

Postactivation Potentiation for Muay Thai Kicking Performance

Lee Brown, Gary Doyle, Stewart Bruce-Low, Silvino Domingos, Karl Anthony, Fionn Rowan, and Andy Galbraith

Applied Sport Sciences Research Group, Health, Sport, and Bioscience, University of East London, London, United Kingdom

Abstract

Brown, L, Doyle, G, Bruce-Low, S, Domingos, S, Anthony, K, Rowan, F, and Galbraith, A. Postactivation potentiation for Muay Thai kicking performance. *J Strength Cond Res* 37(10): 2032–2037, 2023—The purpose of this study was to investigate the effects of postactivation potentiation (PAP) on Muay Thai kicking performance based on 3 different rest intervals. Aiming to quantify and indicate timing protocols for conditioning coaches when training athletes using PAP. 17 male (25.3 ± 3.6 years old; 179.3 ± 2.3 cm; 78.0 ± 5.2 kg), experienced Muay Thai fighters completed a standardized warm-up, including a 10-minute cycle on the Wattbike at 60 watts and 30 body mass squats for a dynamic stretch. Subjects then completed a baseline test by striking a PowerKube using the roundhouse and Teep kick techniques. PAP exercise consisted of 4 squat repetitions to maximum effort, followed by a rest period of 2, 5, or 8 minutes. Subjects then struck the PowerKube again using the roundhouse and Teep kick techniques. Rest periods were presented in a randomized order on separate days, with 72 hours between conditions. The level of significance was set at $\alpha = 0.05$. Significant increases in both roundhouse ($\chi^2(3) = 38.51, p < 0.05$) and Teep kick ($\chi^2(3) = 26.33, p < 0.05$) striking power were observed when compared with baseline. For the roundhouse kick, significant differences and large effect sizes were present between all conditions except baseline and 2-minute rest. For the Teep kick, significant differences and large effect sizes were present between baseline and 5-minute rest and baseline and 8-minute rest. This indicates that PAP with 5- or 8-minute rest increased roundhouse and Teep kick power. This research reports that a PAP stimulus from a 4RM squat exercise, followed by a 5- or 8-minute rest period, enhances kick power in trained Muay Thai fighters. This technique provides a readily available, time-efficient method to enhance performance that can be built into the warm-up procedure of athletes before training or competition.

Key Words: warm-up, power, recovery, training, competition

Introduction

Muay Thai is a combat sport that originated in Thailand, referred to as "the art of 8 limbs." Competitors can kick, punch, knee, elbow, and clinch their opponents (19,20,26). A Muay Thai bout can last up to 5 rounds of 3 minutes each but is sometimes shortened depending on the competitors' competence and experience. Muay Thai fighters build their fitness through traditional training, involving a mixture of running, pad work, strength training, and fighting. Most competitors are averse to strength training for fear of losing flexibility and gaining body mass (25). The latter aspect is critical and creates a substantial obstacle because competitors frequently compete at their lightest feasible body mass to battle against opponents of lesser mass (26). Research analyzing sport-specific kinematics of kicks (10,27) has enhanced coaches ability to identify the most effective exercises to generate increased force output, improving performance, compared with traditional training methods (25).

The roundhouse kick can be an effective technique when actioned by a high hip angular velocity; Diniz et al. (10) found that when comparing the roundhouse kick technique, used in other striking-based martial arts, with Muay Thai, the angular velocity of the hip is greater and can produce a higher impact, causing destructive damage to gain points or incapacitate an opponent. The Teep kick (front push kick) also has similar efficacy; being one of the most used techniques in Muay Thai for

attacking and countering attacks from the opponent, showing benefits from increasing competitors kicking performance impact power (14,19,22). Vagner et al. (27) identified the Teep kick to be highly effective in close quarter combat, and the need for increased destructive impact was key to successful performances.

The fundamental goal of the suggested kicking method is to transfer energy from the hip to the foot by maintaining a proximal-distal movement pattern that couples the dynamic sequence of the trunk, hip, knee, ankle, and foot (10). The dynamic result of the kick is influenced by the sum of their body's effective mass, linear velocity, and angular velocity; therefore, the kinematic chain's coordination is essential for assuring the efficacy of the kick technique (27). The amount of transferred momentum or energy determines the magnitude of the kick impact, the greatest force, and impulse that are projected into the target during the kick, which are included in the dynamics of kicking (22,27).

The rectus femoris and iliopsoas accelerate the thigh, producing the hip flexor moment during the kick. The shank accelerates quickly as the motion of the thigh slows. The hamstrings have an impact on the lower limb's acceleration and velocity just before making contact with the target, demonstrating the significance of intersegmental linkages in producing the greatest kick force. The core stabilizes the body position before knee extension, which helps to increase the kick's high impulse (27). Identifying methods that increase a kick's impact force, that can be transmuted through the core to the striking limbs, would be a beneficial approach to winning performances in combat sports such as boxing and Muay Thai (8).

Address correspondence to, Lee Brown, l.brown@uel.ac.uk.

Journal of Strength and Conditioning Research 37(10):2032–2037

© 2023 National Strength and Conditioning Association

Postactivation potentiation (PAP) is a phenomenon of increased power output after a set of 1 to 6 maximum strength contractions through resistance exercise. PAP is shown to occur when an increase in type II muscle fiber motor unit recruitment, rate coding, and low-frequency tetanic force is used (3,20), which can be readily applied to elicit increased rate of force development (RFD) for athletic performance. Myosin regulatory light chain (RLC) phosphorylation is increased in type II muscle fibers during PAP, making the actin-myosin complex more sensitive to calcium (Ca^{2+}), increasing muscle twitch response (5,20). These physiological factors have the potential to increase force and power of kicks to gain an advantage over opponents. There is a dearth of research focusing on the potential improvements to striking performance in martial arts through PAP.

PAP requires the execution of the working muscles in a maximal voluntary contraction activity, i.e., the back squat, leading to increased muscle force exertion (17,23). Xenofontos et al. (29) found that muscles mainly consisting of type II fibers will show greater PAP, but this is dependent on the training status.

PAP is larger in those with an increased strength and power baseline (1–3), which suggests that strength levels are an essential factor when PAP is applied to athletic populations. Given the importance of type II fibers and the net balance of potentiation and exhaustion, the individual's athletic status will almost certainly play a role in determining the best way to induce PAP. PAP protocols involve a maximal loaded exercise, followed by a given rest interval, before an explosive activity such as a punch or kick strike. Research into PAP has been conducted to examine different timings for rest interval periods to identify the most effective potentiation effect (28); Bevan et al. (4) demonstrated that 8 minutes was the optimal rest time for improved sprint times succeeding maximal squats.

However, Do Carmo et al. (11) described rest intervals that elicited the most significant results in vertical jump athletes were determined by the subjects in the study, as opposed to preset intervals, which may allow for adequate recovery. Aandahl et al. (1) used elastic band tubing to initiate a PAP response in a warm-up with a velocity increase of 3.3% with Taekwondo style kicking, demonstrating the efficacy of such an approach to enhance kicking velocity. Although Aandahl et al. (1) showed an increase in kicking velocity with a PAP protocol, there is a dearth of research that examines the effect of rest duration, between the PAP stimulus and performance, on kick impact power.

Using a PAP stimulus less than the 1 repetition maximum (1RM) (i.e., a 4RM load) would allow the PAP movement to be performed at a faster velocity, closer to the execution velocity of a kick in Muay Thai. Using a different RM load may also require less recovery than has been previously recommended and may influence the optimal recovery time between PAP and the post-PAP performance task.

The purpose of this study was to investigate the effects of PAP on Muay Thai kicking performance based on 3 different rest intervals. Therefore, this study aims to quantify and indicate timing protocols for conditioning coaches when training athletes who may be aiming for PAP. It was hypothesized that the Muay Thai fighters would demonstrate increased kicking power output after a longer rest period after PAP stimulus, when compared with shorter rest intervals and baseline values.

Methods

Experimental Approach to the Problem

A within-subject study design was used to compare different restorative periods to test the hypothesis that longer rest

periods improved the PAP response, when striking with a Roundhouse and Teep kick. The subjects had their baseline strength tested before PAP testing to ensure they could lift over 1.5 times their body mass. The subjects were then instructed to repeat the same protocol 3 times but each time using a different rest interval (2, 5, and 8 minutes). Each condition was randomly assigned an order for each subject to ensure there was no order bias.

Subjects

Seventeen male (25.3 ± 3.6 years old; 179.3 ± 2.3 cm; 78.0 ± 5.2 kg) super-middleweight experienced Muay Thai fighters from gyms based in London, with a minimum of 2 years' competitive experience (32 ± 7 professional bouts) and a minimum of 2 years' resistance training experience (3.2 ± 0.9 years). Subjects provided written informed consent to participate and reported being free from injury and ill-health. The study was approved by the institutional ethics committee at the University of East London. A single weight category was selected to control and minimize variables for the study, so PAP responses could be identified.

Procedures

Subjects arrived at the laboratory in a rested state, with no exertional work or physical training 72 hours before testing (Figure 1). Stature (Seca 213, Birmingham, United Kingdom) and body mass (Seca 761, Birmingham, United Kingdom) were measured before testing.

Baseline Strike Power Testing. Baseline testing used the PowerKube (Birmingham, United Kingdom) to measure the impact power produced (watts) for the roundhouse (Figure 2) and Teep kick (Figure 3), all subjects were given a familiarization session with the Muay Thai coach overseeing technique. After a 10-minute cycle on a Wattbike Pro (Nottingham, United Kingdom) at 60 watts and dynamic stretches, the best of 10 strikes using the roundhouse and then the Teep kick were performed by each subject.

Data from Steinebronn et al. (24) reported a typical error of 1.8% for accurate strikes on the PowerKube. The PowerKube identifies the striker's impact power using a padded dynamometer (8), being preferred over a metal force plate, which has an increased risk of injury when struck by forceful kicks.

Baseline Maximal Strength Testing. Subjects completed a 10-minute warm-up at 60 watts on the Wattbike, followed by 30 body mass squats for dynamic stretching. Subjects then rested for 2 minutes before performing their 1RM strength testing, overseen by a National Strength and Conditioning–Certified and –Registered Strength and Conditioning Specialist (CSCS, RSCC) to spot the lifts and identify the correct technique. Maximal strength testing followed the National Strength and Conditioning Association (NSCA) 1RM protocols for the back squat to ascertain prescription percentage for the 4RM (15).

Postactivation Potentiation Testing Protocols. A 10-minute warm-up on the Wattbike at 60 watts followed by a series of dynamic stretches for safe lifting was conducted. This was followed by the subjects performing 30 body mass squats and then resting for 2 minutes. Four squat repetitions to their

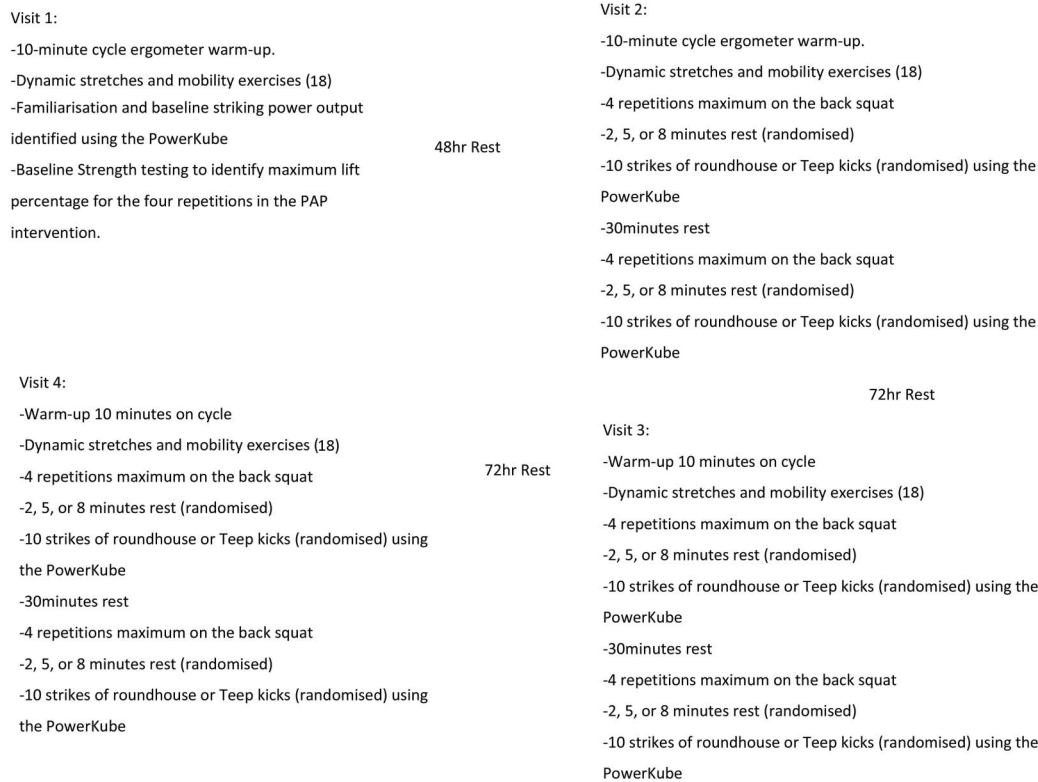


Figure 1. A schematic of the testing protocols used within the study.



Figure 2. The roundhouse kick impact power (W) being measured on the PowerKube.



Figure 3. Teep kick impact power being measured on the PowerKube.

maximum effort were performed, calculated from their percentage of 1RM from the baseline maximal strength testing. After the squats, the subjects rested in a holding area, allowing them to sit and wait for 2, 5, or 8 minutes. Finally, subjects struck the PowerKube with 10 roundhouse and 10 Teep kicks, with the highest scores recorded. This was then repeated identically across 2 further visits to allow all 3 rest periods to be assessed in a randomized order for each subject (Figure 1).

Statistical Analyses

The peak values (watts) recorded by the PowerKube, for each condition, was scaled to body mass. The normality of data was assessed using a Shapiro-Wilk test. As 2 conditions (1 from each type of kick) were not normally distributed, descriptive data were expressed as median and IQR. Friedman ANOVA with post hoc Wilcoxon signed-rank tests to identify statistical changes and effect sizes derived from Z-scores were used to quantify the magnitude of the change (12). Effect size was rated as 0.1–0.3 = small effect; 0.3–<0.5 = moderate effect; and >0.5 = large effect (12,13).

Results

All conditions showed an increase in the median value compared with the baseline condition. This suggests that the PAP protocol showed an improvement over baseline for the roundhouse kick (Table 1 and Figure 4) and the Teep kick (Table 1 and Figure 5). The rest period caused a statistical improvement in the roundhouse kick power from baseline ($\chi^2(3) = 38.51, p < 0.05$). Post hoc Wilcoxon tests (Table 2) with a Bonferroni correction with level of significance of (0.05/4) 0.013 showed statistical improvements between all conditions except baseline and 2-minute rest. Large effect sizes were reported between all conditions except the baseline and 2-minute rest, which reported a trivial difference. This suggests that PAP with 5- or 8-minute rest increased roundhouse kick power.

Similarly, the rest period caused a statistical change in the Teep kick power from baseline ($\chi^2(3) = 26.33, p < 0.05$). Post hoc Wilcoxon tests (Table 3) with a Bonferroni correction with level of significance of (0.05/4) 0.013 showed statistical differences between baseline and 5-minute rest and baseline and 8-minute rest. Large effect sizes were reported between baseline and 5-minute rest and baseline and 8-minute rest. Although no statistical difference was reported between baseline and 2-minute rest, a moderate effect size of 0.38 was reported. This indicates that PAP with 5- or 8-minute rest increased Teep kick power.

Table 1
Kick power.*

Condition	Roundhouse kick power (W)	Teep kick power (W)
Baseline	546.1 (31.3–610.4)	106.4 (86.4–141.0)
2-min rest	567.6 (311.8–622.3)	122.4 (90.9–157.1)
5-min rest	634.2 (504.9–746.4)	123.4 (112.2–212.0)
8-min rest	692.5 (466.6–778.8)	139.1 (113.1–201.0)

*Values are presented as median (IQR).

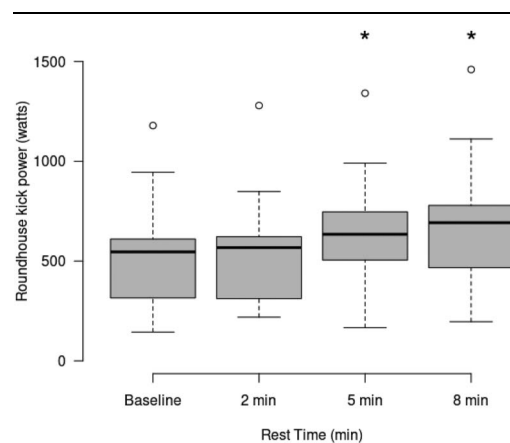


Figure 4. Box and whisker plot of roundhouse kick power at baseline and across the 3 rest conditions. *Significant difference from baseline (Wilcoxon test).

Discussion

The current study reports a statistical improvement ($p < 0.05$) in kick power, with large effect sizes ($r = 0.88$) between baseline and 5-minute rest and baseline and 8-minute rest, for both the roundhouse and Teep kick. A statistical difference with a large effect size in kick power was shown between 5-minute rest and 8-minute rest for the roundhouse kick, indicating that the longer rest period showed the greatest increase in roundhouse kick power (Table 2). No statistical difference, but a moderate effect size, was shown for Teep kick power between the 5-minute and 8-minute rest conditions (Table 3).

This may suggest that when Muay Thai coaches are training athletes using a roundhouse kick, PAP followed by an 8-minute rest period would seem to produce the greatest gains in kicking power. However, when training athletes using a Teep kick, PAP followed by a 5-minute rest period may be sufficient to produce gains in kicking power. It is possible that because of the lower impact power of the Teep kick, compared with the roundhouse kick, it requires less rest time for the PAP effect to be realized. Conversely, because of the higher levels of impact power when using a roundhouse kick, a longer rest period is needed to fully develop the PAP effect.

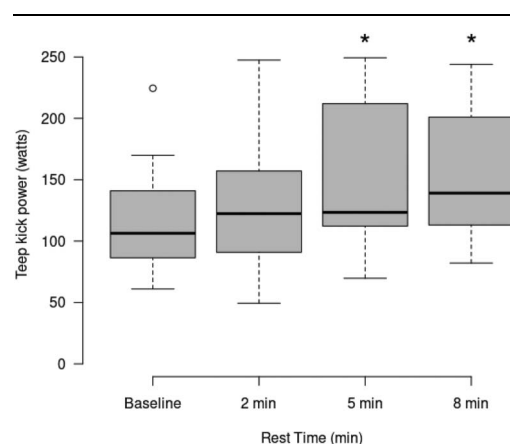


Figure 5. Box and whisker plot of Teep kick power at baseline and across the 3 rest conditions. *Significant difference from baseline (Wilcoxon test).

Table 2
Statistics for the Roundhouse kick.

Comparison	Wilcoxon		ES (r)	Evaluation
	Sig	Z-score		
Baseline vs. 2-min rest	0.747	-0.355	-0.09	Trivial
Baseline vs. 5-min rest	<0.001*	-3.621	-0.88	Large
Baseline vs. 8-min rest	<0.001*	-3.621	-0.88	Large
2 min rest vs. 5-min rest	<0.001*	-3.148	-0.76	Large
2 min rest vs. 8-min rest	<0.001*	-3.574	-0.87	Large
5 min rest vs. 8-min rest	0.002*	-2.959	-0.72	Large

*Significantly different, alpha 0.013.

Smaller effect sizes ($r = 0.1$ – 0.3) were demonstrated by the shorter 2-minute rest period, which reflects other research in different sports and exercise modalities, suggesting longer rest periods after PAP stimulus produce the greatest gains (11,15). This would indicate that a 2-minute recovery may not be sufficient to develop a performance-enhancing response and that the subjects were still experiencing fatigue from the PAP stimulus. These results confirm the general consensus in the literature that a 2-minute rest period is not sufficient for a PAP effect (1,26). Specifically, the current results agree with similar findings from Aandahl et al. (1); however, the current research study assessed kick performance using an ecologically valid, kick-specific, measurement device (PowerKube), making the results more transferable to competitive performance.

The PAP modality used needs to be specific to the action that is to be enhanced. In this study, a 4RM squat was used as the PAP stimulus. The squat is a commonly performed exercise and is considered kinematically similar to the Teep kick in terms of motor unit recruitment patterns. The motor unit firing patterns that are improved during training of these exercises would enhance the firing pattern of these motor units during both kick strikes (27). The improved performance after PAP seen in the current study suggests the squat is an effective PAP modality for enhancing kick power of Muay Thai fighters. By using a 4RM protocol compared with 1RM protocol, it may allow subjects to execute the PAP stimulus at a higher velocity, which may have greater sport specificity.

PAP is more effective in stronger subjects, according to studies, which suggests that strength levels may be an important predictor of PAP and should be taken into consideration when planning periodized training cycles (20,21,23,29). The subjects in this study all demonstrated strength level baselines above 1.5 times their body mass in their 1RM, which would agree with current literature on the need for existing strength levels to be elevated for PAP responses (2,4,7,15).

Table 3
Statistics for the Teep kick.

Comparison	Wilcoxon		ES (r)	Evaluation
	Sig	Z-score		
Baseline vs. 2-min rest	0.12	-1.577	-0.38	Moderate
Baseline vs. 5-min rest	<0.001*	-3.621	-0.88	Large
Baseline vs. 8-min rest	<0.001*	-3.622	-0.88	Large
2-min rest vs. 5-min rest	0.159	-1.444	-0.35	Moderate
2-min rest vs. 8-min rest	0.045	-2.012	-0.49	Moderate
5-min rest vs. 8-min rest	0.225	-1.254	-0.30	Moderate

*Significantly different, alpha 0.013.

A possible limitation of the current work is that the different weight categories of Muay Thai were not explored; therefore, the applications of this research are primarily directed at super-middleweight Muay Thai fighters and their coaching teams. Although the subjects were instructed not to train before testing, general fatigue detriments were not addressed, such as sleep and general activity levels, which may have affected performance outcomes. Future studies should include a wider range of weight categories and monitor rest and recovery patterns between conditions.

Practical Applications

The practical applications of these results suggest that a PAP-enhanced kick performance is possible with 5- or 8-minute rest periods after PAP stimulus. A PAP protocol 5–8-minutes before a bout may allow subjects to enhance their kick impact power, improving the ability to exact more powerful strikes on their opponents and gain a tactical advantage during competition. Although the underlying mechanisms of PAP are still to be thoroughly determined, the results indicate the importance of the rest period after the PAP event. In summary, this research reports that a PAP stimulus from a 4RM squat exercise, followed by a 5- or 8-minute rest period, enhances kick impact power in trained Muay Thai fighters. This technique provides a readily available, time-efficient method to enhance performance that can be built into the warm-up procedure of athletes before training or competition.

Acknowledgments

This study would not have been possible without the Muay Thai fighters that took part and gave up their time to take part. Although no external funding was received in support of this research, PowerKube Ltd supplied the authors with the striking dynamometer equipment for the purpose of data collection for this study. The results of this study do not constitute endorsement of the PowerKube product by the authors or the NSCA.

References

- Aandahl HS, Von Heimburg E, Van den Tillaar R. Effect of postactivation potentiation induced by elastic resistance on kinematics and performance in a roundhouse kick of trained martial arts practitioners. *J Strength Cond Res* 32: 990–996, 2018.
- Banks ST. Postactivation potentiation: Practical implications in the collegiate setting. *Grad Stud Theses, Diss, Pro Pap*: 10643, 2016.
- Beato M, Bigby AEJ, De Keijzer KL, et al. Post-activation potentiation effect of eccentric overload and traditional weightlifting exercise on jumping and sprinting performance in male athletes. *PLoS One* 14: e0222466, 2019.
- Bevan HR, Cunningham DJ, Tooley EP, et al. Influence of postactivation potentiation on sprinting performance in professional rugby players. *J Strength Cond Res* 24: 701–705, 2010.
- Blazevich AJ, Babault N. Post-activation potentiation versus post-activation performance enhancement in humans: Historical perspective, underlying mechanisms, and current issues. *Front Physiol* 10: 1359, 2019.
- Bogdanis GC, Tsoukos A, Brown LE, et al. Muscle fiber and performance changes after fast eccentric complex training. *Med Sci Sports Exerc* 50: 729–738, 2018.
- Borba DDA, Ferreira-Júnior JB, Santos LAD, Carmo MCD, Coelho LGM. Effect of post-activation potentiation in athletics: A systematic review. *Brazilian Academy of Kinesiology & Human Performance* 19: 128–138, 2017.

8. Brown L, Hastings K, Doyle G, Bruce-Low S, Galbraith A. The effects of lower core resistance training on rear hand punching performance in professional boxers. *J Aust Strength Cond* 29: 15–24, 2021.
9. Chiu LZ, Fry AC, Schilling BK, Johnson EJ, Weiss LW. Neuromuscular fatigue and potentiation following two successive high intensity resistance exercise sessions. *Eur J Appl Physiol* 92: 385–392, 2004.
10. Diniz R, Del Vecchio FB, Schaun GZ, et al. Kinematic comparison of the roundhouse kick between taekwondo, karate, and Muay Thai. *J Strength Cond Res* 35: 198–204, 2021.
11. do Carmo EC, De Souza EO, Roschel H, et al. Self-selected rest interval improves vertical jump postactivation potentiation. *J Strength Cond Res* 35: 91–96, 2021.
12. Field A. *Discovering Statistics Using IBM SPSS Statistics*. London: Sage, 2013.
13. Fritz CO, Morris PE, Richler JJ. Effect size estimates: Current use, calculations, and interpretation. *J Exp Psychol Gen* 141: 2–18, 2012.
14. Grymanowski J, Glińska-Wlaz J, Ruzbarsky P, Druzbecki M, Przednówek K. Analysis of time-space parameters of the front kick using the example of an athlete training in Muay Thai. *Ido Movement for Culture. J Martial Arts Anthropol* 19: 107–110, 2019.
15. Juárez D, González-Ravé JM, Navarro F. Effects of complex vs non-complex training programs on lower body maximum strength and power. *Isokinet Exerc Sci* 17: 233–241, 2009.
16. Lim JH, Barley CL. Complex training for power development: Practical applications for program design. *Strength Cond J* 38: 33–43, 2016.
17. Lorenz D. Postactivation potentiation: An introduction. *Int J Sports Phys Ther* 6: 234–240, 2011.
18. McGuigan MR. Administration, scoring and interpretation of selected tests. In: *Essentials of Strength Training and Conditioning*. Haff GG and Triplett NT, eds. Champaign, IL: Human Kinetics, 2016.
19. Myers T, Balmer N, Nevill A, Al-Nakeeb Y. Techniques used by elite Thai and UK Muay Thai fighters: An analysis and simulation. *Adv Phys Educ* 3: 175–186, 2013.
20. Sale DG. Postactivation potentiation: Role in human performance. *Exerc Sport Sci Rev* 30: 138–143, 2002.
21. Santos EJAM, Janeira MAAS. Effects of complex training on explosive strength in adolescent male basketball players. *J Strength Cond Res* 22: 903–909, 2008.
22. Syarifoeuddin EW. The effect of plyometric exercise using continual, interval, and muscle power methods towards push kick frequency on Muay Thai athletes in mataram, west nusa tenggara. *Res World* 9: 112–121, 2018.
23. Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Med* 39: 147–166, 2009.
24. Tong-Iam R, Rachanavy P, Lawsirirat C. Kinematic and kinetic analysis of throwing a straight punch: The role of trunk rotation in delivering a powerful straight punch. *J Phys Edu Sport* 17: 2538–2543, 2017.
25. Turner AN. Strength and conditioning for Muay Thai athletes. *Strength Cond J* 31: 78–92, 2009.
26. Vail P. Muay Thai: Inventing tradition for a national symbol. *J Social Issues Southeast Asia* 29: 509–553, 2014.
27. Vagner M, Olah V, Cleather DJ, Stastny P. Evidence-based functional training to improve front push kick technique, speed, and net force production. *Strength Cond J* 44: 58–68, 2022.
28. Wilson JM, Duncan NM, Marin PJ, et al. Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. *J Strength Cond Res* 27: 854–859, 2013.
29. Xenofontos A, Laparidis K, Kyranoudis A, et al. Post-activation potentiation: Factors affecting it and the effect on performance. *J Phys Edu Sport/Citius Altius Fortius* 28: 32–38, 2010.