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Sprint performance following plyometric conditioning activity in elite sprinters

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Abstract

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Keywords

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Article

Sprint performance following plyometric conditioning activity in elite sprinters

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Keywords: post-activation performance enhancement, PAPE, Achilles tendon, ankle joint, jumping, kinematic.

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1. Introduction

Sprint velocity primarily relies on three main factors, which include step frequency, average vertical force applied to the ground, and contact length, i.e. the distance your center of mass translates over the course of one contact period [1]. Sprint performance is a consequence of the forces generated by the lower limb muscles through the hip, knee, and ankle joints [2]. Besides a high degree of strength and power, significant neural coordination is required, which can translate through training into optimal sprinting techniques.

Considering that the rate of force development and the stretch-shortening cycle ability play important roles in determining running speed, the ankle joint may be of great significance to sprinting due to the elastic properties of the Achilles tendon [3]. The Achilles tendon acts as a spring in the athlete's body, returning the energy accumulated during the stretch [4]. Along with the plantar flexor muscles, it forms a tendon-muscle complex that can generate forces exceeding 10–12 times the body mass of the athlete without engaging high-energy substrates [5]. It is quite evident that during the acceleration phase of the sprint, the rate of power development plays a crucial role; yet at top speed, foot contact time is limited to 0.11–0.14s with a dominance of eccentric contractions. Thus training should concentrate on accumulating and generating as much elastic energy through the tendon-muscle complex as possible [6].

An acute performance enhancement in sprinting can be achieved by the use of different training methods and training devices which can be implemented directly before competition or prior to training sessions in which acceleration or top speed are prioritized. In the past few decades, a significant amount of attention in sprinting has been dedicated to post-activation performance enhancement – PAPE) [7–9]. In practical settings, this phenomenon is applied through complex training in which exercises are paired in one set due to their biomechanical similarity. The activating exercise, called conditioning activity (CA), precedes the explosive one and enhances its performance. Most often, this exercise is a heavy resistance exercise performed 2 to 12 minutes before a lighter, similar but more explosive exercise [10]. A significant issue to consider in PAPE research is the sprint distance used during testing and the type of athletes participating in these evaluations. Most team sport athletes are tested over short distances (5–30m) as acceleration is a prerequisite [9, 11–13]. On the other hand, sprinters, long jumpers, and hurdlers are in need of maximal velocity sprinting and are more often tested at 40 to 50 m or during a flying start at 20 to 30 m. As a result of these specific demands and conditions, more explosive CAs have been used in PAPE research in an attempt to enhance sprinting performance, especially maximal velocity sprinting. Numerous authors have proposed and tested plyometric exercises as those provide specific loading necessary to potentiate sprinting [9]. Many plyometric exercises provide high-ground reaction forces and specific movement patterns, similar to sprinting. However previous PAPE results with plyometric exercises such as bounding, jump squats, or tuck jumps have given unequivocal results [11,14,15], which has been mostly explained by the inadequate volume of the applied exercises.

Besides CA and post-CA characteristics, an individual's training background and fitness level are significant PAPE effect moderators. Athletes with well-developed muscle strength and extensive experience in resistance training often have a more prominent manifestation of the PAPE effect [16]. On the other hand, those with less training experience might still experience the PAPE effect, albeit to a lesser degree. However, incorporating such a short bout of plyometric exercises can be part of injury prevention protocols within the warm-up; nevertheless, it is crucial to establish whether it will have a significant impact on the later part of the training.

Considering the significance of the ankle joint for sprinting with the spring-like properties of the Achilles tendon, it seems that plyometric activating exercises could significantly potentiate maximum velocity sprinting. Therefore, the objective of this study was to evaluate the effects of specific plyometric exercises engaging the ankle joint, called stiff-legged hops as a conditioning activity (CA) on countermovement jump (CMJ) and sprinting performance evaluated over a distance of 50m in elite female and male sprinters that differ in athletics level.

2. Materials and methods

2.1. Experimental approach to the problem

A randomized, single-blind, parallel-group intervention was conducted to evaluate the effects of stiff-legged hops on sprinting and countermovement jump performance. Participants were assigned into experimental and control groups, while the experimental group was further equally divided by the 50 m sprint time (ELITE – elite sprinters group; S-ELITE – sub-elite sprinters group). All participants performed pre-CA (5 min before) and post-CA (5 and 10 min after CA) countermovement jumps and 50m sprints. The experimental groups performed 3 sets of 10 repetitions of stiff-legged hops with a 1 min rest interval between sets, while the control group did not perform any activity.

2.2. Participants

Thirty-two sprinters of the Polish National Team (from 100 to 400 m) (males: n=19; age: 21 ± 5 years, body mass: 74.8 ± 7.1 kg, body height: 181 ± 6 cm, 100m best time: 10.59 ± 0.36s and females (n=13; age: 20 ± 3 years, body mass: 57.9 ± 3.8 kg, body height: 169 ± 3 cm, 100m best time: 11.55 ± 0.36s) were selected to participate in this study. The following inclusion criteria were considered: (a) being free from neuromuscular diseases, (b) being a member of the national team, (c) competing in national and international competitions in the previous year, and (d) being involved in sprint training during the previous 12 months. Part of the athletes involved in this study were medalists of international track and field events including European Championships, World Championships and Olympic Games. In order to prevent fatigue, athletes were encouraged not to do any resistance exercises 48 hours before testing, to keep their regular sleeping and eating habits, and to abstain from using any caffeine-containing beverages or supplements. Before giving their written informed consent for participation, athletes were informed of the benefits and possible risks of the project and were given an option to withdraw from the research at any time. The expected outcomes of the study were not disclosed to the athletes. The protocol was approved by the Bioethics Committee for Scientific Research (3/2021) at the Jerzy Kukuczka Academy of Physical Education and performed according to the ethical standards of the Declaration of Helsinki 2013.

2.3. Experimental sessions

To prevent the influence of weather conditions on the study outcomes, testing was performed on an indoor certificated synthetic track. All athletes used their sprint spikes during testing. Athletes were randomly divided into two groups: experimental and control (CTRL). In addition, the experimental group was additionally divided into two subgroups: ELITE and S-ELITE due to the time obtained in the 50 m sprint. One athlete from the ELITE group did not complete the experiment due to an injury. Therefore, there were 9 athletes in the ELITE group, 10 in the S-ELITE and 13 in the CTRL. All of the athletes performed a sprint-specific warm-up that was consistent with participants' normal training habits and then proceeded to perform the baseline measurements: CMJ, followed by the 50 m sprint. Such a set of exercises was performed twice with a 5-minute rest interval. The athletes assigned to ELITE and S-ELITE groups then proceeded to perform a CA consisting of 3 sets of 10 repetitions of stiff-legged hops on a 30 cm height box with a 1 min rest interval. Athletes assigned to the CTRL group did not perform an activation protocol and were resting in time equivalent to the CA. Afterwards, the athletes performed re-test measures in the 5^{th} and 10^{th} min after completing the CA.

2.4. Measurement of countermovement jump performance

The countermovement jump with arm swing was performed on a force plate (ForceDecks, Vald Performance, Australia) with a sampling rate of 1000 Hz, which has been previously confirmed as valid and reliable [21]. Each athlete performed a single CMJ with an arm swing at each time point (four in total). Athletes dropped into the countermovement position to a self-selected depth and immediately followed by a maximal effort vertical jump. The athletes were instructed to land in the same position as the take-off in the midsection of the force plate. The jump height from take-off velocity and relative peak power were evaluated. The best jump before and after CA in terms of height was kept for further analysis.

2.5. Measurement of sprint performance

Sprint times were recorded using timing photocells (Microgate, Bolzano, Italy), with gates at 0, 5, 20, 30, and 50 m. The height was set at approximately 1 m off the ground, corresponding to athletes' hip height, to avoid the timing gates being triggered prematurely by a swinging arm or leg. The subjects started from the crouched position 0.3 m behind the first timing gate to prevent any early triggering of the photocells. The OptoJump–Microgate optical measurement system (Microgate, Bolzano, Italy) was used to measure the kinematic variables of the sprint step: ground contact time, flight time, stride length, step frequency. The measurement system uses a series of interconnected rods (100 cm × 4 cm × 3 cm) fitted with optical sensors. Each rod (RX bars and TX bars) is fitted with 32 photocells, arranged 4cm one from another and 0.2 cm above the ground. The rods were distributed along the length and width of the track (50 m × 1.22 m). Times were measured to the nearest 0.001 s. The fastest 50m sprint time before and after the CA was kept for further analysis.

2.6. Statistical analysis

All statistical analyses were performed using SPSS (version 25.0; SPSS, Inc., Chicago, IL, USA) and were shown as means with standard deviations (±SD) with their 95% confidence intervals (CI). Statistical significance was set at $p < 0.05$. The Shapiro–Wilk and Mauchly's tests were used to verify the normality and sphericity of the sample's data variances, respectively. A one-way ANOVA was used to verify differences in 50 m sprint time between groups. The two-way mixed ANOVA (3 groups [ELITE; S-ELITE; CTRL] × 2 time-points [pre-CA; post-CA] or a nonparametric equivalent test were used to investigate the CMJ and sprint performance. When a significant main effect or interaction was found, the post-hoc tests with Bonferroni correction were used to analyze the pairwise comparisons. The magnitude of mean differences was expressed with standardized effect sizes. Thresholds for qualitative descriptors of Hedges g were interpreted as ≤ 0.20 "small", 0.21–0.79 "medium", and > 0.80 as "large" [22].

3. Results

The Shapiro-Wilk test showed a statistically significant violation of data distribution only for 50 m sprint time.

3.1. Countermovement jump performance

The two-way ANOVA indicated no statistically significant interaction for CMJ height ($F = 1.66$; $p = 0.208$; $\eta^2 = 0.103$) and CMJ relative peak power output ($F = 0.028$; $p = 0.973$; $\eta^2 = 0.002$), nor a main effect of time-point ($F = 0.024$; $p = 0.877$; $\eta^2 = 0.001$ and $F = 0.067$; $p = 0.798$; $\eta^2 = 0.002$; respectively). However, a statistically significant main effect of the group for CMJ height ($F = 5.550$; $p = 0.009$; $\eta^2 = 0.277$) and CMJ relative peak power output ($F = 4.576$; $p = 0.019$; $\eta^2 = 0.24$) was found. The post-hoc analysis showed significantly higher CMJ height ($p = 0.007$; ES = 1.29; 65 ± 9.7 vs 51.6 ± 10.4 cm) and CMJ relative peak power output ($p = 0.016$; ES = 1.1; 84.1 ± 9.5 vs 64.2 ± 14 W/kg) in the ELITE group than in CTRL (Table 1).

Table 1. Changes in countermovement jump performance.

	Pre-CA	Post-CA	ES	Δ [%]
	Jump Height [cm]			
ELITE	64.2 ± 9.5 (57.9 to 70.5)	65.9 ± 10.4 (59.3 to 72.5)	0.16	2.8 ± 7.3%
S-ELITE	57.4 ± 7.4 (51.4 to 63.4)	56.3 ± 6.8 (50.1 to 62.5)	-0.15	-1.7 ± 4.5%
CTRL	51.8 ± 10.3 (46.6 to 57)	51.4 ± 10.9 (46 to 56.9)	-0.04	-0.8 ± 5.3%
	Relative Peak Power [W/kg]			
ELITE	84.1 ± 11 (73.6 to 94.7)	84.1 ± 8.6 (73.6 to 94.7)	0.00	0.5 ± 6.1%
S-ELITE	75.3 ± 7.7 (65.2 to 85.3)	73.2 ± 6 (63.1 to 83.2)	-0.29	-0.3 ± 7.1%
CTRL	64 ± 21.3 (55.3 to 72.8)	64.3 ± 22.5 (55.5 to 73.1)	0.01	-0.7 ± 7.4%

CA – conditioning activity; ES – effect size; ELITE – elite sprinters group; S-ELITE – sub-elite sprinters group; CTRL – control condition.

3.2. Sprint performance

3.2.1. Time

The two-way ANOVA indicated no statistically significant interaction for 5 m (F = 0.957; $p = 0.396$; $\eta^2 = 0.062$), 20 m (F = 0.174; $p = 0.841$; $\eta^2 = 0.012$), 30 m (F = 0.026; $p = 0.974$; $\eta^2 = 0.002$), and 50 m (F = 0.075; $p = 0.928$; $\eta^2 = 0.006$) sprint time. However, a significant main effect of the group for 5 m (F = 6.274; $p = 0.005$; $\eta^2 = 0.302$), 20 m (F = 6.894; $p = 0.004$; η^2=0.322), 30m sprint time (F = 6.853; $p = 0.004$; $\eta^2 = 0.321$) was revealed. Similarly, a statistically significant main effect of time for an increase in 20 m (F = 5.589; $p = 0.025$; $\eta^2 = 0.162$) and 30 m sprint time (F = 6.045; $p = 0.02$; $\eta^2 = 0.172$) was reported. On the other hand, there was no statistically significant main effect of time for 5 m sprint time (F = 0.852; $p = 0.363$; η^2=0.029).

The post-hoc analysis showed a significantly lower sprint time in ELITE sprinters in comparison to the CTRL group at 5 m ($p = 0.004$, ES = 1.36; 0.674 ± 0.054 vs 0.768 ± 0.075 s), 20m ($p = 0.003$; ES = 1.43; 2.46 ± 0.06 vs. 2.66 ± 0.17 s), and 30 m ($p = 0.003$; ES = 1.33; 3.478 ± 0.074 vs. 3.768 ± 0.27 s).

A Kruskal-Wallis H test showed that there was a statistically significant difference in 50 m sprint time between the groups at pre-CA ($\chi^2(2) = 11.436$, $p = 0.003$), as well as post-CA ($\chi^2(2) = 10.554$, $p = 0.005$). Pairwise comparisons showed a significantly lower 50m sprint time in the ELITE group than in S-ELITE ($p = 0.017$; ES=1.34) and CTRL ($p = 0.005$; ES = 2.24) at pre-CA, as well as post-CA ($p = 0.017$; ES = 1.33 and $p = 0.009$; ES = 2.54). A Wilcoxon signed rank test did not show a significant difference between pre-CA and post-CA 50 m sprint time in any group.

Table 2. Changes in sprint time at a particular distance.

	Pre-CA	Post-CA	ES	Δ [%]
	5 m [s]			
ELITE	0.671 ± 0.056 (0.624 to 0.719)	0.677 ± 0.054 (0.635 to 0.718)	0.1	0.9 ± 4.2
S-ELITE	0.739 ± 0.053 (0.694 to 0.784)	0.735 ± 0.063 (0.696 to 0.774)	-0.07	-0.6 ± 4.8
CTRL	0.759 ± 0.086 (0.719 to 0.798)	0.778 ± 0.063 (0.744 to 0.813)	0.24	3.2 ± 7.6
	20 m [s]			
ELITE	2.449 ± 0.065			2.449 ± 0.065
S-ELITE	(2.361 to 2.538)	2.468 ± 0.06		(2.361 to 2.538)
CTRL	(2.385 to 2.551)	0.29	0.8 ± 1.5	(2.385 to 2.551)
	30 m [s]			
ELITE	3.466 ± 0.076 (3.339 to 3.594)	3.489 ± 0.075 (3.366 to 3.612)	0.29	0.7 ± 0.9
S-ELITE	3.665 ± 0.101 (3.544 to 3.786)	3.686 ± 0.098 (3.570 to 3.803)	0.2	0.6 ± 0.9
CTRL	3.759 ± 0.269 (3.653 to 3.865)	3.777 ± 0.259 (3.675 to 3.880)	0.07	0.5 ± 1.7
	50 m [s]			
ELITE	5.404 ± 0.110 (5.195 to 5.614)	5.438 ± 0.108 (5.230 to 5.645)	0.30	0.6 ± 0.8
S-ELITE	5.750 ± 0.181 (5.551 to 5.948)	5.779 ± 0.148 (5.582 to 5.976)	0.17	0.5 ± 0.8
CTRL	5.404 ± 0.110 (5.195 to 5.614)	5.438 ± 0.108 (5.230 to 5.645)	0.30	0.6 ± 0.8

CA – conditioning activity; ES – effect size; ELITE – elite sprinters group; S-ELITE – sub-elite sprinters group; CTRL – control condition.

3.2.2. Kinematic Variables of Sprint

The two-way ANOVA revealed no statistically significant interaction for stride length (F=1.357; p=0.273; η^2=0.086), step frequency (F=0.324; p=0.726; η^2=0.022), ground contact time (F=2.646; p=0.090; η^2=0.169), and flight time (F=2.088; p=0.144; η^2=0.138). Moreover, no statistically significant main effect time-point for stride length (F=1.082; p=0.307; η^2=0.036), step frequency (F=2.002; p=0.168; η^2=0.065), and flight time (F=0.565; p=0.459; η^2=0.021) was reported. However, a statistically significant main effect time-point for ground time contact (F=7.738; p=0.009; η^2=0.211; 0.113 ± 0.010 vs. 0.112 ± 0.011 s) to increase from pre-CA to post-CA was found. Furthermore, no statistically significant main effect of the group for step frequency (F=2.094; p=0.141; η^2=0.126), ground contact time (F=0.315; p=0.732; η^2=0.021), and flight time (F=1.123; p=0.340; η^2=0.080) was indicated. On the other hand, a significant main effect of the group was reported for stride length (F=3.825; p=0.034; η^2=0.209). Post-hoc comparison indicated significantly higher stride length in the ELITE group compared to S-ELITE (p=0.30; ES=1.09; 193.1 ± 9.6 vs 182.8 ± 8.3 cm) (Table 2).

Table 3. Changes in kinematic variables during sprints.

	Pre-CA	Post-CA	ES	Δ [%]
	Stride Length [cm]			
ELITE	193.3 ± 10.3 (187.7 to 199)	192.8 ± 9.5 (187.8 to 197.8)	-0.05	-0.2 ± 1
S-ELITE	183.5 ± 9.0 (177.5 to 189.4)	182.1 ± 8.1 (176.8 to 187.3)	-0.16	-0.8 ± 1.5
CTRL	187.3 ± 7.1 (182.3 to 192.2)	187.7 ± 5.7 (183.4 to 192.1)	0.06	0.3 ± 1.6
	Step Frequency [step/s]			
ELITE	4.62 ± 0.23 (4.44 to 4.8)	4.61 ± 0.22 (4.44 to 4.79)	-0.04	-0.0 ± 1
S-ELITE	4.59 ± 0.21 (4.40 to 4.78)	4.57 ± 0.22 (4.38 to 4.75)	-0.09	-0.5 ± 1.4
CTRL	4.41 ± 0.34 (4.25 to 4.56)	4.39 ± 0.33 (4.23 to 4.54)	-0.06	-0.4 ± 1.3
	Ground Contact Time [s]			
ELITE	0.110 ± 0.011 (0.103 to 0.117)	0.112 ± 0.011 (0.105 to 0.118)	0.17	1.1 ± 2.8
S-ELITE	0.108 ± 0.006 (0.101 to 0.115)	0.110 ± 0.006 (0.103 to 0.117)	0.32	1.8 ± 1.5
CTRL	0.117 ± 0.012 (0.111 to 0.123)	0.117 ± 0.011 (0.112 to 0.123)	0.00	0.1 ± 2.7
	Flight Time [s]			
ELITE	0.107 ± 0.007 (0.102 to 0.111)	0.106 ± 0.006 (0.102 to 0.111)	-0.15	-0.2 ± 1
S-ELITE	0.110 ± 0.006 (0.105 to 0.114)	0.110 ± 0.006 (0.105 to 0.115)	0.00	0.8 ± 1.5
CTRL	0.112 ± 0.007 (0.108 to 0.116)	0.112 ± 0.007 (0.108 to 0.116)	0.00	0.3 ± 1.6

CA – conditioning activity; ES – effect size; ELITE – elite sprinters group; S-ELITE – sub-elite sprinters group; CTRL – control condition.

4. Discussion

The main objective of this study was to verify whether stiff-legged hops contribute to improving sprint time over 50 m and how they affect the kinematic variables of this sprint. In addition, the second aim was to determine whether participants' physical fitness would moderate the magnitude of the PAPE effect. The main finding of this study was that stiff-legged hops had no significant effect on both CMJ and the 50 m sprint performance in both the ELITE and S-ELITE athletes. However, there was a significant increase in 20 and 30 m sprint time, with an increase in ground reaction time in post-CA from pre-CA with no difference between the groups.

Studies on the effect of PAPE on groups of well-trained sprinters are scarce, and those available provide conflicting results. For example, the study by Bomfim-Lima et al. [20] showed improvements in CMJ height and 50 m sprint times after 2 sets of 5 drop jumps from a 75 cm box. In turn, in the study by Pereira et al. [8], the same CA but from a 60 cm box failed to improve CMJ and the 60 m sprint performance. The different results may be related to the fact that participants in the Pereira et al. [8] study appeared to be more trained than those in the Bomfim-Lima et al. [20] study. This might be indicated by differences in CMJ height of 56.1–57.2 cm vs. 44.2–44.1 cm in the Bomfim-Lima et al. [20] study. The results of these studies, as well as the extensive PAPE literature [16,23], might suggest that the fitness level determines the characteristics of the CA. Therefore, Pereira et al. [8] concluded that the volume and intensity of the CA used in their study may not have been sufficient to induce the PAPE effect in such highly trained athletes. Nevertheless, results from the current study did not confirm that. In this study, the CA protocol was different, consisting of 3 sets of 10 stiff-legged hops from a 30 cm box with the purpose of targeting the ankle tendon-muscle complex that is responsible for producing force during running [24]. However, this CA also failed to produce the PAPE effect in both ELITE and S-ELITE sprinters. Therefore, it appears that it was not the fitness level that influenced the obtained results but that the plyometric CAs were unable to induce the PAPE effect. Other studies on sprinters, such as Dechechi et al. [25] and Guo et al. [26] showed improved sprinting after 3 back squats at 90% one-repetition maximum in sprinters. Also, a meta-analysis by Seitz and Haff [16] indicated that well-trained athletes need high intensity instead of high volume CA to experience the PAPE effect, and one set of high-intensity CA is sufficient to produce a significant PAPE effect. Thus, plyometric CAs may be a weak stimulus to elicit a significant PAPE effect in elite and sub-elite sprinters. Nonetheless, the participants in these studies and those included in Seitz and Haff's [16] meta-analysis were not as highly trained as in this study and the one by Pereira et al. [8], thus a confirmation of this thesis requires a direct comparison of different CAs in sprinters of various sports levels.

To the best of the authors' knowledge, this is the first study to evaluate both time and kinematic variables in a 50 m sprint in the PAPE procedure. An insignificant increase in 50 m sprint time and a significant increase at 20 and 30 m were related to the recorded significant increase in ground reaction time. This may indicate an early onset of fatigue, decreased ability for force production, and reduced stretch-shortening cycle utilization. Since no differences were found between the groups, it seems that the reported results were not related to the CA used, and, to a greater extent, to the subsequent sprint and jump attempts. On the other hand, the fact that there were different directions of change in CMJ and sprint performance after the CA is interesting. As mentioned before, one of the most important methodological issues of the PAPE complex includes the selection of pairs of exercises [16, 27]. The chosen pairs of exercises should engage the same muscle groups and have a similar movement structure to be the most effective [16, 27]. Although the differences were insignificant, the ELITE group showed an increase in CMJ height (ES = 0.16; +1.7-cm), while sprint time increased marginally (performance decrement; ES = 0.1–0.30 on particular distances). This phenomenon may be related to the fact that the movement pat-tern of the CA used in this study was more similar to the CMJ than to the sprint, as it was not performed unilaterally. Moreover, the PAPE effect may be less pronounced in movements that require high force production with high frequency than in single movements or very short high-velocity tasks. This can also be seen in the magnitude of variation in sprint time over each distance. At 5 m, the reported performance decrease was the smallest (ES = 0.1) while it gradually increased over the next distances (through 20 to 50 m, ES = 0.29–30). Similar findings were noted by Cuenca-Fernández et al. [28] in 50 m swimming among competitive swimmers. This study showed that the PAPE protocols (arm stroke and lunges performed on either the Smith machine or inertia device) contributed to the improvement of the first 15 m, but with a performance decrease in the subsequent distance, finally resulting in a lack of effects on the 50 m swimming sprint time. The authors found that the PAPE effect may improve the initial period of exercise, but it have a negative effect as it continues. This phenomenon might be related to faster fatigue build-up, due to additional exercise volume related to the CA performed previously. However, more studies involving the assessment of physiological and biochemical fatigue markers are needed to clarify this issue.

On the other hand, the fact that the short plyometric session had no significant impact on jumping and sprinting performance, as well as kinematic variables, highlights the potential feasibility and benefits of including low-volume plyometric exercises focused on ankle joints. Therefore, coaches and individuals may incorporate short-duration plyometric training sessions as part of their warm-up or ankle joint and Achilles tendon injury prevention [29, 30], bearing in mind that this strategy will not compromise sprinting performance.

The results of this study should be interpreted in light of a number of its limitations. Extrapolation of these results to other groups of athletes should be carried out with caution because the participants in our study were highly trained. Moreover, we studied only the effects of plyometric CA and its one setting, thus it is unknown whether other CAs would not be effective in the studied group. In addition, we did not take any physiological measurements, thus we are unable to provide information on what mechanisms underlie the results of this study.

5. Conclusions

The results of this study showed that a plyometric CA, namely 3 sets of 10 stiff-legged hops had no significant effect on CMJ and 50 m sprint time performance among elite and sub-elite sprinters. However, there was a deterioration in sprint time at 20 m and 30 m which was also due to an increase in ground reaction time in both the CA and non-CA groups. Hence, the results of this research do not provide evidence that supports the use of such CA in training or pre-competition contexts. Nevertheless, for the purpose of ankle joint and Achilles tendon injury prevention, it seems that a short-duration plyometric exercise as part of warm-up might be a strategy that will not compromise sprinting performance.

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