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Human Kinetics
ORIGINAL INVESTIGATION

Continuous Jumps Enhance Twitch Peak Torque and Sprint Performance in Highly Trained Sprint Athletes

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Purpose: The objective of this study was to analyze the effects of a conditioning activity (CA) composed of continuous countermovement jumps on twitch torque production and 30-m sprint times. ***Methods:*** A total of 12 sprint athletes, 10 men (23.5 [7.7] y) and 2 women (23.0 [2.8] y), volunteered to participate in this study. The participants were evaluated in 2 sessions as follows: (1) to determine the effects of the CA (3 sets of 5 continuous vertical jumps with a 1-min interval between sets) on 30-m sprint performance over time (2, 4, 6, 8, and 10 min) and (2) to evaluate twitch peak torque to determine the magnitude and time course of the induced postactivation potentiation at the same recovery intervals. ***Results:*** Mixed-model analysis of variance with Bonferroni post hoc verified that there was a decrease on the 30-m sprint time at 2 minutes ($P = .01$; $\Delta = 2.78\%$; effect size [ES] = 0.43) and 4 minutes ($P = .02$; $\Delta = 2\%$, ES = 0.30) compared with pre when the CA preceded the sprints. The peak torque of quadriceps also showed significant increase from pretest to 2 minutes ($P < .01$; $\Delta = 17.0\%$ [12.2%]; ES = 0.45) and 4 minutes ($P = .02$; $\Delta = 7.2\%$ [8.8%]; ES = 0.20). ***Conclusion:*** The inclusion of CA composed of continuous countermovement jumps in the warm-up routine improved 30-m sprint performance at 2- and 4-minute time intervals after the CA (postactivation performance enhancement). Since postactivation potentiation was confirmed with electrical stimulation at the time when sprint performance increased, it was concluded that postactivation potentiation may have contributed to the observed performance increases.

Keywords: voluntary performance, postactivation performance enhancement, myosin light chains, conditioning contraction

It is known that contraction history contributes to subsequent contractile responses of skeletal muscle,[1] affecting its ability to produce force. One consequence of prior muscle contraction is an increased contractile response for a known activation, traditionally evaluated with electrical stimulation.[2] This increase of intrinsic muscle properties is referred to as postactivation potentiation (PAP), and the prior muscle activity is called conditioning activity (CA).[1] Thus, using CA to induce PAP can theoretically lead to increases in contractile response, and this may lead to a subsequent improvement in voluntary performance, known as postactivation performance enhancement (PAPE).[3–5]

Physical performance may be affected after a CA either positively or negatively, depending on the balance between fatigue and potentiation.[6] From this perspective, several studies have been conducted over the years, testing different CA protocols and their effects on athletic performance.[3,7] Most studies have used maximal voluntary contractions[8,9] or high-intensity dynamic strength exercises as CA.[10,11] However, this type of CA is not easy to perform without specific equipment, limiting its use as a warm-up before competitions. For this reason, CA consisting of continuous countermovement jump (CMJ) protocols emerges as an attractive alternative, as they can be easily performed by athletes just prior to their competition.[12]

Previous research using jump exercises as CA has found positive results on the performance of drop jumps,[13] vertical jumps,[14,15] long jump,[16] supramaximal cycling time-trial,[17] and 1000-m running performance time.[18] However, few studies have tested the effect of these CAs on sprint performance. Till and Cooke[19] found that a single set of 5 vertical jumps did not improve a subsequent 10- and 20-m sprint performance in soccer players. Recent meta-analyses showed that multiple sets appear to be more efficient in increasing athletic performance,[20,21] suggesting that 1 set of 5 vertical jumps is not sufficient (low volume) to trigger positive effects on sprint performance. Conflicting responses after jump-related CA on athletic performance have been attributed to the different CA used, as well as the difference in intensity, volume, and recovery period used.[7]

Thus, in order to complement the available literature, it is necessary to evaluate the effect of multiple sets of continuous CMJs as a CA on sprint performance optimization at different rest intervals after the CA in highly trained sprint athletes. To our knowledge, there are no data in the literature confirming whether CAs composed of continuous CMJs are effective to induce PAP and PAPE in this population. In addition, to verify the PAP time course and its possible contribution to performance optimization, it is necessary to evaluate contractile properties after the CA at the same time intervals where the main performance is tested. It is noteworthy that no study has confirmed PAP in the quadriceps muscles after vertical jumps as CA, and it is not known whether the magnitude of PAP after this type of CA may be related to subsequent performance increases (PAPEs).

Therefore, the objective of this study was to analyze the effects of continuous CMJs as CA composed of multiple sets of vertical jumps on the performance of 30-m sprints over different recovery intervals. In addition, contractile properties will be evaluated to determine the presence or absence of PAP at the same time intervals. The main hypothesis is that the CA will induce PAP on the quadriceps muscles and positively affect the performance of subsequent sprints (PAPE).

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Methods

Subjects

A total of 12 sprint athletes, 10 men (age = 23.5 [7.7] y; height = 177.0 [8.6] cm; body mass = 70.4 [10.1] kg) and 2 women (age = 23 [2.82] y; height = 169.0 [0.7] cm; body mass = 55.5 [0.7] kg) participated in this study. The sample size was calculated a priori based on a statistical power of 0.8, an effect size of 0.5, and an alpha level of $P < .05$, taking sprint performance as a reference variable. A minimum sample size of 11 individuals was obtained (G*Power–software package [version 3.1.9.2], Franz, Universitat Kiel, Germany). We recruited 13 athletes to account for possible sample loss. One athlete was unable to complete the data collections, leaving a final number of 12 individuals. The athletes were exclusively sprinters (specializing in the 100 m), with a personal best time ranging from 10.38 to 11.45 seconds for men and from 11.77 to 11.92 seconds for women. The participants were actively engaged in sprint training 5 days per week, weight training 2 days per week, and had a minimum of 3 years of experience in sprint training, competing at a national level. Athletes who had experienced any musculoskeletal injuries in the past 3 months were excluded from the study. The selected participants were instructed to avoid training during the evaluations, to eat and hydrate similarly at the same time before the tests, and to avoid caffeine-containing drinks for the 24 hours prior to testing. All study participants were informed about the research objectives and the proposed methodology, and then signed the informed consent form. The study was approved by the Federal University of Santa Catarina ethics committee (protocol number 11433319.9.0000.0121) and was conducted according to the Declaration of Helsinki.

Design

The present study was conducted with 2 objectives, as follows: (1) to verify the influence of a continuous CMJ-based CA consisting of 3 sets of 5 vertical jumps (independent variable) on the sprint performance (dependent variable) and (2) to evaluate the impact of this CA on the PAP of the quadriceps muscles through the application of electrical stimulation. This study used a crossover design, with a control condition and an experimental condition, in which the same participants performed both conditions, respecting the same procedures.

The tests were conducted over 4 days. On the first day, the athletes were familiarized with the continuous CMJs (CA), sprints, and application of the electrical stimulus (twitch). On the second and third day (at least 24 h apart), the athletes returned to determine the sprint performance for control (without previous CA) or experimental conditions (with previous CA), in a randomized order. On the fourth day, at least 24 hours after, the time course of the twitch contractile response was evaluated with and without CA.

Procedures

Determination of the Effect of the CA on Sprint Performance. The athletes performed their warm-up and sprint trials on an official synthetic track, in the control condition (without CA) and in the experimental condition (with CA), separated by at least 24 hours. Prior to the tests, a general warm-up was performed, simulating what is usually performed by the athletes before competitions. This general warm-up consisted of 5 minutes of low-intensity running (jogging), followed by specific coordination exercises for up to 10 minutes—3 accelerations of 50 m and 2 maximum effort short sprints (10 m). Four minutes later, 2 maximum 30-m sprints were performed (2-min interval in between) as the pretest measure. In the experimental condition, the CA was included 2 minutes after the second pretest sprint. The CA consisted of 3 sets of 5 maximal continuous vertical jumps, with a 1-minute interval between sets. During the movement, the athletes were instructed to keep their hands on their hips, to flex their knees in the descending phase close to 90°, and to jump as high as possible. Following the CA, the subjects performed maximum sprints at 2, 4, 6, 8, and 10 minutes. These time intervals were selected based on the meta-analyses by Wilson et al[21] and Seitz and Haff,[20] which showed that intervals of up to 10 minutes are adequate to increase power production after a CA. The same procedures were performed in the control condition, but without inclusion of CA. There were 8 minutes between pre and post (ie, at 2 min) for both the control and experimental conditions. Figure 1 illustrates the protocol for the sprints.

The sprints were timed electronically using photocells (Speed Test version 6.0; Cefisa Ltda ME, Nova Odessa, Brazil) at the start, 10 m, and 30 m, positioned at the height of the subject's hip. The participants initiated their sprint at 0.5 m before the first photocell, from a crouched position. The timing started automatically when the athlete interrupted the first light beam and ended when the last light beam was interrupted.

Determination of Twitch Contractile Properties. The participants were positioned on the isokinetic dynamometer (Biodex Medical Systems Inc, Shirley, NY), with the lateral epicondyle of the knee aligned with its axis. The knee was positioned at 70° of flexion (0 = full extension). Inextensible bands fixed the participant's trunk, waist, and thigh. Two self-adhesive electrodes (ValuTrode; Axelgaard Manufacturing Co Ltd, Fallbrook, CA) for surface stimulation were used. The anode (97.5-cm^2 area) was positioned below the gluteal fold and the cathode (circular, 5 cm^2) was positioned in the femoral triangle over the femoral nerve. Rectangular pulses of 0.2 millisecond were applied (Digitimer Ltd, Hertfordshire, United Kingdom) initially with submaximal current and high voltage (400 V). Electrode placement was adjusted to yield the highest twitch torque. After detecting the best electrode position, the current of the electrical stimulation was progressively increased until the highest twitch torque was observed. For this, the stimulus intensity was increased by approximately 15 mA at each 5-second interval until 3 successive increases of current no longer resulted in torque increases.[22] An intensity of 50% above that was then selected for subsequent supramaximal stimulation,[13] thus ensuring the activation of all motor units.

Two conditions were performed to determine the effects of the CA (3 sets of 5 maximal vertical jumps with a 1-min interval between sets) on the contractile properties: twitches at the control (without previous CA) and experimental condition (with previous CA). In the experimental condition, the participants performed the CA and, immediately after, were carefully positioned in the dynamometer chair with the electrodes remaining in the same position. Supramaximal stimulations (150% of maximum current) were applied at the same time intervals (2, 4, 6, 8, and 10 min) to determine the peak torque (Pt) at each of these intervals. During the control measures, the participants remained seated on the dynamometer and were instructed to relax and not voluntarily contract the muscles evaluated during the entire session.

Before the evaluations, the participant remained seated quietly for 10 minutes to allow the dephosphorylation of myosin RLC, and, therefore, dissipation of any PAP resulting from prior activation. This procedure allowed us to test the real effects of

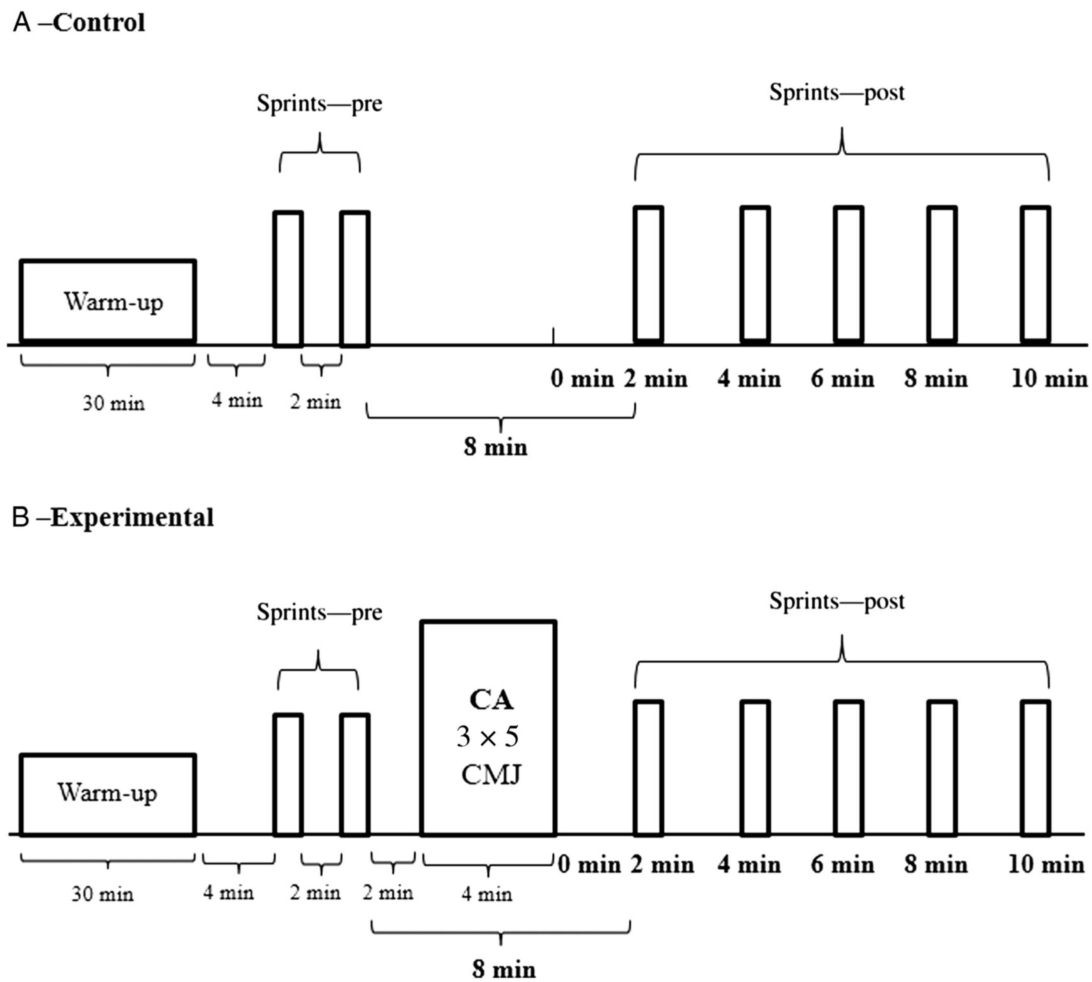

Figure 1 — Experimental design for sprint performance measurement. CA indicates conditioning activity; CMJ, countermovement jump.

a continuous CMJ-based CA on twitch contractile properties and intrinsic muscle force capacities, without interference of warm-up effects and associated increased muscle temperature of any prior walking or muscle contraction, which would generate distorted values, as pointed out by MacIntosh et al.[2]

The presence or absence of PAP was calculated as the percentage difference in magnitude of the peak twitch torque of pre-CA twitch compared with twitches obtained after the CA, as follows: PAP = (Post twitch/Pre-CA twitch × 100). Figure 2 illustrates the protocol design for the twitches in the isokinetic dynamometer.

Statistical Analysis

The reliability of the precondition sprint times was calculated using the intraclass correlation coefficient (2:1), with the following classification: <.50, poor; .50 to .75, moderate; .75 to .90, good; and > .90, excellent.[23] The typical error of measurement (SD of the differences of pre in experimental and control condition/square root of 2) and the smallest worthwhile change for 0.2 (small change) and 0.6 (moderate change) were calculated to test the sensitivity of the variables (by comparing typical error of measurement with the smallest worthwhile change). Mixed-model analysis of variance (time × condition) with Bonferroni post hoc was used for analysis. Data sphericity was tested by the Mauchly tests, and the Greenhouse–Geisser correction was used when necessary. The effect sizes were calculated and classified as small (<0.40), moderate (0.41–0.79), and large (>0.80). The significance level adopted was $P < .05$. Statistical procedures were performed using SPSS (version17.0; SPSS Inc, Chicago, IL) software.

Results

Table 1 shows the reliability and sensitivity results of the sprint-related and twitch variables. Good reliability was observed for sprint performance, especially for the 30-m sprint times. Twitch Pt demonstrated excellent reliability (intraclass correlation coefficient values >.90). In addition, the sensitivity analysis showed that all variables presented typical error of measurement (absolute) smaller than changes of small effect size (ie, 0.2), which means that even the small changes observed in these variables are real and unlikely due to measurement error.

For the 30-m sprint performance (Figure 3B), analysis of variance showed a condition × time interaction ($P < .01$; $F = 3.61$). Post hoc analysis revealed that there was a significant decrease in the 30-m sprint time at 2 ($P = .01$) and 4 minutes ($P = .02$) compared with the pretest value for the experimental condition. In the control condition, no significant differences were found across all times ($P > .05$). Analysis of variance also

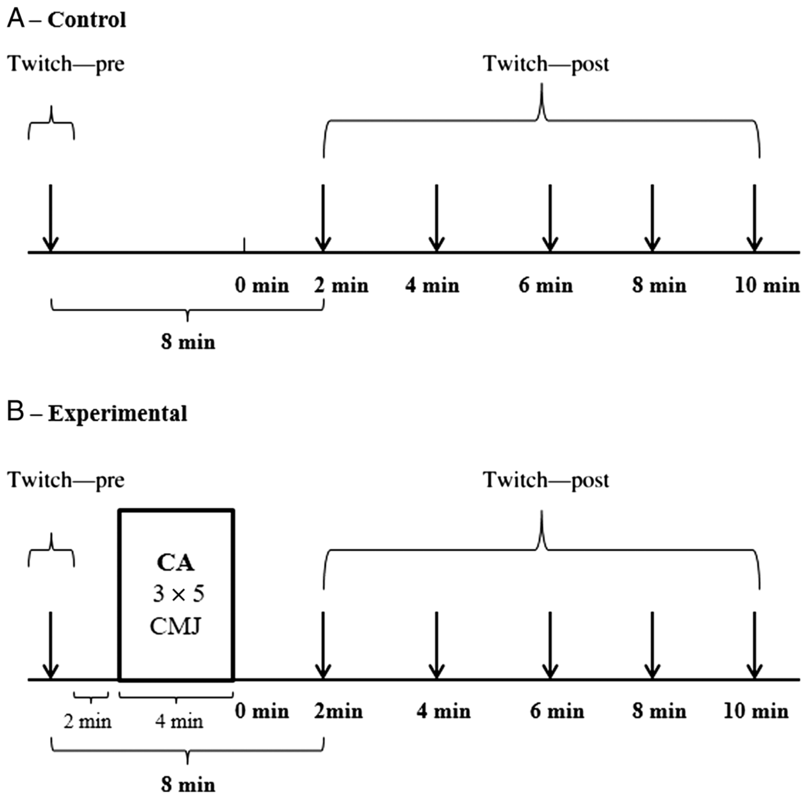

Figure 2 — Control (A) and experimental condition (B) for determination of torque twitch. CA indicates conditioning activity; CMJ, countermovement jump.

Table 1 Reliability and Sensitivity of Premeasurements Between Control and Experimental Conditions for Sprints and Twitch Peak Torque

Measure	$PRE_{CONTROL}$, mean (SD)	$PRE_{EXPERIM}$, mean (SD)	ICC (95% CI)	TEM (95% CI)	TEM (%CV)	$SWC_{0.2}$	$SWC_{0.6}$
Sprint time 0–10 m, s	1.676 (0.127)	1.731 (0.151)	.72 (.38 to .93)	.018 (.014 to .041)	1.11%	0.027	0.083
Sprint time 0–30 m, s	3.990 (0.239)	4.046 (0.266)	.89 (.68 to .97)	.037 (.018 to .045)	0.93%	0.050	0.151
Twitch Pt, N·m	43.52 (14.26)	41.72 (13.67)	.99 (.92 to .99)	.39 (.28 to .66)	0.91%	2.79	8.38

Abbreviations: CV, coefficient of variation; ICC, intraclass correlation coefficient; Pt, peak torque; SWC, smallest worthwhile change (0.2 = small changes; 0. 6 = moderate changes); TEM, typical error of measurement.

showed a condition × time interaction for the 10-m sprint performance ($F = 3.04$; $P = .01$; Figure 3A), with post hoc revealing a difference between 4 and 10 minutes ($P = .02$) in the experimental condition, indicating that the times were increasing over time in this condition. In the control condition, no significant differences were found for any interval ($P > .05$).

Table 2 shows the percentage changes and the effect sizes, comparing the pre values with each time interval for the 30-m sprint performance (the sprint distance for which significant differences were found). We observed moderate effect sizes at the 2-minute interval for the experimental condition.

Regarding the effects of the CA on PAP (ie, effects on Pt), there was a significant condition × time interaction ($P < .01$; $F = 25.64$), indicating that the effects over time were different between conditions (Figure 4A). In the control condition, there was no difference at any time ($P > .05$) compared with pre. On the other hand, in the experimental condition, post hoc analysis verified a significant increase from pre to 2 ($P < .01$) and 4 minutes ($P = .02$), demonstrating that twitch Pt remained elevated for 4 minutes after the CA. The twitch Pt of each condition (PAP magnitude) is expressed as a percentage of pretest values (Figure 4B).

Discussion

The aim of this study was to evaluate the effects of a CA composed of continuous CMJs on 30-m sprint performance and on the appearance of PAP at different recovery intervals: 2, 4, 6, 8, and 10 minutes. The main finding was that continuous CMJs as CA significantly improved the 30-m sprint performance (PAPE) at 2- and 4-minute intervals, but not at the other times assessed. In addition, at 2 and 4 minutes, there was an increase in twitch torque (PAP) of quadriceps muscles evaluated with electrical stimulation, indicating greater twitch force for a given stimulation. Thus, the hypothesis of the study was confirmed, indicating that CA can induce PAP in the quadriceps muscles and positively affect sprint performance in highly trained sprinters.

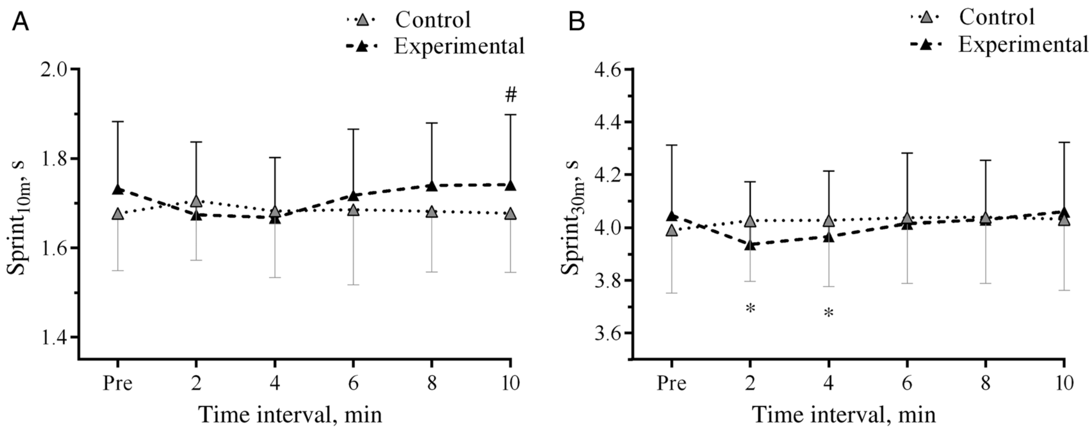

Figure 3 — Comparison of sprint times between conditions and time intervals. (A) 10-m sprint and (B) 30-m sprint. *Difference from pre values. #Difference from 4-minute interval values.

Table 2 Descriptive Values (Mean [SD]), Δ%, and ES of 30-m Sprint Performance for Control and Experimental Conditions

Measure	Pre	2 min	4 min	6 min	8 min	10 min
Control	3.991 (0.23)	4.026 (0.23)	4.026 (0.25)	4.037 (0.24)	4.039 (0.25)	4.032 (0.26)
Experimental	4.046 (0.26)	3.937 (0.23)	3.967 (0.247)	4.015 (0.26)	4.030 (0.22)	4.060 (0.26)
		Pre vs 2 min	**Pre vs 4 min**	**Pre vs 6 min**	**Pre vs 8 min**	**Pre vs 10 min**
Control	Δ%	+0.87	+0.89	+1.14	1.19	+1.01
	ES (95% CI)	0.15 (−0.02 to 0.28)	0.14 (−0.05 to 0.31)	0.18 (−0.03 to 0.37)	0.19 (−0.01 to 0.37)	0.16 (−0.03 to 0.33)
Experimental	Δ%	−2.78	−2.00	−0.77	−0.40	+0.33
	ES (95% CI)	0.43 (0.19 to 0.68)	0.30 (0.18 to 0.42)	0.11 (−0.06 to 0.27)	0.06 (−0.18 to 0.31)	0.05 (−0.07 to 0.17)

Abbreviations: CI, confidence interval; ES, effect size; Δ%, percentage changes from pretest.

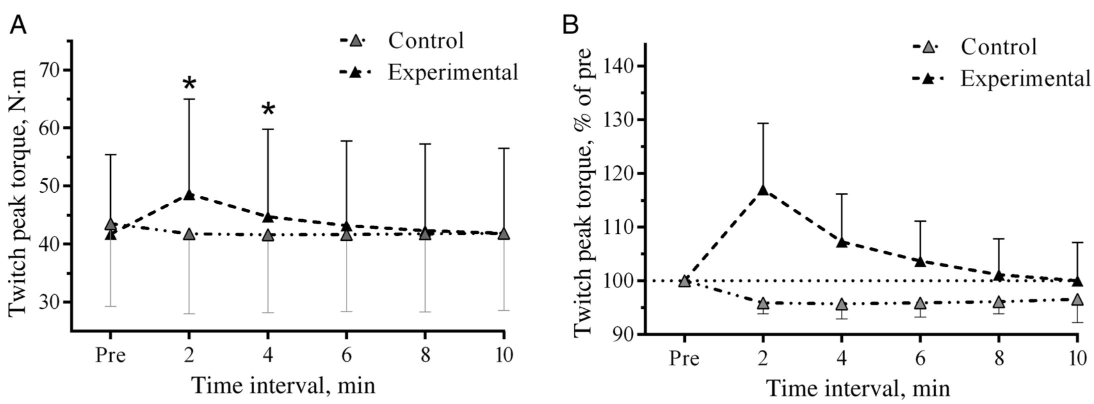

Figure 4 — Variation of twitch peak torque for control and experimental condition at each time interval. (A) Absolute values (N·m). (B) Values expressed as percentage of pretest at each subsequent time. *Difference from pretest values.

It has been shown that type II fibers demonstrate higher levels of phosphorylation and consequently higher PAP magnitude after a CA.[24] The reason is the greater activity of the enzyme myosin light chain kinase that regulates phosphorylation in type II fibers of the vastus lateralis[25] than in type I fibers. This partially explains the higher PAP verified for athletes involved in sports, which requires elevated power, compared with endurance athletes.[26] In the present study, the confirmation of PAP (augmented twitch Pt) in the quadriceps muscles with electrical stimulation and the positive performance results obtained at 2 and 4 minutes (faster 30-m times) suggests that this population (sprinters—power athletes) is very responsive to the effects of a CA.

Until the present study, PAP and consequent PAPE in sprints in highly trained sprint athletes using vertical jumps as CA had not been confirmed. In fact, only 2 recent studies measured twitch Pt to confirm PAP after a jump-based CA.[13,22] However, Johnson et al[22] did not check the PAP influence on subsequent voluntary performance, and Bergmann et al[13] tested the influence of 10 maximal hops only on drop jump rebound height, leaving doubt about whether PAP could actually contribute to improvements in a more complex sport activity, like sprinting. In the present study, the PAP of the quadriceps muscles was confirmed at 2 and 4 minutes after the CA (17.04% [12.26%] and 7.26% [8.89%], respectively), the same time intervals at which sprint performance enhancements were found (2.78% and 2.0% at 2 and 4 min, respectively). This suggests that the PAP phenomenon may have an influence on the performance enhancement (PAPE) observed.

Recently, an interesting point of view emerged, presenting the possibility of the participation of the PAP phenomenon in long-term performance.[27,28] Since the PAP mechanism is more evident in low calcium concentrations,[29] it was speculated that PAP could contribute to enhanced long-term submaximal exercise.[30] This line of investigation dictates that, if the levels of fatigue in a sport or activity are relatively lower than the levels of PAP, not only athletes performing maximal activities will benefit, but athletes performing submaximal activities could also benefit from this mechanism.[27,28,30] This was seen in the study by Low et al[28] in which the authors used loaded squat jumps as CA, with increased endurance performance observed. They found enhanced contractile force (PAP) and theorize that the increased muscle performance was possible as PAP overcame the onset of fatigue in sustained exercise; this would act like a mechanism to prolong endurance activities. However, more research is needed to better clarify the role of PAP in prolonged sustained exercise.

The results from the present study appear to be consistent with several other studies in which enhanced sprint performance has been reported after a CA.[12,31,32] However, these other studies have not confirmed the presence of PAP at the time of the PAPE. In fact, some of these studies observed PAPE at a time when PAP would not be expected. This suggests that enhanced sprint performance after the CA can occur by other mechanisms, such as temperature increases,[33] increases in the circulating concentration of testosterone,[11] increased excitability of motoneurons,[7] increased recruitment of motor units,[7] acute elevations in plasma catecholamine levels,[34] learning effect, and familiarization with the main task.[2] Therefore, it is important to keep in mind that PAPE may have occurred in this study due to these mechanisms in conjunction with PAP, and not PAP alone.

An important aspect to be highlighted is that each sprint could generate additional PAP (or fatigue), which would affect the subsequent sprint. However, it was observed that the sprint performance did not change over the sprints in the control condition, showing that the CA was responsible for inducing changes in sprint performance in the experimental condition. However, the changes were found only for the 30-m sprint times, while changes for 10 m did not reach significance. In spite of this, the time difference for 10 m was nearly as large as the time difference for 30 m; the higher speed at 10 m in the experimental condition may have contributed to making the overall difference significant for 30 m.

It can be speculated that the general warm-up performed prior to sprint exercise may have potentiated muscle (increased Pt) and be responsible for the improvement observed. However, there were no improvements in sprint performance in the control condition without the addition of the CA (Figure 3). This demonstrates that the general warm-up used here was not responsible for the improvements observed, since only in the experimental condition (where athletes performed both warm-up and the CA) was performance improved. Therefore, as the only difference between the control and experimental condition was the addition of the CA, which optimized the contractile properties (confirmed by Pt), it can be speculated that, somehow, the phosphorylation of myosin regulatory light chain and the magnitude of PAP (8%–17%) may have been contributing in the PAPE observed.

Positive PAP effects have been observed only when there is an optimal recovery interval between the CA and evaluation of the twitch response. This interval must allow recovery from the fatigue generated by the CA while the increased contractile response, reflected by enhanced Pt, is not dissipated.[7] Studies that sought to verify the effects of jump-based CA on PAPE found positive results at recovery intervals ranging from 0 to 15 minutes after the CA.[12,31,32] The PAP after a jump-based CA was dissipated, usually within 6 minutes after drop jumps in the quadriceps muscles[22] and after 4 minutes after our CA protocol of 3 sets of 5 maximal vertical jumps. Therefore, PAP was no longer present when PAPE was found in some of these studies. This shows the importance of evaluating twitch contractile properties to guarantee the presence of PAP, since PAPE could be achieved via several mechanisms, as discussed above. Furthermore, the recovery interval must be carefully selected, since this interval depends on the type of CA and the training level of the subjects evaluated.[20] In the present study, the positive results at 2 and 4 minutes indicate that these recovery intervals are ideal for increasing the contractile response of the muscles when 3 sets of 5 vertical jumps with a 1-minute interval were used as CA in trained sprinters.

The CA volume is also an important factor when considering PAPE. Low jump-based CA volumes have already been shown to have no effect on sprint performance,[19] while volume greater than 10 jumps seems to decrease the sprint time.[12,31,32] However, these improvements occur predominantly at times when PAP would not be present. In our study, 15 jumps (3×5) was enough to generate PAP and also improvements in sprint performance, demonstrating that this volume of jumps seems to be enough to trigger positive responses at 2- and 4-minute recovery intervals. The magnitude of PAP (ie, twitch Pt) in the quadriceps muscles after our protocol (17.0% [12.2%] and 7.2% [8.8%] for 2 and 4 min, respectively) is lower compared with previously reported twitch enhancement after jump-based CAs in the literature. Johnson et al[22] found increases of 23% immediately after drop jumps, and Bergmann et al[13] found 32% enhancement 30 seconds after 10 maximal hops as CA.

Lately, it has been found that the training level of the subjects tested seems to influence the manifestation of the positive effects of CAs.[6] The main explanation is due to the improved ability to activate large motor units that increase with training time, affecting the amount of PAP generated.[7] Theoretically, in addition to more PAP, athletes with more training and greater strength may also demonstrate less fatigue after performing a CA compared with sedentary subjects,[6] resulting in a greater advantage. As previously discussed, it is suggested that strength level and increases in performance are due to a higher proportion of type II fibers in strength- and power-trained athletes, which leads to a greater PAP magnitude.[24] Due to this, highly trained power athletes could be more positively affected by PAP effects than other populations. Indeed, the small changes in performance related to the use of CAs are more interesting especially for elite athletes, due to the similar level of performance observed in competitions. In our study, a decrease of approximately 2% in 30-m sprint time was observed, which may represent an important change for sprint-running performance, especially in highly trained athletes. However, future studies should be conducted to investigate whether these results are observed for a race with official distances (eg, 60- or 100-m dash).

Some limitation can be highlighted in this study. The first one is that the assessment of the contractile properties and sprint performance was in different sessions, considering that it was very difficult to apply supramaximal twitches in the track-and-field free-living environment. Another possible limitation was that we provided only a 24-hour interval between the sprint assessments (control and experimental conditions). We also point out that the several sprints over time during the evaluations could have added some potentiation effect; that is, the first sprint could affect the next one, and so on. On the other hand, this problem may have been minimized by using the control condition (ie, no previous CA), in which no difference was found in sprint performance at any time interval. Finally, we provided 8 minutes of rest in the control condition between the last sprint of pre-CA and the first sprint post-CA. This time without any activity might reduce the muscle temperature to some degree and cause dephosphorylation of myosin light chain. In future studies, a low-intensity exercise could be used to maintain muscle temperature during the rest period. In twitch verification protocol, we suggest that future studies also use a low-intensity warm-up before the CA, aiming to verify whether the low-intensity exercise associated with continuous CMJ-based CA has additive effects.

Practical Applications

The present study shows that a simple continuous CMJ protocol that can be performed easily before competition was found to induce PAP and improve 30-m sprint performance. As both CMJs and sprinting include a stretch-shortening cycle, it can be speculated that matching the nature of the CA with the main performance task seems to be a good way to use the benefits of a CA in a sporting context. Furthermore, since this type of CA activates multiple muscle groups and does not require a specific skill set and techniques, it is very practical for sport coaches and conditioning specialists to use with their athletes before competitions or during training sessions. One should only be aware that the contractile properties remained enhanced only for 4 minutes after 3 sets of 5 vertical jumps, during which, sprint performance was also improved. The protocol used in our study could be beneficial not only for track and field athletes, but also for team sports where sprints are performed, like soccer, football, rugby, and so forth. In these circumstances, athletes may include continuous CMJs as CA to induce PAP at the appropriate moment before a key task, given that PAP dissipates in about 4 minutes, after which, the possible performance improvement (PAPE) due to this phenomenon is lost.

Conclusion

In summary, it was verified that the use of previous sets of continuous CMJs enhances muscle function (PAP) and allows acute sprint performance improvement (PAPE). It was verified that 3 sets of 5 vertical jumps as CA generated approximately a 2% to 3% improvement in the subsequent 30-m sprint performance at the 2- and 4-minute recovery intervals. The confirmed increase in twitch Pt of quadriceps muscles in these same time intervals suggests that sprint performance enhancement may be related to the PAP phenomenon in the quadriceps muscles. However, we cannot assume a cause-and-effect relationship, as other PAPE mechanisms may also have been involved in the observed sprint performance enhancement in conjunction with PAP.

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