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Effects of Isometric and Dynamic Postactivation Potentiation Protocols on Maximal Sprint Performance

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Abstract

Lim, JJH and Kong, PW. Effects of isometric and dynamic postactivation potentiation protocols on maximal sprint performance. *J Strength Cond Res* 27(10): 2730–2736, 2013—This study examined the effects of 3 types of postactivation potentiation (PAP) protocols (single-joint isometric, multijoint isometric, and multijoint dynamic) on subsequent 10-m, 20-m and 30-m sprint performance in 12 well-trained male track athletes (mean ± *SD* age = 22.4 ± 3.2 years). The subjects performed 4 protocols in a randomized order on different days as follows: control (4 minutes of passive rest), maximum voluntary isometric knee extension (3 repetitions of 3-second isometric knee extension), maximum voluntary isometric back squat (3 repetitions of 3-second isometric squat), and dynamic back squat (3 repetitions of back squats at 90% 1 repetition maximum). After each protocol, a 4-minute recovery period was incorporated before a 30-m maximal sprint assessment. Maximal sprint times at 10 m, 20 m, and 30 m were measured using timing gates to reflect sprint performance. One-way repeated measures analyses of variance revealed no differences in sprint performance among the 4 protocols at 10-m, 20-m, or 30-m intervals. There were, however, large individual variations in the response to the PAP protocols with some athletes benefiting from the PAP effect and others not. In summary, this study showed no enhancement of short-distance sprint performance after PAP protocols with a 4-minute recovery period, regardless of isometric or dynamics, single-joint or multijoint. Coaches considering the use of PAP protocols to improve sprinting performance of their athletes should exploit the effectiveness of different PAP protocols on an individual basis.

Key Words knee extension, squat, athletic, single joint, multijoints, complex training

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Introduction

Optimal training protocols to maximize strength and power performance are greatly sought after by athletes, coaches, and strength and conditioning professionals. As sports evolve to become more competitive, there is an increased demand for athletes to perform to their maximum physical potential. Therefore, developing optimal training protocols that will maximize athletic performance has received considerable attention. The use of strength-power potentiating complexes is one such training method to develop explosive strength in athletes (27). This involves muscular contractions of near-maximal loads, before performing an explosive movement with similar biomechanical characteristics (12,19). This training technique takes the advantage of postactivation potentiation (PAP) to increase the rate of force development that would lead to an increase in acceleration and velocity (3,13,30). Postactivation potentiation refers to the enhanced neuromuscular condition observed after an initial bout of heavy resistance exercise (27,32). Both acute and chronic gains in muscular strength and power may be further enhanced by performing an explosive exercise, whereas the affected muscle groups are in the potentiated state (32).

Past research had shown that utilizing a previous contractile activity, dynamic contractions or isometric maximal voluntary contractions (MVC), was able to augment a subsequent athletic performance. These enhanced performance measures included the vertical jumps (16,28), horizontal jumps (21), and drop jumps (9,10). However, relatively less is known about the effects of PAP on sprint performance. Using a dynamic PAP protocol, a significant improvement (0.87%) in 40-m sprint performance was reported after 3 repetitions of back squats at 90% of 1 repetition maximum (RM) (19). Similar improvements in short-distance sprint trials were also reported after 10 sets of 1 repetition of back squats at 90% of 1RM (5) and after progressive sets of submaximal intensity back squats (30–70% of 1RM) (35). Others have found mixed results (18) or no PAP effect on sprint performances (28).

Most studies on sprinting utilized dynamic PAP protocols (4,5,7,17,22,28,35), with some utilizing a single-joint isometric knee extension protocol (23,28). Isometric contractions were reported to activate more muscle fibers than dynamic contractions, and this might result in greater percentage of regulatory light chain phosphorylation and greater changes in muscle architecture (8,29). The type of muscle contraction would induce different neuromuscular fatigue (1,15,29), with dynamic contractions resulting in an earlier onset of peripheral fatigue than isometric contractions due to lactate accumulation (14). To date, it remains unclear whether an isometric or dynamic PAP protocol is superior in enhancing subsequent performance as there are limited studies directly comparing the 2 contraction modes (8,29). One study reported an increase in countermovement jump height (2.9%) after three 3-second isometric MVC back squats but no improvement after a 3RM dynamic back squats (24). This preliminary evidence suggested that isometric protocols might induce a greater PAP response than dynamic protocols, though the 2 conditions used in this study were not matched with respect to volume or frequency, and therefore make it difficult to compare the PAP effects directly. Thus, there is a need to clarify whether isometric contraction is more effective than dynamic contraction in inducing PAP effect on subsequent sprint performance.

Sprinting involves powerful extensions of the hip extensor, knee extensor, and plantar flexor muscles (20,37). Thus, the implementation of an isometric MVC that involves multiple joints may be a more effective warm-up routine for sprinting performance than a single-joint MVC. The patterns of motor unit recruitment differ between single-joint and multijoint actions, thus the resulting activation patterns may affect subsequent PAP effects (36). To our knowledge, there is no study comparing the effect of single-joint and multijoint isometric PAP protocols on subsequent sprint performance. Thus, the aim of this study was to investigate the effects of 3 different types of PAP protocols (single-joint isometric, multijoint isometric and, multijoint dynamic) on subsequent maximal sprint performance. It was hypothesized that (a) isometric protocols would induce better sprint performance compared with the dynamic protocol, and (b) the multijoint isometric protocol would be superior to the single-joint isometric protocol.

Method

Experimental Approach to the Problem

This study used a within-subject randomized cross-over design to approach the research problem. To minimize the effect of possible confounders such as sex, training status, and training type, a homogenous group of well-trained male sprinters were recruited. Subjects performed 3 PAP and a control protocol on 4 different days. A maximum voluntary isometric knee extension protocol was chosen to represent single-joint isometric contraction, maximum voluntary isometric back squat for multijoint isometric contraction, and dynamic back squat for multijoint dynamic contraction. Maximal sprint times at 10 m, 20 m, and 30 m were measured using timing gates to reflect sprint performance. Data were analyzed to determine the effect of different isometric and dynamic PAP protocols on subsequent sprint performance in well-trained male sprinters.

Subjects

This study was approved by the Nanyang Technological University Institutional Review Board and was performed in accordance with the Helsinki Declaration. All subjects were informed of any risks associated with participation in the study and were free to withdraw if they desired. Subjects signed a written informed consent form before participating in any of the testing procedures. Data collection was conducted at the training facility at the Singapore Sports Council. Twelve well-trained male sprinters, competing in 100-m, 200-m, and 400-m track events at both the national

Table 1. Subject ($n = 12$) anthropometry, personal best sprint times, and strength characteristics.

Subjects	Age (yrs)	Height (cm)	Body mass (kg)	100 m (sec)	200 m (sec)	400 m (sec)	1RM (kg)	1RM:BM
1	21.4	175.5	64.5	10.70	21.86		130.0	2.02
2	25.1	171.0	64.1	10.62	21.74		120.0	1.87
3	20.3	170.3	63.8	10.78	22.04		130.0	2.04
4	19.7	185.5	78.2			53.59	130.0	1.66
5	22.6	169.5	74.5	10.90			155.0	2.08
6	29.5	175.5	69.8			48.70	110.0	1.58
7	20.2	172.5	70.7		22.34	49.10	135.0	1.91
8	19.5	174.5	61.2	11.30	23.27		102.5	1.67
9	18.8	180.4	66.9		22.05	47.97	102.5	1.53
10	25.2	171.1	64.1	10.73	22.23		120.0	1.87
11	24.8	175.5	71.5	10.97	21.53		142.5	1.99
12	21.7	173.5	62.0	11.41	23.76		115.0	1.85
Mean	22.4	174.6	67.6	10.93	22.31	49.84	124.4	1.84
SD	3.2	4.6	5.3	0.29	0.73	2.54	15.9	0.19

1RM = absolute back squat; 1RM:BM = relative 1RM back squat.

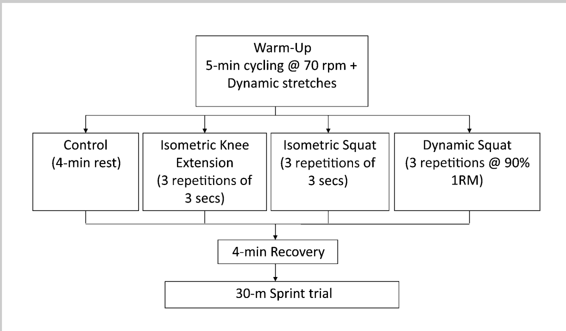

Figure 1. Flow diagram of experimental protocols of control, isometric knee extension, isometric squat, and dynamic squat before sprint tests. Both isomeric protocols involved maximal effort, whereas the dynamic protocol involved submaximal effort at 90% of 1 repetition maximum.

and club levels, were recruited for the study (Table 1). At the time of the study, the subjects were training at the precompetition phase, which was 1.5 months before the Southeast Asian Games. All subjects had at least 12 months of resistance training experience and were able to perform a minimum of 1 back squat with a load greater than 150% of the subjects' body mass. A physical activity and medical questionnaire was administered to determine training history and to inquire about any medical contra-indications.

Procedures

The overview of the experimental design is outlined in Figure 1. Subjects participated in one baseline test session and then completed 4 main protocols on different days. After each main protocol, maximal sprint times at 10 m, 20 m, and 30 m were recorded to reflect sprint performance. All testing sessions were separated by at least 48 hours, and subjects were asked to maintain their normal training and dietary habits throughout the study.

Baseline Test

The baseline test was used to familiarize subjects with the experimental set up and to assess their maximal strength level. Before testing, the height and weight of the subjects were measured. The order of maximal strength testing was the knee extension MVC, isometric squat MVC, and 1RM dynamic back squat, respectively, as isometric contractions were associated with lower metabolic cost and less fatigue in comparison to dynamic contractions of the same duration (24). All tests were separated by 10 minutes to minimize fatigue.

For the isometric MVC tests, subjects were instructed to perform 3 sets of 3-second maximal isometric contractions, with a 2-minute rest period between sets. Subjects first performed maximal bilateral isometric knee extensions against the lever arm of a leg extension machine (Nautilus Sports/Medicine Industries, Inc., Dallas, TX, USA). Subjects then performed maximal isometric back squats on a force platform (400 series, Fitness Technologies, Adelaide, Australia) against a barbell secured across the FT700 power cage (Fitness Technologies). Peak force and rate of force development for the isometric back squat were obtained from the force data. These isometric MVC values served as baseline measurements to ensure maximum effort by the subjects in the main PAP protocols.

The 1RM back squat strength for each subject was determined according to standard practice outlined by the National Strength and Conditioning Association (2). A 1RM lift was deemed successful if the top of the thigh is parallel to the ground at the lowest point of the squat and finished at the apex with a complete range of motion. The safety squat device (Bigger Faster Stronger, Incorporated, Salt Lake city, UT, USA) was used to ensure that each participant archived a proper squat position. This device was placed on the anterior portion of the widest girth of the thigh and would emit a "beep" sound when the subject squatted to correct depth, corresponding to it being angled parallel to the ground. The 1RM value determined was used to calculate approximately 3RM (90% 1RM) values for use in the dynamic squat protocol during the main PAP trials.

Main Protocol Trials

Subjects reported to the laboratory on 4 different days separated by at least 48 hours apart (Figure 1). On each day, they warmed up on a cycle ergometer (Monark Ergomedic 828E, Varberg, Sweden) at 60 watts for 5 minutes at a cadence of 70 rpm. This was followed by a standardized dynamic warm-up stretches (leg swings, butt kicks, high knees, and pogo hops; 2 sets of 10 repetitions each). The subjects then performed the control or one of the 3 PAP protocols, with the orders of the protocols randomized.

Table 2. Between-day reliability analysis of sprint performance at 10-m, 20-m, and 30-m intervals ($n = 5$).

Sprint interval	r	ICC	Paired t-test, p	SEM (s)	MD (s)
10 m	0.818	0.754	0.737	0.039	0.107
20 m	0.915*	0.918*	0.679	0.043	0.120
30 m	0.933*	0.942*	0.828	0.058	0.162

*Statistically significant ($p < 0.05$).

r = Pearson's correlation coefficient; ICC = intraclass correlation (2-way random, absolute agreement, single measures); SEM = standard error of measurement; MD = minimal difference needed to be considered real.

Table 3. Sprint performance (in seconds) at 10-m, 20-m, and 30-m intervals after control and postactivation potentiation protocols ($n = 12$).

Protocol	Mean	*SD*	95% CI (lower)	95% CI (upper)
10-m interval				
Control	1.77	0.06	1.74	1.81
Isometric knee extension	1.78	0.08	1.73	1.83
Isometric squat	1.76	0.07	1.71	1.80
Dynamic squat	1.75	0.05	1.71	1.78
20-m interval				
Control	2.97	0.05	2.94	3.00
Isometric knee extension	2.96	0.08	2.91	3.01
Isometric squat	2.93	0.08	2.88	2.99
Dynamic squat	2.94	0.06	2.90	2.98
30-m interval				
Control	4.09	0.06	4.05	4.13
Isometric knee extension	4.06	0.07	4.01	4.10
Isometric squat	4.04	0.09	3.98	4.10
Dynamic squat	4.06	0.08	4.00	4.11

CI = confidence interval.

For the control protocol, subjects sat through 4 minutes of passive rest to emulate the average time undertaken by the other PAP protocols.

The isometric knee extension protocol was carried out on the leg extension machine. Subjects were seated upright and secured around the chest, hip, and thigh. The legs were positioned at 90° angle of knee flexion and secured to the machine's lever arm. Subjects were instructed to perform maximal bilateral isometric knee extension against the lever arm of the machine for 3 repetitions of 3 seconds. Each repetition was interspersed by a 2-minute rest period. This protocol was similar to those in other studies that showed improvements in subsequent sprinting or jumping performance (9,24,28).

For the isometric squat protocol, the subjects were instructed to squat against a barbell secured on 2 sliding pins across the power rack. The isometric contractions were held for 3 seconds for 3 repetitions, with a rest period of 2 minutes in between repetitions. Before the trials, a goniometer was used to set the subjects' knee angle between 120° and 130°. This knee angle was kept constant throughout all repetitions. This isometric MVC protocol was similar to the one utilized in a previous PAP study that reported significant improvements in countermovement jumps (24).

For the dynamic squat protocol, the subjects performed a warm-up set of 10RM and 5RM back squats, before completing 3 repetitions of dynamic back squats at 90% of 1RM. These weights were based on the strength data obtained earlier in the baseline strength test. The safety squat device was used to ensure that each of the squat is performed with strict range of motion. This protocol was similar to other studies involving dynamic squat exercises (19,24).

After the control and PAP protocols, all subjects rested for a further 4 minutes before performing 1 trial of 30-m maximal sprints on an indoor rubber track. The 4-minute recovery period was in accordance with other studies that have shown improvements in sprinting performance (19,28,35). The Speedlight Timing System (SWIFT Performance Equipment, Alstonville, Australia) was used to measure the 30-m sprint times and the 10-m and 20-m split times. Four sets of timing gates were placed at 0-m, 10-m, 20-m, and 30-m intervals along a straight line. The first set of timing gates was set with the top beam at a height of 0.8 m, and the bottom beam at a height of 0.5 m. The other 3 pairs of timing gates were set with the top beam at a height of 1.1 m and the bottom beam at a height of 0.8 m. The subjects started behind the first timing gate in a stationary position with the dominant front foot at the 0-m mark and sprinted only when they were ready.

Table 4. Statistical analyses for 10-m, 20-m, and 30-m sprint times ($n = 12$).

Sprint interval	*F*	*p*	Partial eta squared	Post hoc power
10 m	0.76	0.525	0.065	0.94
20 m	0.75	0.530	0.064	1.00
30 m	1.16	0.340	0.095	1.00

Results are from 1-way repeated measures analyses of variance.

Reliability Tests

To determine reliability of the sprint performance test, a subset of 5 subjects performed 2 additional trials of maximal 30-m sprint, separated 1 week apart. No PAP interventions were applied in the reliability tests. The between-day sprint times at 10 m, 20 m, and 30 m were assessed by intraclass correlation (2-way random, absolute agreement, single measures), paired *t*-test (2 tailed), *SEM* and Pearson's correlation (2 tailed). The minimal difference

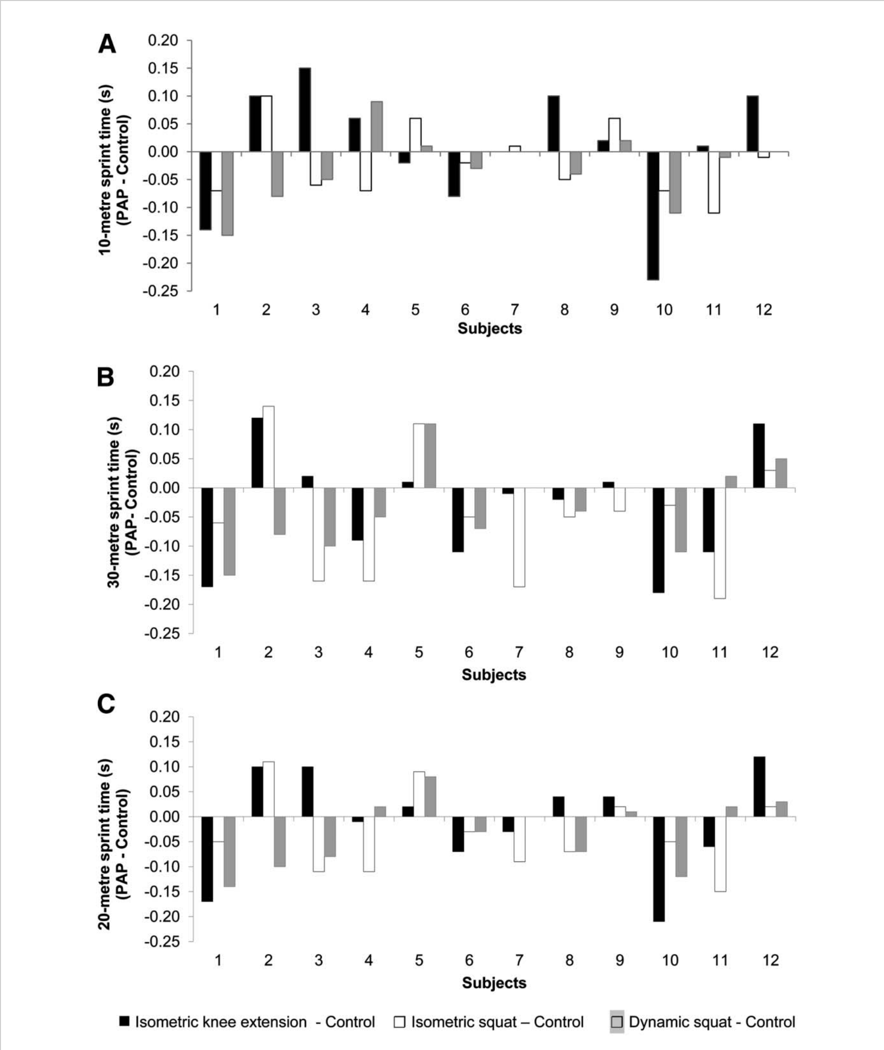

Figure 2. Individual ($n = 12$) sprint time after isometric knee extension, isometric squat, and dynamic squat protocol, compared with control; at (A) 10-m interval, (B) 20-m interval, and (C) 30-m interval (note: missing bars represent postactivation potentiation sprint time is identical to control sprint time).

needed to be considered real difference for each sprint interval was also calculated (33). The reliability test results are presented in Table 2.

Statistical Analyses

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 16.0; SPSS Inc., Chicago, IL, USA). Shapiro Wilk tests confirmed that all data were normally distributed. Thus, parametric statistical tests were applied throughout. In all analysis, the results are presented as means and *SD*, with statistical significance set as $p < 0.05$.

There were 3 dependent variables as follows: 10-m, 20-m, and 30-m sprint times. One-way repeated measures analyses of variance (ANOVA) were used to detect differences in sprint performance among the 4 protocols. A total of 3 one-way repeated measures ANOVA were run, 1 for each dependent variable. Effect sizes were calculated using partial eta squared (31) and interpreted using the scale proposed by Stevens (26). For all negative findings, a post hoc power analysis was performed using G*Power 3.1.4 based on the actual effect size and test-retest correlation.

Results

There were no significant differences in sprint performance among the control, isometric knee extension, isometric squat, and dynamic squat protocols, regardless of the 10-m, 20-m, or 30-m split times (Tables 3 and 4). The effect size was considered moderate (0.06 < partial eta squared < 0.14) and the post hoc power was high (>90%) across all sprint intervals. Large between-subject variations were observed in the sprint performance after all 3 PAP protocols (Figure 2). Some subjects responded positively to all PAP protocols (subjects 1, 6, 10), whereas others responded only to selected protocols. The absolute difference in sprint times between the control and PAP protocols are mostly less than the minimal difference that is needed to be considered real.

Discussion

This study investigated the effects of 3 different types of PAP protocols (single-joint isometric, multijoint isometric, and multijoint dynamic) on subsequent 30-m sprint performance in well-trained athletes. As a whole group, there was no improvement in sprint performance after any of the PAP protocols. Large between-subject variations in response to the PAP protocols were, however, observed.

Our negative findings were in agreement with a study (28) that found no PAP effect on 10-m and 20-m sprint performances regardless of dynamic or single-joint isometric protocols. Mixed results were observed in other studies in which PAP improved sprint performance only in selected intervals. For example, a study reported positive PAP effect from heavy-load squats in subsequent 40-m dash time but not for 10-m or

30-m (18). Similarly, heavy back squats produced faster sprinting speeds at 10–20 m and 30–40 m intervals but not 0–10 m or 20–30 m intervals; whereas heavy front squats did not improve performance (35). In contrast, some studies have reported clear positive findings to PAP protocols on subsequent sprint performances (5,17,19,24). These studies, however, did not randomize their experimental order and therefore make the results inconclusive.

The rest interval between PAP and subsequent sprint trial may have played a role in our negative findings. We chose a 4-minute recovery period because other studies have shown improvements in sprinting performance using similar rest intervals (19,28,35). A recent meta-analysis on PAP training, however, concluded that a rest period of 7–10 minutes seems to optimally augment power output after a conditioning activity (34). Thus, the 4-minute rest interval used in this study may not be sufficient to demonstrate the effect of PAP on sprinting performance.

Absolute strength level may be another compounding factor that influences an individual's capacity to utilize PAP to improve sprint performance. Previous studies that reported positive findings engaged rugby, football, and team sport players, who had a higher mean absolute back squat of 170.3 ± 17.3 kg, 185.7 ± 39.7 kg and 151.0 ± 12.0 kg, respectively (4,5,19). The current strength levels in the subject pool of this study might be low (absolute back squat = 124.4 ± 15.9 kg) and thus, could not effectively utilize PAP to improve sprint performance.

We originally hypothesized that isometric PAP protocols would be superior to a dynamic protocol in enhancing subsequent sprint performance, but our results did not demonstrate any advantage of the isometric knee extension or isometric squat over the dynamic squat protocols. Isometric contractions were reported to activate more muscle fibers than dynamic contractions, and this might result in greater percentage of regulatory light chain phosphorylation and greater changes in muscle architecture (8,29). Practically, isometric muscle actions have an advantage in comparison to dynamic actions in that they are more feasible to use in an athlete's warm-up (9). However, the different intensities between the isometric and dynamic protocols may have confounded our results. Recently, it was concluded that moderate intensity (60–84% 1RM) exercise is better for eliciting PAP when compared with very high intensities (>85% 1RM) (34). Because our isometric protocols involved maximal effort compared with submaximal effort in the dynamic protocol, the extra benefit that may be resulting from isometric protocols may be masked by the higher intensity used. In addition, the fatigue induced during the isometric and dynamic protocols may differ and therefore require different recovery intervals that we did not consider. During an isometric contraction, central fatigue was preferential in the beginning although peripheral fatigue developed toward the end (1). In contrast, an opposite profile in the fatigue pattern was observed during a dynamic contraction (1). Thus, the 4-minute rest interval used in this study may not suit the different fatigue profiles exhibited by isometric and dynamic contractions.

The present study also compared 2 isometric PAP protocols, single joint and multijoint, in their effectiveness to augment sprint performance. It was hypothesized that the multijoint isometric squat protocol would be superior to the single-joint isometric knee extension protocol, but our results did not support this hypothesis. Sprinting is a multijoint movement involving simultaneous extensions of the hip extensor, knee extensor, and plantar flexor muscles (20,37). Thus, it was reasonable to expect that the resulting activation patterns from the isometric squat protocol may be more specific to sprinting than the isometric knee extension protocol and therefore improving the subsequent PAP effects (36). Although this may be conceptually appealing, there is no evidence that the implementation of an isometric MVC that involves multiple joints may be a more effective method than single-joint knee extension to induce PAP for superior short-distance sprinting performance.

Large variations in individual responses to PAP protocols were observed among our subjects, despite all of them being well-trained male sprinters with resistance training experience. It is known that responses to PAP protocols varied extensively between subjects, with interindividual variables of training status and strength levels being of great effect (6,10,11,25). Although no statistically significant differences were found, we obtained a moderate effect size in the difference at all sprint intervals. At the elite level, a very small change in performance outcomes could potentially differentiate athletes making the competition podium. As illustrated from Figure 2, it is plausible for some individuals to benefit from the PAP effect and to utilize such strategies to augment subsequent sprint performance. For example, subject 10 ran remarkably faster after the isometric knee extension protocol (10 m: 0.23 seconds, 20 m: 0.21 seconds, 30 m: 0.18 seconds) compared with the control, with an average improvement of 7.8% across all sprint intervals. Such improvements exceeded the 95% confidence interval boundaries and the minimal detectable difference needed to be considered real. Thus, the present study reinforces previous findings that PAP should be considered on an individual basis due to the large individual differences (28).

Pratical Applications

This study showed no enhancement of short-distance sprint performance after PAP protocols with a 4-minute recovery period regardless of contraction type or the number of joints involved. There are, however, large individual variations in the response to the PAP protocols with some athletes benefiting from the PAP effect and others not. Coaches considering the use of PAP protocols to improve sprinting performance of their athletes should exploit the effectiveness of different PAP protocols on an individual basis. Factors such as strength levels, PAP protocol intensity, and recovery interval between the preconditioning activity and the sprint need to be further investigated before successful implementation of PAP into a warm-up protocol.

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