.09	3.90
Body mass (kg)	75.2	5.28
BFP (%)	16.42	2.84
FM (kg)	12.34	2.97
LBM (kg)	59.19	4.51
Training experience (years)	7.09	3.62
Strength training experience (years)	6.50	3.86
	4.22	3.39

BFP: body fat percentage, FM: fat mass, LBM: lean body mass

Table 2. Sprint performance values for all distances and times (X ± SD).

Distance	Set Type	Baseline	15th s	2nd min	4th min	8th min	12th min	16th min
10 m (s)	Single Set	1.76 ± 0.22	1.91 ± 0.25	1.87 ± 0.08	1.85 ± 0.08	1.84 ± 0.09	1.81 ± 0.17	1.85 ± 0.10
	Three Sets	1.85 ± 0.11	1.89 ± 0.15	1.87 ± 0.20	1.84 ± 0.11	1.83 ± 0.09	1.82 ± 0.07	1.82 ± 0.14
Flying 10 m (s)	Single Set	1.26 ± 0.04	1.30 ± 0.05	1.27 ± 0.05	1.28 ± 0.05	1.29 ± 0.04	1.29 ± 0.05	1.29 ± 0.05
	Three Sets	1.26 ± 0.04	1.31 ± 0.09	1.29 ± 0.05	1.28 ± 0.05	1.28 ± 0.04	1.28 ± 0.05	1.28 ± 0.04
20 m (s)	Single Set	3.02 ± 0.17	3.22 ± 0.27	3.14 ± 0.11	3.13 ± 0.12	3.13 ± 0.12	3.10 ± 0.20	3.14 ± 0.13
	Three Sets	3.11 ± 0.13	3.20 ± 0.18	3.16 ± 0.22	3.12 ± 0.14	3.11 ± 0.12	3.10 ± 0.11	3.10 ± 0.16
Flying 20 m (s)	Single Set	2.45 ± 0.09	2.49 ± 0.22	2.48 ± 0.10	2.50 ± 0.10	2.49 ± 0.10	2.53 ± 0.16	2.53 ± 0.16
	Three Sets	2.45 ± 0.11	2.52 ± 0.10	2.49 ± 0.10	2.49 ± 0.11	2.49 ± 0.09	2.50 ± 0.11	2.51 ± 0.13
30 m (s)	Single Set	4.21 ± 0.15	4.40 ± 0.18	4.35 ± 0.15	4.35 ± 0.16	4.33 ± 0.17	4.34 ± 0.18	4.38 ± 0.23
	Three Sets	4.30 ± 0.17	4.41 ± 0.22	4.36 ± 0.24	4.33 ± 0.19	4.32 ± 0.16	4.32 ± 0.17	4.33 ± 0.17

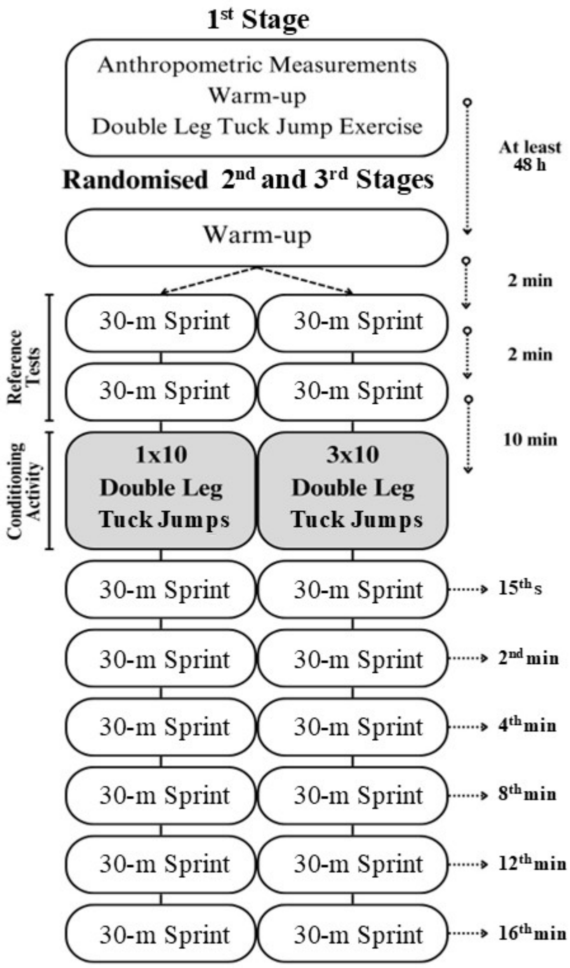

Figure 1. Research design.

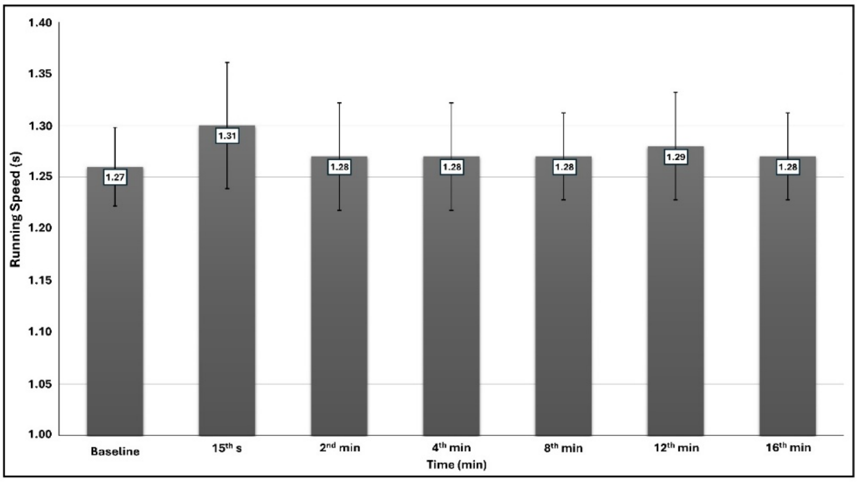

Figure 2. Time effect for flying 10-m sprint speed before and after both sets of the CA.

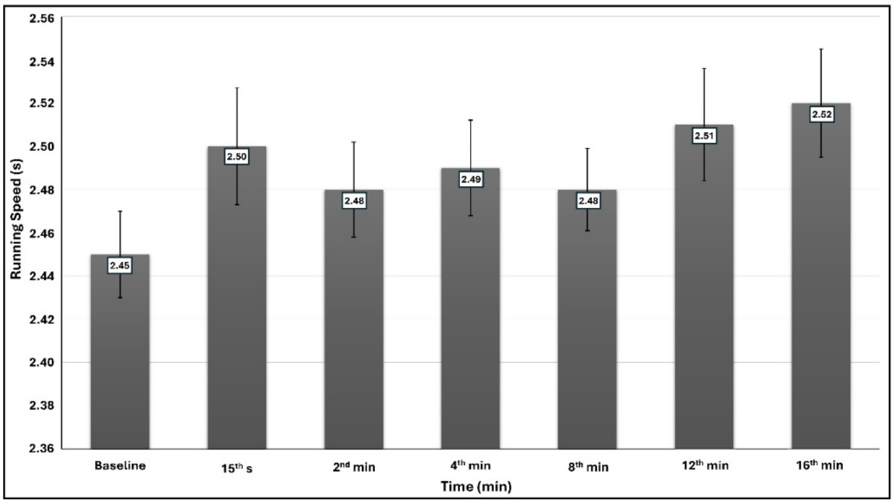

Figure 3. Time effect for flying 20-m sprint speed before and after both sets of the CA.

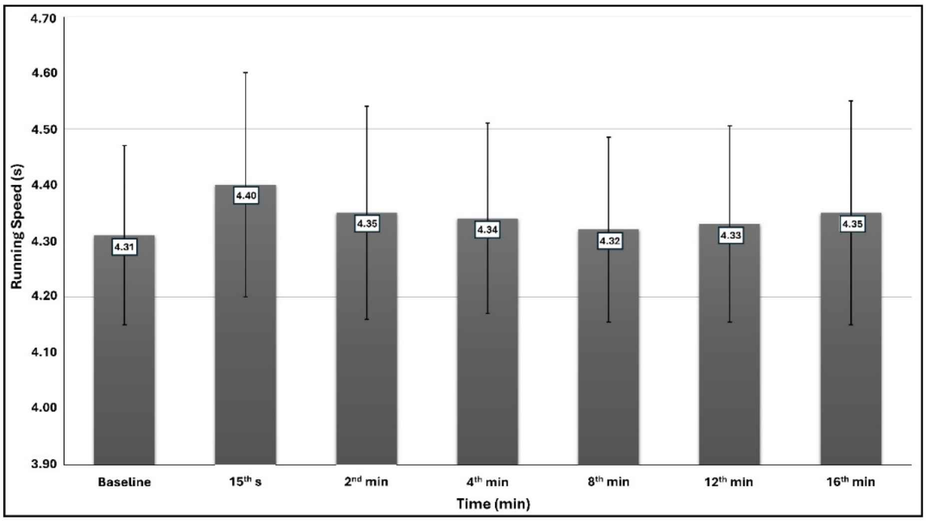

Figure 4. Time effect for 30-m sprint speed before and after both sets of the CA.

In some studies, using plyometric exercises as a CA, no PAPE effect was found. For instance, Lim and Kong (2013) did not observe any change in the 30-m sprint performance after a 4-min rest interval following an isometric and dynamic PAPE protocol. Similarly, Till and Cooke (2009) did not find any change in 10-m and 20-m sprint time in the 4th, the 5th, and the 6th min after one set of 5 tuck jumps. Also in our study, the tuck jump exercise did not have a positive effect on 10-m, flying 10-m, 20-m, flying 20-m, and 30-m sprint performances. This could be attributed to the tuck jump exercise not adequately activating the motor units, or it could be that other plyometric exercises that are more biomechanically similar to sprint performance could have a greater PAPE effect on sprint performance (Mcbride et al., 2005; Nakata and Mishima, 2024). Hilfiker et al. (2007) investigated the effects of drop jumps performed from a height of 60 cm on subsequent countermovement jumps and squat jumps, specifically examining jump height and maximum power output. Their study demonstrated that incorporating drop jumps into a warm-up routine enhanced explosive power development in athletes. Likewise, Dello Iacono et al. (2016) found that performing three sets of 10 repetitions of drop jumps had a performance-enhancing effect on 20-m sprint speed. These findings highlight the importance of selecting the most appropriate strength-power potentiation complex to optimize sprint performance. In other words, sprint performance improvements are best achieved through training programs that emphasize greater horizontal acceleration, such as bounding exercises and horizontal displacement jumps. Turner et al. (2015) conducted a study which demonstrated that plyometric exercise, particularly alternating leg bound exercise, is an effective method for inducing the PAPE compared to the full control conditions. The effectiveness of the PAPE may differ based on the particular sprinting phases being studied since sprinting is divided into three unique phases: starting, acceleration, and maximal speed phases (Morin et al., 2011). Maximizing horizontal impulses and limiting vertical impulse production are necessary during the early acceleration phases of sprinting (Hunter et al., 2004). In conclusion, the plyometric exercise used in the Turner et al.'s (2015) study, which required maximizing the horizontal impulse, might explain the improvements in sprint acceleration performance, in addition to the importance of the selected strength-power-potentiation complex having similar biomechanical properties in creating the PAPE effect.

An important factor in eliciting the PAPE effect is the number of sets and repetitions, as well as the strategy used to increase total training volume. Wilson et al. (2013) reported that multiple sets of the CA may contribute to PAPE more than a single set, although responses can vary depending on training status. In that study, inexperienced individuals showed a reduction in power output, while trained and experienced athletes demonstrated significant improvements. Similarly, recent studies have also explored PAPE as a method to acutely boost training volume. Alves et al. (2019) demonstrated that a PAPE protocol (3 × 1 rep at 90% 1RM) improved bench press performance at 75% 1RM and increased total work volume. However, Krzysztofik and Wilk (2020) found that plyometric push-ups enhanced performance only in the first set, with diminishing effects in subsequent sets. Similarly, Sharma et al. (2018) reported that plyometric exercises (40 jumps) resulted in greater CMJ height and faster sprint times compared to heavy resistance training (10 squats at 90% 1RM), indicating improved performance in the first sets. These findings reflect inconsistencies in the literature. In our study, both single- and multiple-set tuck jump protocols may have lacked sufficient neuromuscular stimulation due to their low volume. Increasing the number of repetitions may enhance motor unit recruitment, but it is also important to emphasize strength development and fatigue resistance. Ultimately, optimizing the number of sets and total training volume is crucial for maximizing neuromuscular outcomes (More et al., 2024).

When considering both our study and previous meta-analyses, it appears that many factors, such as the volume of training, the load used, recovery time, and inter-individual variability, are important in revealing the PAPE effect (Dickey et al., 2025). The inter-individual variability includes training experience, training status, chronological age, genetics (muscle fibre type), gender, and the strength level (Cormier et al., 2022). In the literature, training experience and the strength level of participants are regarded as crucial factors in inducing PAPE (Seitz et al., 2014). Moreover, after a near-maximal effort, strong individuals may tolerate more fatigue from heavy loads, which might influence the balance between fatigue and potentiation following the CA (Chiu and Barnes, 2003). For instance, Seitz and Haff (2016) found a correlation between strength and PAPE, as well as between strength and sprinting. That study demonstrated that stronger participants had faster sprint times and higher vertical jump performance than the weaker group. Supporting this, Ruben et al. (2010) found that individuals who could squat >2.0 body weight produced a significantly greater PAPE effect and higher fatigue resistance to heavier loads than weaker individuals (<1.7 body weight). In our study, no distinction was made between weaker and stronger individuals; however, it is considered that individual assessment of PAPE would be more accurate. When evaluating individual sprint performance results in our study, most participants showed neutral PAPE effects, while only few showed positive or negative effects.

Similarly, Aytac et al. (2024) investigated the effects of back squat exercises with three sets of three repetitions at %90 of 1 RM separated by 2-min rest intervals on participants' performance on the 505 test and the T-test, and they found no significant differences in their PAPE responses. However, Lim and Kong (2013) examined the impact of four different PAPE protocols on 10-m, 20-m and 30-m sprint performance and found no difference among the protocols, although they noted considerable variation in participants' PAPE responses. Mola et al. (2014) indicated in their study that due to individual differences, the time for PAPE application to show an effect in participants may differ at the individual level and individuals should be divided into responsive and unresponsive to PAPE.

As known, the CA can be applied with various exercise methods such as traditional high- and moderate-intensity exercises, plyometrics and maximal isometric contractions (Pereira et al., 2025; Seitz and Haff, 2016; Stastny et al., 2024). However, the most significant PAP effect on sprint performance has been achieved through plyometric exercises (Seitz and Haff, 2016). The mechanism of PAP is myosin light chain phosphorylation, which explains the performance enhancement observed within a 4–5 min period (Blazevich and Babault, 2019). Although the mechanism is not yet fully understood, recent studies describe performance enhancement over longer duration as PAPE. The possible mechanisms of PAPE involve increases in muscle temperature, muscle water content, and muscle activation (Blazevich and Babault, 2019). The enhancement of muscle contractile properties has been attributed to the release and reuptake of Ca^{2+} (via Ca^{2+} ATPase) from the sarcoplasmic reticulum, along with increased muscle temperature, and the increased intramuscular fluid (Blazevich and Babault, 2019). An increased blood flow and, consequently, the elevated muscle fluid may enhance the rate of cross-bridge formation and the speed of muscle contraction (Blazevich and Babault, 2019). Additionally, it may improve the rate of force development (RFD) by increasing muscle stiffness (Rodrigues et al., 2022). The movement of water within the cellular muscle area reduces the hypotonicity (i.e., ionic strength) of muscle fibres, which in turn enhances their strength and fast-twitch characteristics (Sugi et al., 2013). Therefore, the effect of reduced ionic strength will increase the number of cross-bridge formations which generate strongly bound forces during muscle contraction (Sugi et al., 2013). Additionally, the increased microvascular circulation and intramuscular fluid will enhance the stiffness of the entire muscle-tendon unit (comprising the elastic components of muscle fibres), which will help positively alter the elastic properties of the muscle (Sugi et al., 2013). It has also been stated that acute strength training leads to an increase in the efficacy of corticospinal-motoneuronal synapses or an enhancement in motoneuron excitability (Krutki et al., 2017). It has been proposed that the strong excitation of muscle fibres from motoneurons significantly enhances the potential for maximal contractile force production in muscles following strength training (Krutki et al., 2017). Possible mechanisms include increased corticospinal excitability, enhanced efficacy of corticospinal-motoneuronal synapses, or the formation of new excitatory synapses by stimulating motoneurons in the spinal cord (Nuzzo et al., 2016).

To clearly observe the effects of PAPE, the influence of the warm-up protocol alongside the CA should be carefully considered. Warm-up exercises may already elicit a PAPE effect during the warm-up itself by increasing muscle temperature and activating neuromuscular mechanisms (Blazevich and Babault, 2019). If this occurs, it may become difficult to isolate the effect of the subsequent CA during performance measurements. However, this situation is closely related to the intensity and content of the warm-up. If high-intensity resistance exercises using 85–95% of 1RM loads, high-intensity sprinting or jumping exercises are included as part of the warm-up, a significant PAPE effect may already be induced during that phase (de Villarreal et al., 2007). As a result, the CA may not produce any additional benefit in subsequent exercises, as a high level of activation has already occurred. On the other hand, general warm-ups as in the present study (such as light jogging, dynamic stretching, submaximal sprint and jumps), dynamic exercises performed with 30% of the maximal load, submaximal sprints and jump efforts, as well as DJ exercises from an optimal height do not appear to induce a PAPE effect on explosive dynamic muscle actions (de Villarreal et al., 2007). Additionally, the likelihood of the PAPE effect is influenced by both the rest interval provided after the reference tests conducted prior to the CA and the number of repetitions of these reference tests (Bielitzki et al., 2024; Cuenca-Fernández et al., 2020). For instance, in a study in which squat jumps and push-ups were used as reference measurements, four different PAPE protocols were implemented: four repetitions of the back squat, four repetitions of the bench press and four repetitions of both the back squat and the bench press at 90% of 1RM, together with a control condition where participants were instructed to stand still for four minutes to match the duration of the exercise protocols (Cuenca-Fernández et al., 2020). Interestingly, the PAPE effect was observed across all conditions, including the control condition. This finding suggests that the reference measurements themselves may induce a PAPE effect. Therefore, it is important to allow a longer interval (7–10 min) between the reference tests and the CA in order to mitigate any potential warm-up effects induced by the reference tests (Cuenca-Fernández et al., 2020). Moreover, since the manifestation of the PAPE effect is highly individual-dependent, a participant who performs relatively better on the reference test on a given day may exhibit elevated baseline values, which could obscure the detection of a PAPE effect. As such, conducting multiple reference tests is crucial (Cuenca-Fernández et al., 2020).

As a conclusion, single-set and three-sets of tuck jump exercises did not have any PAPE effect on the 10-m, flying 10-m, 20-m, flying 20-m and 30-m sprint performance. In addition, when individual responses were examined, the majority of participants had a neutral response to all sprint distances. To fully benefit from the application of the CA to induce PAPE, practitioners must consider several factors when selecting exercises, including intensity, volume, recovery time, and individual differences.

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