Pol. J. Sport Tourism **2025**, *32(2), 25-29*
DOI: 10.2478/pjst-2025-0010

Original research papers

ISOMETRIC AND WEIGHTED PULL-UPS AS CONDITIONING ACTIVITIES TO INDUCE POST-ACTIVATION PERFORMANCE ENHANCEMENT (PAPE) ON DYNAMIC CAMPUS BOARD EXERCISE

KRZYSZTOF SAS-NOWOSIELSKI

The Jerzy Kukuczka Academy of Physical Education in Katowice, Department of Humanistic Foundations of Physical Culture

Mailing address: Krzysztof Sas-Nowosielski, Department of Humanistic Foundations of Physical Culture, The Jerzy Kukuczka Academy of Physical Education in Katowice, 72b Mikołowska Street, 40-065 Katowice, e-mail: k.sas-nowosielski@awf.katowice.pl

Abstract

Introduction. Upper body power plays a vital role in rock and sport climbing. This study aimed to evaluate the effects of two different Post-Activation Performance Enhancement (PAPE) protocols – isometric pull-ups and 5 RM weighted pull-ups – on the performance of a dynamic campus board exercise known as the Slap. ***Material and Methods.*** Nine climbers (mean age = 31.9 years, weight = 70.2 kg, height = 174.8 cm) of intermediate skill level, belonging to the same intermediate-level training group, participated in the study. Participants completed the International Rock Climbing Research Association (IRCRA) Power Slap Test. A cross-over design was used: all participants went through both baseline and follow-up tests. The Beast inertial sensor (Beast Technologies Ltd., Brescia, Italy) measured velocity ($m \cdot s^{-1}$), force (N), power (W), and estimated one-repetition maximum (1RM). A repeated-measures ANOVA with Tukey post hoc testing assessed pre–post PAPE (post-activation performance enhancement) effects. ***Results.*** The findings indicate that the 5 RM weighted pull-ups significantly improved slap distance and force output, while power and velocity remained unchanged. Specifically, slap distance increased from 74.8 ± 10.1cm pre-intervention to 79.0 ± 8.0 cm post-intervention, with a significant difference ($p = 0.009$) and a moderate effect size ($d = 0.60$). In contrast, the isometric pull-ups did not produce significant changes across any measured parameters. ***Conclusions.*** These results suggest that while the 5 RM weighted pull-ups serve as an effective PAPE stimulus for enhancing climbing power, the isometric variant does not yield similar benefits in this context.

Key words: climbing, post-activation potentiation, power slap

Introduction

Climbing is an increasingly popular sport that involves ascending natural rock formations or artificial climbing walls, requiring precise motor coordination and significant muscular strength. The essence of climbing lies in executing movement sequences using handholds and footholds of varying shapes and orientations [1, 2]. These demands necessitate the development of both fine motor control and explosive power, particularly in the upper body [3].

To enhance these attributes, climbers utilize specialized training equipment, with fingerboards (for finger strength) and campus boards being particularly prominent [4, 5]. Campus boards are primarily used to improve the rate of force development (RFD) in both fingers (contact strength) and arms. RFD, defined as the ability to generate force rapidly during muscle contractions, plays a crucial role in explosive climbing movements, which become increasingly important as climbing techniques advance [6]. Research indicates that elite climbers exhibit superior RFD compared to less advanced climbers, highlighting its significance in climbing performance [4, 5]. Consequently, training methods that enhance RFD, particularly through campus board exercises, are a key focus of climbing-specific conditioning [4]. These exercises generally fall into three categories: laddering (using only the arms to climb up the board), reaching for rungs (reaches or slaps), and performing dynamic jumps between rungs with both hands (dynos). One method for optimizing RFD development is complex training, which leverages post-activation performance enhancement (PAPE) [6, 7]. PAPE refers to the acute improvement in muscular performance following prior contractile activity, typically induced by heavy resistance exercises. This effect is believed to result from mechanisms such as increased motor unit recruitment, enhanced neuromuscular excitability, greater calcium availability in muscle cells, and reduced inhibitory feedback from Golgi tendon organs and Renshaw cells [8, 9, 10, 11]. Research on PAPE has primarily focused on lower-body exercises such as squats and sprints [12, 13, 14, 15], with fewer studies examining its effects on upper-body movements [16, 17]. Among the limited research available, most has investigated pushing exercises like bench presses or throws, leaving pulling movements – especially those relevant to climbing – largely unexplored [9].

A recent study by Sas-Nowosielski and Kandzia [18] examined the effects of weighted pull-ups on climbing-specific power using the Power Slap Test, a standardized assessment tool recommended by the International Rock Climbing Research Association (IRCRA). Their findings demonstrated that weighted pull-ups significantly improved slap performance compared to a control condition. However, further research by the same authors suggested that one-arm pull-ups may not elicit effective

PAPE responses. While weighted pull-ups appear to be a promising conditioning activity for enhancing explosive movements on campus boards, their implementation may be limited by the availability of external weights at climbing facilities.

An alternative to weighted pull-ups could be isometric exercises, which have been successfully used to elicit PAPE in activities like vertical jumps and cycling sprints [19, 20]. Isometric training may offer advantages such as reduced fatigue and faster recovery, potentially enhancing its effectiveness in climbing contexts. Additionally, because isometric exercises do not require external loading, they could be more accessible for climbers training in outdoor settings or at gyms with limited equipment. However, little research has explored the potential benefits of isometric conditioning for climbing-specific explosive movements.

Therefore, this study aims to investigate the effects of two PAPE protocols – weighted pull-ups (5RM) and isometric pull-ups – on subsequent dynamic campus board slap performance. By evaluating their efficacy, this research seeks to expand current understanding of upper-body PAPE strategies and their practical applications for climbers.

Material and Methods

Participants

A total of nine climbers (mean ± SD: age: 31.9 ± 11.8 years; body height: 174.8 ± 12.8 cm; body mass: 70.2 ± 12.8 kg) were recruited for this study. All participants were at least intermediate-level climbers and members of the same sports climbing workout team. The criterion for inclusion was membership in the intermediate training group, defined by the prism of regularly passing level-three boulder problems in flash style and most level-four problems on the six-level difficulty scale in effect in the gym. It also meant having training experience in special strength for climbers, such as pull-ups on a bar with an extra weightand fast strength exercises on a campus board. Their climbing performance level, based on self-reported best red-point (RP) climbs and transformed into the IRCRA reporting scale was 21.6 ± 5.5. Since all participants had experience with campus board and weighted pull-up exercises, familiarization sessions were not included in the present study. Participants were informed of the aims and procedures of the study before taking part in the investigation. The tests were conducted at the same time, in the late afternoon.

Design and Procedures

The Power Slap [21], chosen as a power test, was performed on a board marked with a scale indicating distances in centimetres. The rung from which the slap was performed had a folding surface that allowed participants to curl their fingers over the lip of the hold. Participants were permitted to dry their fingers with chalk (magnesium carbonate) before the test. According to the IRCRA recommendations, the climber's task was to hold on to the rung with straight arms, initiate an explosive pull-up, and slap as high as possible with the right arm. Performance was measured by establishing a point on the scale touched by the climber's hand. To ensure greater accuracy in distance readings, each climber was video-recorded.

Instruments

The Beast inertial sensor (dimensions: 20 x 19 x 40 mm, 38 g) (Beast Technologies S.r.l., Brescia, Italy) was used to register velocity (m/s), force (N), power (W) of pull-ups, and calculation of 1RM. The device contains a three-dimensional accelerometer and allows recordings at a sampling frequency of 50 Hz. Participants had the Beast sensor fixed at waist level on the back in line with the spine and connected to an Android 13-based smartphone Samsung (Samsung Electronics Co. Ltd, Seoul, South Korea) via Bluetooth.

Procedure

A crossover study design was used. All participants performed two trials: after 5RM weighted pull-ups and after isometric pull-ups. Prior to both tests, a standard warm-up protocol was carried out, including three series of 10 push-ups performed alternately with 5 pull-ups on a bar, and an equal number of series of 10 half-overhang pull-ups on a TRX performed alternately with trunk flexions in a lying-back position. The individual trials were planned at weekly intervals. The load to perform the 5RM was defined based on the current results of fitness tests conducted by a coach. During both dynamic and isometric pull-ups, athletes gripped the bar with an extended grip, with fingers interlocked, thus making the grip of the bar similar to the grip used during the hang slap test. At baseline, participants performed three Power Slaps consecutively, rested for 5 minutes, performed one of the conditioning stimuli, and after a 4-minute rest interval, they performed a second series of Power Slaps in both experimental trials. The choice of a 4-minute rest interval was based on two reasons: firstly, according to Lowery et al. [22] and Wilson et al. [23], 4-8 min rest intervals are close to optimal; secondly, 4 minutes is a typical rotation time in bouldering competitions, which influenced our research protocol. The load values for the 5RM were individualized based on each participant's training program and ranged from 9 to 25 kg. Participants performed pull-ups on a horizontal bar, starting with their arms fully extended until their chin reached bar level. Pull-ups were executed consecutively without stopping. For isometric pull-ups, subjects pulled against a static rope (9 mm in diameter) attached near the floor; the rope length was adjusted so that each participant's elbow joint was bent at a 90° angle. The participant's task was to perform a pull-up, to a given angle of arm flexion limited, and stop the movement for three seconds, resisting the resistance produced by the rope. The Ethics Committee approved the study protocol of Biomedical Research at the Academy of Physical Education in Katowice – resolution no 1/2019 – 17.01.2019.

Statistical Analysis

Descriptive statistics (means, standard deviations, and 95% confidence intervals for mean values) were used to describe the data. Assumptions of normality and homogeneity of variance were tested with the Shapiro-Wilk and Levene's tests, respectively. A two-way ANOVA with repeated measures with a Tukey post hoc test was used to assess the effects of the pre-post PAPE. As a measure of effect size between both conditions, Cohen's d was calculated, and the obtained values were interpreted as recommended by Cohen as: 'trivial' $d < 0.20$, 'small' $d = 0.20$-0.49, moderate' $d = 0.50$-0.79, and 'large' $d > 0.80$ [24]. Statistical significance was accepted at $p \leq 0.05$. All analyses were conducted using Statistica 13.3 (Statsoft, Cracow, Poland) software, while the effect sizes were determined using the Stats.xls calculator (missouristate.edu/rstats, accessed on October 21, 2019).

Results

Table 1 shows the effects of both PAPE protocols on slap distance, power, and force. The results indicate that the 5RM pull-ups PAPE intervention led to statistically significant improvements in slap distance and force output, while power and velocity showed non-significant changes between pre- and post--intervention. The pre-intervention slap distance was measured at 74.8 ± 10.1 cm, which increased to 79.0 ± 8.0 cm post-intervention. This difference was significant ($p = 0.009$) with an effect size of 0.60, indicating a moderate effect. The peak force was significantly greater after the weighted pull-up PAP condition compared to baseline (16.3 ± 1.9 $N \cdot kg^{-1}$ vs. 18.2 ± 3.2 $N \cdot kg^{-1}$; $p = 0.022$, $d = 0.50$), but there were no significant changes in power or velocity. In contrast, the isometric pull-ups PAPE intervention did not yield significant changes across the measured parameters. The average slap distances were 73.8 ± 12.0 cm pre--intervention and 72.2 ± 8.8 cm post-intervention, with a p-value of 0.499, indicating no significant difference between the two conditions. No significant differences were observed in the remaining measured parameters: power ($p = 0.203$), velocity ($p = 0.191$), and force ($p = 0.216$).

Table 1. Power slap scores across all tested protocols

	Mean ± SD	95%CI	p value	Effect size
Weighted pull-ups (%RM)				
Slap distance pre (cm)	74.8 ± 10.1	67.0-82.6	0.009	0.60
Slap distance post (cm)	79.0 ± 8.0	72.9-85.2		
Power ($W \cdot kg^{-1}$)	15.3 ± 13.8	11.2-19.5	0.828	trivial
Power post ($W \cdot kg^{-1}$)	15.7 ± 13.8	12.8-18.7		
Velocity pre ($m \cdot s^{-1}$)	1.2 ± 0.3	1.1-1.4	0.996	trivial
Velocity post ($m \cdot s^{-1}$)	1.2 ± 0.2	1.0-1.4		
Force pre ($N \cdot kg^{-1}$)	16.3 ± 1.9	14.8-17.7	0.022	0.50
Force post ($N \cdot kg^{-1}$)	18.2 ± 3.2	15.8-20.6		
Isometric pull-ups				
Slap distance pre (cm)	73.8 ± 12.0	64.6-83.0	0.499	trivial
Slap distance post (cm)	72.2 ± 8.8	65.4-79.0		
Power pre (W·kg)	13.6 ± 3.5	10.9-16.3	0.203	0.19
Power post (W·kg)	12.4 ± 4.87	8.7-16.1		
Velocity pre ($m \cdot s^{-1}$)	1.1 ± 0.2	0.8-1.2	0.191	trivial
Velocity post ($m \cdot s^{-1}$)	1.0 ± 0.3	0.9-1.2		
Force pre ($N \cdot kg^{-1}$)	17.6 ± 2.3	15.9-19.4	0.216	0.18
Force post ($N \cdot kg^{-1}$)	16.4 ± 3.0	14.0-18.7		

When analysing the study results, it is worth paying attention to the observed intra-group differences, which may shed light on the participants' individual reactions to the applied conditioning stimulus. Overall, although all but one participant showed improvement in SLAP distance after dynamic PAPE, performance after the isometric condition was more mixed – with some subjects achieving a better slap test score, while others experienced a worsening in it. The individual results against the averages for both groups are shown in Figure 1.

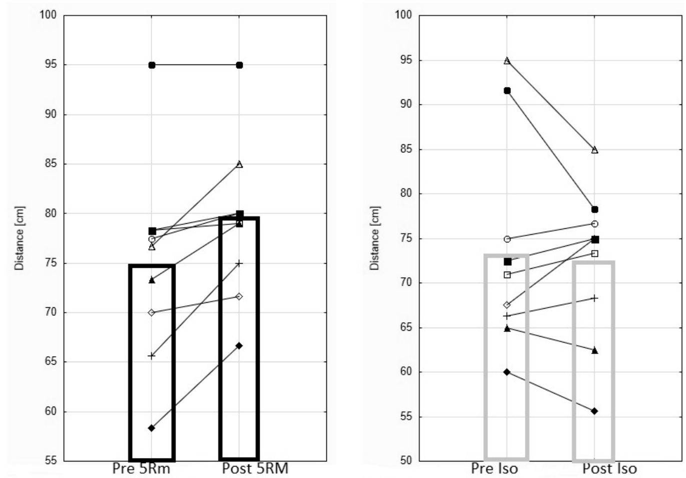

Figure 1. Individual responses (lines) and group mean (bars) of Power slap distance (cm)

Discussion

The study aimed to investigate the effects of two types of Post-Activation Potentiation (PAPE) protocols – isometric pull-ups and 5 RM weighted pull-ups – on subsequent campus board slap test, which serves as a direct measure of a climber's vertical pulling power.

The results demonstrated that the 5 RM weighted pull-ups significantly improved both slap distance and peak force output, while the isometric pull-ups did not yield significant changes across the measured parameters. With respect to the former PAPE protocol, the distance improved by an average of about 4 cm, which is in line with the results of previous studies using 5RM weighted pull-up as a conditioning activity [18, 25]. The value of effect size of 0.60 suggests a moderate and practically meaningful improvement, indicating that they can expect meaningful improvements in their explosive pull-up movements, especially when initiated by upper body (usually called 'campus movements').

In contrast, under the isometric pull-up conditions, a reduction in the slap distance of about 1.5 cm was observed, although as mentioned above, this difference was not statistically significant. Nevertheless, the lack of significant improvements from the isometric pull-ups suggests that this protocol may not be as effective for enhancing dynamic climbing performance. However, the lack of significant improvement with protocol used in this study suggests that other factors may need to be considered. For instance, future research could explore alternative variations of the isometric pull-up, such as adjusting the intensity and/or duration of the contraction. Also, the results may vary depending on the participants' climbing experience, i.e. intermediate or advanced climbers might respond differently to isometric pull-ups.

Previous studies have shown that isometric contractions, particularly maximal voluntary isometric contractions, can induce post-activation potentiation (PAPE) [20, 26, 27, 28, 29]. However, the research results are mixed, with some studies reporting a significant effect, while others find no such impact [27]. Moreover, research on isometric protocols as a PAP stimulus remains limited, especially regarding their influence on upper-body explosive performance.

For example, a study involving young tennis players [28] examined the impact of two tennis-specific 3-second isometric contractions (shoulder internal rotation and shoulder flexion) on serve velocity and accuracy. The results revealed that joint-specific PAPE significantly improved serve velocity, but did not affect serve accuracy. In another study, Kontou et al. [26] evaluated the impact of four conditioning activities – two targeting the lower body and two the upper body – on shot put performance. One such intervention involved 6-second isometric push-ups, which were associated with performance improvements. Similarly, Tsolakis et al. [28] studied fencers performing both isometric and dynamic exercises. Their results indicated that isometric protocols decreased peak leg power in male fencers and had no effect on upper-body performance, reinforcing the variability in outcomes.

The findings of our study seem to be in the trend of these observations, suggesting that dynamic PAPE protocols may be more effective than isometric ones for eliciting improvements in explosive upper-body performance. Weighted pull-ups at a 5 RM intensity involve submaximal muscle contractions, enhancing motor unit recruitment and firing rates. This neuromuscular activation likely contributes to improved force production in subsequent explosive tasks. Furthermore, weighted pull-ups better replicate the dynamic nature of climbing movements, whereas isometric pull-ups do not, potentially limiting their effectiveness as a preparatory stimulus.

The study has several limitations that should be acknowledged. First, the sample size may have been insufficient to generalize the findings to a broader population. Future research should include climbers of diverse skill levels, ages, and genders to better understand how different groups respond to PAPE protocols. Second, the absence of a control group that performed no conditioning activity limits our ability to attribute performance changes solely to the tested interventions. Including a control group would help distinguish the specific effects of the PAPE protocols from natural variation or warm-up effects. Third, performance was only measured at a single time point. As PAPE effects can be time-dependent, future studies should examine multiple time points to identify when peak performance occurs post-conditioning. Finally, given the diversity of isometric exercise parameters, further research is needed to explore different configurations (e.g., joint angle, contraction type, and duration) to determine their potential efficacy.

Conclusions

These results suggest that while the 5 RM weighted pull-ups serve as an effective PAPE stimulus for enhancing climbing power, the isometric variant does not yield similar benefits in this context.

References

1. Fischer G., Schneeberger M., Petter S.A., Scheibler A.G., Wolf P. et al. (2024). Motion analysis of the wrist and finger joints in sport climbing. *Bioengineering (Basel, Switzerland)* 11(4), 370. DOI: 10.3390/bioengineering11040370
2. Seifert L., Cordier R., Orth D., Courtine Y., Croft J.L. (2017). Role of route previewing strategies on climbing fluency and exploratory movements. *Plos One* 12(4), e0176306. DOI: 10.1371/journal.pone.0176306
3. Stien N., Riiser A., Shaw M.P., Saeterbakken A.H., Andersen V. (2023). Effects of climbing- and resistance-training on climbing-specific performance: A systematic review and meta-analysis. *Biology of Sport* 40(1), 179-191. DOI: 10.5114/biolsport.2023.113295
4. Stien N., Vereide V.A., Saeterbakken A.H., Hermans E., Shaw M.P., Andersen V. (2021). Upper body rate of force development and maximal strength discriminates performance levels in sport climbing. *Plos One* 16(3), e0249353. DOI: 10.1371/journal.pone.0249353
5. Vereide V., Andersen V., Hermans E., Kalland J., Saeterbakken A.H., Stien N. (2022). Differences in upper-body peak force and rate of force development in male intermediate, advanced, and elite sport climbers. *Frontiers in Sports and Active Living* 4, 888061. DOI: 10.3389/fspor.2022.888061
6. Boullosa D., Beato M., Dello Iacono A., Cuenca-Fernández F., Doma K. et al. (2020). A new taxonomy for postactivation potentiation in sport. *International Journal of Sports Physiology and Performance* 15(8), 1197-1200. DOI: 10.1123/ijspp.2020-0350
7. Blazevich A.J., Babault N. (2019). Post-activation potentiation versus post-activation performance enhancement in humans: Historical perspective, underlying mechanisms, and current issues. *Frontiers in Physiology* 10, 1359. DOI: 10.3389/fphys.2019.01359
8. Tillin N.A., Bishop D. (2009). Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Medicine* 39(2), 147-166. DOI: 10.2165/00007256-200939020-00004
9. Docherty D., Hodgson M.J. (2007). The application of postactivation potentiation to elite sport. *International Journal of Sports Physiology and Performance* 2(4), 439-444. DOI: 10.1123/ijspp.2.4.439
10. Scott S.L., Docherty D. (2004). Acute effects of heavy preloading on vertical and horizontal jump performance. *Journal of Strength and Conditioning Research* 18(2), 201-205. DOI: 10.1519/R-13123.1
11. Finlay M.J., Bridge C.A., Greig M., Page R.M. (2022). Upper--body post-activation performance enhancement for athletic performance: A systematic review with meta-analysis and recommendations for future research. *Sports Medicine* 52(4), 847-871. DOI: 10.1007/s40279-021-01598-4
12. Stastny P., Kolinger D., Pisz A., Wilk M., Petruzela J., Krzysztofik M. (2024). Effects of eccentric speed during front squat conditioning activity on post-activation performance enhancement of hip and thigh muscles. *Journal of Human Kinetics* 91, 5-18. DOI: 10.5114/jhk/183917
13. Kolinger D., Stastny P., Pisz A., Krzysztofik M., Wilk M. et al. (2024). High-intensity conditioning activity causes localized postactivation performance enhancement and nonlocalized performance reduction. *Journal of Strength and Conditioning Research* 38(1), 1-7. DOI: 10.1519/JSC.0000000000004590
14. Duthie G.M., Young W.B., Aitken D.A. (2002). The acute effects of heavy loads on jump squat performance: an evaluation of the complex and contrast methods of power development. *Journal of Strength and Conditioning Research* 16(4), 530-538. DOI: 10.1519/00124278-200211000-00007
15. Loturco I., Tricoli V., Roschel H., Nakamura F.Y., Cal Abad C.C. et al. (2014). Transference of traditional versus complex strength and power training to sprint performance. *Journal of Human Kinetics* 41, 265-273. DOI: 10.2478/hukin-2014-0054
16. Liossis L.D., Forsyth J., Liossis C., Solakis C. (2013). The acute effect of upper-body complex training on power output of martial art athletes as measured by the bench press throw exercise. *Journal of Human Kinetics* 39, 167-175. DOI: 10.2478/hukin-2013-0079
17. Bartolomei S., Lanzoni I.M., Fantozzi S., Cortesi M.A. (2022). Comparison between non-localized post-activation performance enhancements following resistance exercise for the upper and the lower body. *Applied Sciences* 12, 1639. DOI: 10.3390/app12031639

18. Sas-Nowosielski K., Kandzia K. (2020). Post-activation potentiation response of climbers performing the upper body power exercise. *Frontiers in Psychology* 11, 467. DOI: 10.3389/fpsyg.2020.00467
19. Vargas-Molina S., Salgado-Ramírez U., Chulvi-Medrano I., Carbone L., Maroto-Izquierdo S., Benítez-Porres J. (2021). Comparison of post-activation performance enhancement (PAPE) after isometric and isotonic exercise on vertical jump performance. *Plos One* 16(12), e0260866. DOI: 10.1371/journal.pone.0260866
20. French D.N., Kraemer W.J., Cooke C.B. (2003). Changes in dynamic exercise performance following a sequence of preconditioning isometric muscle actions. *Journal of Strength And Conditioning Research* 17(4), 678-685. DOI: 10.1519/1533-4287(2003)017<0678:cidepf>2.0.co;2
21. International Rock Climbing Research Association (2015). *The IRCRA Performance-Related Test Battery for Climbers*. Test Manual Version 1.5 https://www.ircra.rocks/mct-documents
22. Lowery R.P., Duncan N.M., Loenneke J.P., Sikorski E.M., Naimo M.A. et al. (2012). The effects of potentiating stimuli intensity under varying rest periods on vertical jump performance and power. *Journal of Strength and Conditioning Research* 26(12), 3320-3325. DOI: 10.1519/JSC.0b013e318270fc56
23. Wilson J. M., Duncan N.M., Marin P.J., Brown L E., Loenneke J.P. et al. (2013). Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. *Journal of Strength and Conditioning Research* 27(3), 854-859. DOI: 10.1519/JSC.0b013e31825c2bdb
24. Lakens D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology* 4, 863. DOI: 10.3389/fpsyg.2013.00863
25. Sas-Nowosielski K., Kandzia K. (2022). Acute effects of post activation performance enhancement of 5RM weighted pull ups and one arm pull ups on specific upper body climbing performance. *Journal of Human Kinetics* 84, 206-215. DOI: 10.2478/hukin-2022-0097
26. Kontou E.I., Berberidou F.T., Pilianidis T.C., Mantzouranis N.I., Methenitis S.K. (2018). Acute effect of upper and lower body postactivation exercises on shot put performance. *Journal of Strength and Conditioning Research* 32(4), 970-982. DOI: 10.1519/JSC.0000000000001982
27. Lim J.J.H., Kong P.H. (2013). Effects of isometric and dynamic postactivation potentiation protocol on maximal sprint performance. *Journal of Strength and Conditioning Research* 27, 2730-2736. DOI: 10.1519/JSC.0b013e3182815995
28. Baiget E., Colomar J., Corbi F. (2023). Joint-specific postactivation potentiation enhances serve velocity in young tennis players. *Journal of Strength and Conditioning Research* 37(4), 840-847. DOI: 10.1519/JSC.0000000000004334
29. Tsolakis C., Bogdanis G.C., Nikolaou A., Zacharogiannis E. (2011). Influence of type of muscle contraction and gender on postactivation potentiation of upper and lower limb explosive performance in elite fencers. *Journal of Sports Science and Medicine* 10, 577-583.

Submitted: January 12, 2025
Accepted: May 26, 2025