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Effects of heavy barbell hip thrust vs back squat on subsequent sprint performance in rugby players

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ABSTRACT: The objective of this research was to compare the effect of Post-Activation Performance Enhancement (PAPE) exerted on the back squat (BS) versus the barbell hip thrust (HT) on the sprint performance (5- and 10-m). 17 male amateur rugby players participated in the study (age 22.14 ± 2.52 years; body mass 81.06 ± 9.6 kg; height 1.78 ± 0.05 m). All participants performed a dynamic maximum strength test (3RM) in BS and HT at maximum speed. Two randomized sessions were performed inducing PAPE using BS or HT trough three series with three repetitions at 85% 1RM eight minutes before the sprint tests. An ANOVA of repeated measurement, found no differences in the time for 5-m ($F = 0.398$, $P = 0.537$, $\eta^2p = 0.024$) or 10-m ($F = 2.589$, $P = 0.127$, $\eta^2p = 0.139$). There were no significant differences in the Protocol effect between HT and BS in 5-m or 10-m ($F = 2.963$, $P = 0.104$, $\eta^2p = 0.156$ and $F = 1.472$, $P = 0.243$ $\eta^2p = 0.084$, respectively). There were also no differences in the Time x Protocol interaction at 5-m ($F = 0.001$, $P = 0.976$, $\eta^2p < 0.001$) or 10-m ($F = 4.174$, $P = 0.058$, $\eta^2p = 0.207$). The effect size obtained in the results of the sprint tests was small in both exercises ($ES < 0.2$). None of the BS or HT exercises performed with heavy load induced a significant PAPE phenomenon on the ability to sprint in rugby players.

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INTRODUCTION

Post-Activation Potentiation (PAP) has been described in the literature as an improved neuromuscular state observed after the execution of high intensity exercise (≥ 80% 1RM) [1]; however, when the effect is greater than 28 seconds and a conditional / athletic / sport ability is evaluated, the term Post-Activation Performance Enhancement (PAPE) should be considered [2]. In particular, improvements in muscle strength production are seen as an increase in the rate of force development during higher-speed dynamic contractions [2, 3]. There are possible underlying physiological mechanisms that could explain this phenomenon, among which it can be highlighted those collected in a recent review [2]: a) changes in myosin light chain phosphorylation; b) increased muscle temperature; c) changes in muscle pH; d) changes in muscle blood flow and/or water content; e) increased neural drive/muscle activation; and f) increased muscle-tendon stiffness. These mechanisms can be achieved through prior muscular action, which seems to require a character close to the maximum in order to enhance subsequent action through the PAPE phenomenon [4, 5].

According to the literature, different types of contractions are valid in order to generate PAPE. However, their characteristics would seem to generate different effects on the enhanced action [6]. When attempting to apply PAPE to improve performance in a competitive environment, the interplay between stimulus and fatigue must be considered to determine the optimal conditions in which stimulus and fatigue can coexist to benefit the athlete's performance becomes challenging [7]. Thus, different types of muscle activations would generate enhancing effects to a greater or lesser extent, and this could be related to the level of neuromuscular fatigue that is produced. The powered state remains for a specified period of time, after which fatigue decreases and provides a "window" during which the athlete may be able to reap the ergogenic benefit of the powered state [7–10]. Since fatigue plays a determining role in the expression of PAPE, it is important to highlight that its presence might affect the potentiation of the subsequent activity in a negative way, that is why an harmonic coordination between optimal dose of maximal or near-maximal contraction and time of the subsequent activity is needed [11–13].

Therefore, much of the research has focused on the biological response and the establishment of the dose-response relationship [1, 7, 14, 15]. Under this point of view, some investigations state that the best way to generate PAPE is related to maximum or close to maximum intensities [16]. It has been widely documented that contractions greater than 80% -85% of the maximum voluntary isometric contraction (MVIC) are an optimal environment for the generation of PAPE [17–19]. In contrast, medium or low intensity programs to generate PAPE have not been able to show significant improvements [15]. The other biological variable in the PAPE is the rest time, that is, there is an appearance of both potentiation and fatigue. However, it seems that the fatigue phenomenon dissipates faster than the potentiation [4]. The relationship between PAPE and fatigue is influenced by a combination of factors, such as volume, intensity and type of conditioning stimulus, type of subsequent activity, the characteristics of the subject, etc. [19]. Therefore, breaks of at least 8 to 12 minutes are suggested as the best recovery time for inducing PAPE [20]. Additionally, the magnitude by which the PAPE develops depends on numerous factors, such as the triggering stimulus, fiber type, degree of fatigue, level of training, sex, age [5, 8, 17].

In addition to the biological perspective, there is a perspective on which less emphasis has been placed in its study, and which may be an influencing factor of the PAPE. The effect that the different degrees of similarity may have on the force vector generated on the conditioning activity compared to the required by the activity to be optimized. In this sense, it is known that there are certain contractions that could show a specific pattern of motor unit recruitment relevant to the angle of the joint and the position of movement; therefore, the phenomenon is specific to the types of contraction that are going to be carried out in the following action [21].

The influence of horizontal force vector exercises on sport specific performance has recently been shown [22]. Despite the fact that there is some specificity of the training responses based on the force vector to train (in this case axial load and posterior-anterior loads), it would seem extremely important to take these differences into account when producing a conditioning stimulus for generate PAPE [23]. In this line, recent studies have highlighted the importance of maintaining the principle of biomechanical specificity [24] or, what is the same, the force vector theory [25–27], however, there is insufficient evidence on whether force vectors could influence the PAPE phenomenon.

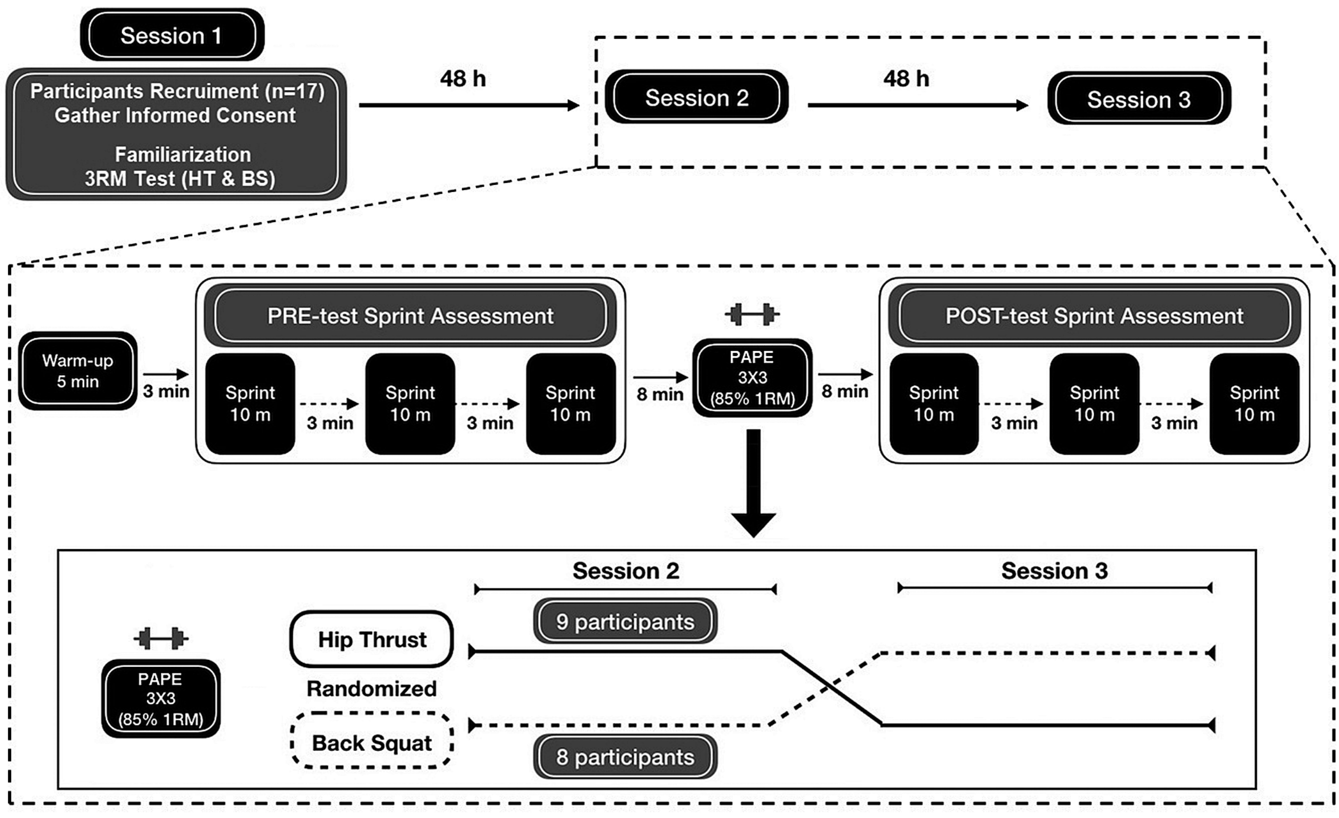

FIG. 1. Schematic representation of the study design.

Thus, it should be emphasized that the effect of PAPE has been studied on activities that require a vertical vector such as jumping and less attention has been paid to the horizontal vector such as horizontal jumps and sprinting. On sprinting performance ability it is one of the most precious athletic qualities in any sport and in rugby it has also demonstrated its importance [28], thus, for example, taking into account the possible specificity of the HT movement with the sprinting gesture [29] as previously suggested by [25]. It can be proposed that being an exercise whose force vector is not completely vertical but includes a more horizontal component than the squat, it could have more specific PAPE results for the sprint activity. Therefore, our main objective was to evaluate and compare the effects of HT with BS with high load on the subsequent ability to sprint in young rugby players. It was established as an initial hypothesis that the HT with high loads will generate a greater effect of PAPE on the ability to sprint than that achieved by the BS.

MATERIALS AND METHODS

Research Design

PAPE is a phenomenon by which previous close-to-maximum muscular contractions allow a higher subsequent performance during a given period of time. However, there is a lack of research regarding the specificity of the PAPE inducing stimulus; therefore, we have chosen two exercises with different biomechanical features – back squat (BS) vs. barbell hip thrust (HT) – to evaluate the improvement on sprint speed. A randomized repeated measures cross-over design was used to evaluate PAPE-induced by BS or HT on sprint performance. In the first visit the subjects performed a dynamic maximum strength test (three-repetition maximum, 3RM) for the BS and HT exercises. After at least 48 hours of rest, the second and third sessions consisted on two consecutive visits to the laboratory. In the second visit, participants were randomly divided into two groups (www.randomizer.org) and then the experimental session to induce the PAPE with the BS or the HT was carried out. The third visit was identical to the second visit but subjects crossed over with respect to the BS and HT. All visits were carried out at the same time and monitored by the same group of researchers (Figure 1).

Participants

Seventeen Argentinian amateur male rugby players (mean ± SD: age 22.14 ± 2.52 years; body mass 81.06 ± 9.6 kg; height 1.78 ± 0.05 m; BMI 25.58 ± 2.59 kg·m^{-2}) with a minimum of two years of experience in strength training participated in this study. All of them were familiar with hip thrust exercises (HT), back squat (BS) and testing procedures. The exclusion criteria were: a) being outside the age range of 18 to 35 years; b) less than two years of experience with high-intensity strength training, specifically with hip thrust and back squat exercises; c) using doping agents (e.g. androgenic anabolic steroids) in the previous two years; d) having suffered a traumatic injury at neuromuscular or musculoskeletal level on the lower limb (e.g. knee or hip) in the previous six months of the study.

Participants were instructed to maintain their nutritional habit before each session, as well as not to exercise or consume stimulants (e.g. coffee) prior to the assessments. Finally, to try to maintain the hydration state of the participants during the experimental session they were allowed to drink water *ad libitum*. Participants were informed about the experimental procedures and the possible risks and signed informed consent. Procedures followed the Declaration of Helsinki [WMA, 30] and its later amendments and were approved by the Research Ethics Committee of the University of Málaga (code: 38-2019-H).

Measures

There were no familiarization sessions for the performed exercises (BS or HT) since the selected subjects proved experience in these movements after the technique assessment of minimum one of the researchers. Only a brief familiarization in the measurement of sprints was made with the use of photocells which consisted of performing three series of ten-meter (10-m) sprint.

Anthropometry

Body mass and stature were recorded using a digital scale ATMA BA7603E (Buenos Aires, Argentina) and a MEDNIB stadiometer (Buenos Aires, Argentina), respectively. All measurements were carried out in the same sports complex and by the same researcher.

Dynamic Maximum Strength Test (3 RM)

A randomized 3RM assessments in the HT and BS exercises (www.randomizer.org) were carried out individually during the first session. Participants performed a general warm-up that included joint mobility and dynamic stretching, mid-zone activation, and specific exercises (e.g., gluteal bridge or squats) [11]. During the initial conditions, the athletes did the same warm-up protocol used during the experimental condition, but without any pre-load exercise (neither BS nor HT). A progression was made to reach 3 RM for both exercises, with a minimum pause of eight minutes between exercises [11, 13], from this 1 RM was estimated [31].

During the technical execution of the BS, a correct posture of the trunk was maintained, feet separated approximately to the width of the hip, with a slight external rotation of the same, avoiding knee valgus, stable support of the foot and, with the bar resting on the upper trapezius, instructions were given to descend until the hip was at the same level as the knee [32]. Confirmation of squat depth was obtained by a research assistant positioned laterally to the subject to ensure accuracy monitoring de degrees flexion using a goniometer. In the HT, participants began the movement lying, resting their backs on a bench with a 49 cm height (Professional Gym, Buenos Aires). Participants used a barbell pad as protection. The bar was placed in the hips crease, between the iliac crests and the anterior superior iliac spine. The knee angle was 90º in the top position, as previously reported [23, 33]. Again, it was encouraged verbally that the thrust would be considered valid once the hip was fully extended.

For this, an expert in resistance training supervised the exercise technique throughout the full movement using a goniometer.

Sprint Test

The sprint assessment test was carried out following the guidelines previously published by [34]. Three measurements of 10-m sprints were made, with data registration at 5- and 10-m by photocells (Winlaborat, Buenos Aires, Argentina), and rest interval of three minutes for each attempt.

The running distance was measured from the starting line (located on the first photocell) to the finish line at 10-m (third photocell), including a mark at 5-m (second photocell). This evaluation has been previously used in [35]. Participants received instructions on the procedure; they were positioned less than a meter from the starting line, feet spread apart in front of each other (high starting position), arms at the side of the body, and semi-flexion of the hip and knees (including a slight forward bending of the trunk). At the sound of an alarm, subjects were instructed that they were ready to start the sprint; time starts once the first photocell is crossed.

PAPE inducing action

The second and third experimental sessions began with a standardized warm-up that included five minutes of stationary cycling as well as dynamic joint mobilization through movements that imitated the exercise to be performed and that therefore included dynamic movements of the hip, knee and ankle [11, 36]. Subsequently, athletes warmed up with a pre-load of 50% of the estimated 1RM for each exercise and, after an eight-minute pause, the enhancing action was carried out, which consisted of executing three sets of 3RM with three minutes of rest between sets of the BS or HT exercise [11, 13, 37, 38]. An experimental drill included three 10-m sprints interspersed with 3 minutes of passive recovery each effort. After last sprint participant rested an 8-minutes after the induced PAPE protocol (HT or HS) followed 10-m sprints interspersed with 3 minutes of passive recovery each effort.

Statistical analysis

Results are expressed as mean and standard deviation (X ± SD). The effect of the exercises on the test times of 5- and 10-m was established through an ANOVA of repeated measurement, for which, according to the study design, the time was established as intra-subject factors, obtained before and after the exercises (*Time*), and the HT and BS (*Protocol*) exercises. The effect size (ES) of each exercise on speed at 5- and 10-m was established with Cohen's *d*. The normality of the data was verified with the Shapiro-Wilk test. A significance level of 0.05 was assumed for all tests. The statistical procedure was performed with SPSS version 25 software IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA)

RESULTS

Subjects baseline characteristics are presented in Table 1.

According to the ANOVA there was no effect considering the *Time* factor for 5-m (F = 0.398, P = 0.537, η^2p = 0.024) or 10-m (F = 2.589, P = 0.127, η^2p = 0.139). Considering the effect of

TABLE 1. Subjects baseline characteristics

Characteristics	X	SD
Age (y)	25.14	2.52
Height (cm)	177.94	5.49
BM (kg)	81.06	9.63
BMI (kg·m^{-2})	25.58	2.59
HT-3RM (kg)	168.09	26.69
HT-1RM (kg)	184.88	29.35
BS-3RM (kg)	134.85	30.80
BS-1RM (kg)	148.32	33.88

Note: BM, body mass; BMI, body mass index; HT, barbell hip thrust; BS, back squat; RM, repetition maximum.

TABLE 2. Sprint assessments after each PAPE exercise protocol

Distance	Group	Before	After	ES	Time			Protocol			Time x Protocol		
					F	P	η^2_p	F	P	η^2_p	F	P	η^2_p
5 m	HT	1.09 ± 0.12	1.10 ± 0.11	0.14	0.398	0.537	0.024	2.963	0.104	0.156	0.001	0.976	0.000
	BS	1.08 ± 0.10	1.09 ± 0.09	0.15									
10 m	HT	1.84 ± 0.18	1.83 ± 0.17	-0.04	2.589	0.127	0.139	1.472	0.243	0.084	4.174	0.058	0.207
	BS	1.84 ± 0.17	1.88 ± 0.19	0.18									

Note: HT: barbell hip thrust BS: back squat.

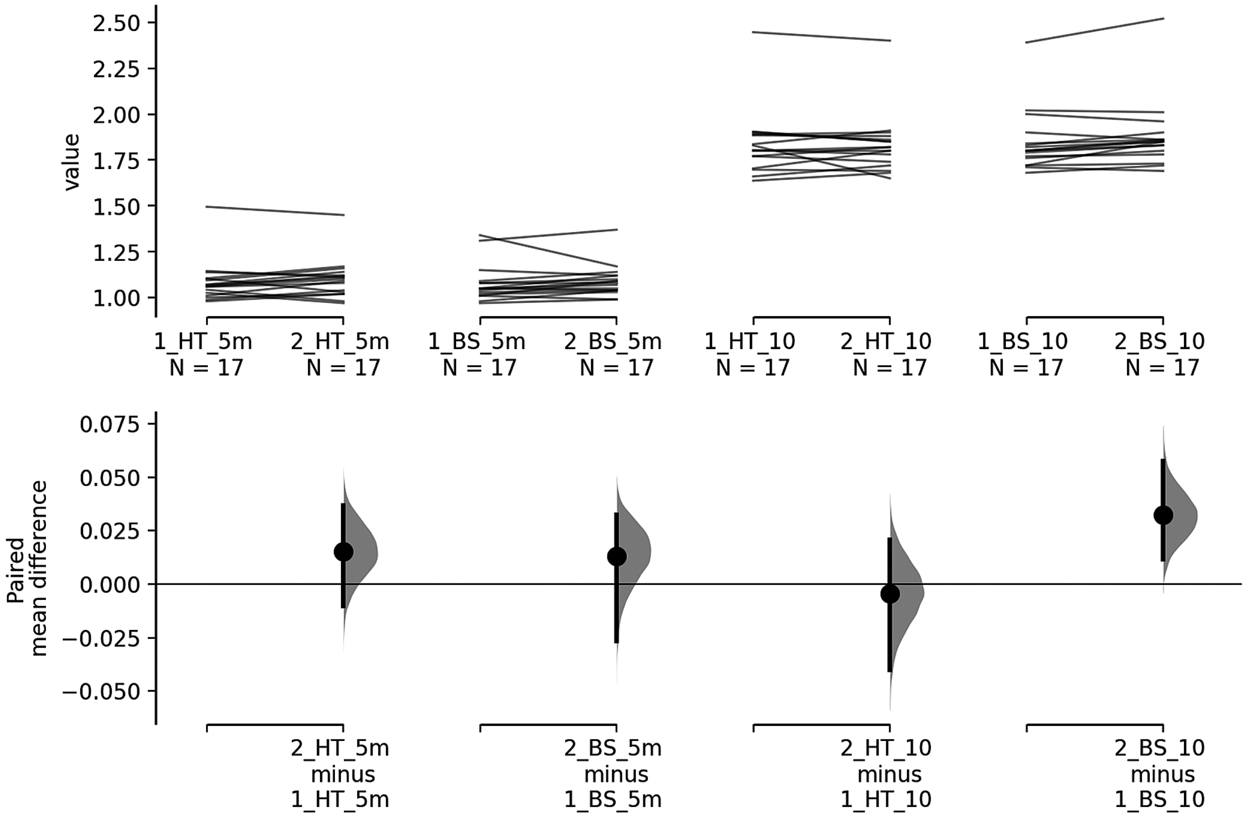

FIG 2. Multi-paired estimation plot. The paired mean differences for the four comparisons are shown in the above Cumming estimation plot.
Note: The raw data is plotted on the upper axes; each paired set of observations is connected by a line. On the lower axes, each paired mean difference is plotted as a bootstrap sampling distribution. Differences of means are depicted as dots; 95% confidence intervals are indicated by the ends of the vertical error bars.

Protocol, there were no significant differences between HT and BS in 5- or 10-m (F = 2,963, P = 0.104, η^2p = 0.156 and F = 1,472, P = 0.243 η^2p = 0.084, respectively). Likewise, there were no differences in the Time x Protocol interaction in 5-m (F = 0.001, P = 0.976, η^2p = 0.000) or 10-m (F = 4.174, P = 0.058, η^2p = 0.207). The effect size obtained on the results of the 5- and 10-m test was small in both exercises (ES = < 0.2). These results are presented in Table 2.

To focus on the magnitude of the individual behavior and to convey important statistical information efficiently, the pairwise comparisons of the results (before and after) of each exercise are presented in a multi-paired estimation plot (Figure 2), which presents a bootstrap 95% confidence interval of the changes on a separate but aligned axes below the raw data [39].

DISCUSSION

The PAPE has been extensively studied after jumping actions, in which a vertical force vector is involved; however, some sports and athletic disciplines require horizontal vectors that condition physical performance [40], although there is less information related to this type of activities. For this reason, this research aimed to compare the effects of PAPE, expressed through the results recorded in the 5- and 10-m sprint tests, using an inducing action of exercise with vertical force vector (BS) versus conditioning exercise with predominantly vertical but also horizontal (HT). Contrary to our initial hypothesis, we did not find greater effect of PAPE on the ability to sprint after HT in comparison to BS. According to the ANOVA, there was no effect of Time, Protocol or the Time × Protocol interaction variable on 5- or 10-m sprint test. In the scientific literature, previous studies have reported that the use of high loads (> 80% of 1RM) and adequate rest (4 to 12 minutes) might cause sufficient PAPE to increase subsequent performance in explosive activities as vertical jump [19, 20]. In relation to the potential influence of the force-vector theory on PAPE, there are few studies; even though the importance of reproducing specific movements to obtain optimal results is well known [21, 41].

In a recent study, [25] reported that the use of HT with 85% of 1RM improve the sprint performance of soccer players after providing four to eight minutes of recovery (ES = 1.22 and 1.59 in 5-m, and 1.01 and 1.39 in 10-m, respectively). In contrast, our study showed small ES (< 0.2) under all conditions and at all times of measurement.

Although strength levels may favor the magnitude of PAPE [7], our results do not support this and did not reveal a positive effect after heavy resistance training as the aforementioned study [25]. Despite the similar mean of HT 1RM in the rugby players that participated in our study, there were important differences in the SD values when comparing to the soccer players in [25]. This might have influenced the results considering that stronger and more powerful individuals are more likely to manifest a greater sprint PAPE response [42]. In particular, a recent review by Seitz & Haff [42] it was concluded that the PAPE depends on greatly on the levels of strength of people and that, in weaker people, a greater volume and lower intensity can induce increases in the PAPE. Additionally, several procedure differences (i.e., 1RM determination) make difficult to compare both studies [13, 44]. This relationship of strength and PAPE magnitude was observed when the strength levels in the BS exercise were compared with those obtained in a previous similar study [37]. Our sample presents 1RM (BS) of 148.32 ± 33.88 kg compared to 170.3 ± 17.3 kg of the mentioned study. The percentage of improvement (calculated as (post-pre)/pre x 100) at 5-m of sprinting was 5.0 ± 1.0% for the study by Bevan et al., compared to 0.92% obtained in ours. Regarding 10-m, the trend was similar, 8.0 ± 1.0% improvement for the study sample of [35] compared to 2.17% worsening of our sample. However, there was a great difference in the experimental procedures since in our methodology we used an eight minutes recovery period while Bevan et al., [35] used 20 minutes. Perhaps the recovery time was insufficient to be able to obtain a significant improvement in the sprint capacity since there was a tendency to show improvement in the *Time x Protocol* in the 10 (p = 0.058) compared to 5-m (p = 0.976). This could be explained by it has been suggested a time recovery above 8 minutes, suggesting 12 minutes or more as the optimal recovery strategy [43]. Finally, we cannot find a PAPE phenomenon and this could be explained because exist a high interindividual heterogeneity and particularly, in the ability to sprint the individual responses to this phenomenon stand out, quantified in 82% of variance [44].

Finally, it should be noted that at present it is known that not only the absolute load is the determining factor of the PAPE magnitude [17] and, therefore, new possibilities are being investigated such as the application of the optimal load considering the load magnitude to determine the number of repetitions proposed by [31].

This study has several limitations and flaws that are important to mention. Firstly, the small sample size and the differences in strength levels between the subjects might have influence in the observed results. Similarly, being aware of the different postulated physiological mechanisms that account for the PAPE phenomenon, the analysis was limited to sprint test; other parameters such as electromyographic analysis or muscle power were not evaluated. Finally, a quality movement study was not carried out in order to analyze possible changes in the running technique that could have influenced the PAPE response.

Future directions to consider include: 1) filming the 10-m sprint assessment to determine possible kinetic changes; 2) adding electromyographic analysis in order to record potential changes; 3) applying the optimized load according to the pattern proposed by [31]; 4) assessing the force-velocity profile as a measurement parameter of the conditioning exercise load to obtain the PAPE and 5) evaluating the absolute and relative power to analyze changes.

CONCLUSIONS

In conclusion, a heavy resistance training protocol (85% 1 RM), with three sets of three repetitions and three minutes of inter-set recovery, in either back squat or hip thrust, did not generated a PAPE response after measuring sprint performance at 5- and 10-m. Thus, this PAPE method appears to be no effective in acutely enhancing sprint performance in rugby players.

Author Contributions

S.V served as the study coordinator. L.C and M.G conceived and designed the experiments. L.C., S.V. served as the lab coordinator. J.B.P. served as project manager. M.G., and L.C assisted in data collection. J.L.P analyzed the data. D.A.A has translated the manuscript. S.V., I.C., J.L.P., D.A.A., L.C., J.B.P., and D.A.B assisted in analysis and manuscript review. L.C., M.G, I.C. and D.A.B wrote the paper. S.V., I.C., L.C., J.L.P., J.B.P., and D.A.B assisted in the statistics advice, discussion analysis, and manuscript preparation. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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