Journal of Human Kinetics volume 82/2022, 145-153 DOI: 10.2478/hukin-2022-0041
Section III – Sports Training

sciendo

Effects of Postactivation Performance Enhancement on the Vertical Jump in High-Level Volleyball Athletes

by

Guilherme P. Berriel[1], Ananda S. Cardoso[1], Rochelle R. Costa[1], Rodrigo G. Rosa[1], Henrique B. Oliveira[1], Luiz Fernando M. Kruel[1], Leonardo A. Peyré-Tartaruga[1]

The objective of this study was to evaluate the effects of a training session with and without an intervention of postactivation performance enhancement (PAPE) on countermovement jump (CMJ) height, perceived recovery status (PRS), and ratings of perceived exertion (RPEs), followed by a specific volleyball training session. The sample consisted of sixteen professional male volleyball players, with an average age of 26.8±6.1 years and average height of 195.9±6.7 cm, randomly divided into a group with PAPE intervention (GPAPE) (n=8), and a control group (CTRL) without PAPE intervention (n=8). The control group carried out the training session with plyometric exercises, and the GPAPE added conditioning protocols for PAPE to plyometric training, followed by a technical tactical volleyball session. At the end of the training session, there was an increase of 16.3% in the height of the CMJ in the GPAPE, while the CTRL showed a decrease of 5% in the height of the CMJ. PRS and RPE variables did not differ between the groups. It was concluded that PAPE had a positive effect on the height of the vertical jump after plyometric training, which was maintained until the end of the technical and tactical volleyball session.

Key words: *team sports, countermovement jump, performance, plyometrics, postactivation performance enhancement.*

Introduction

The ability to jump vertically is paramount in volleyball techniques such as serving, attacking, setting, and blocking (Sattler et al., 2012). Therefore, considering elite athletes, there is a necessity to use innovative and advanced methods of strength and power training to improve volleyball performance. Specifically, these methods need to be optimized in terms of the load to enable explosive movements to promote extreme adaptation in jump performance during the entire volleyball game (McCann and Flanagan, 2010; Sheppard and Newton, 2012).

Complementary strategies such as postactivation performance enhancement (PAPE) have received significant attention (Kilduff et al., 2007; Krzysztofik and Wilk, 2020; Zimmermann et al., 2020). PAPE is aimed at increasing muscle strength and power in response to a previous conditioning activity like sets of heavy-loaded (80–90% 1-RM) (Bevan et al., 2010) resistance exercises employing free-weights (Chen et al., 2017) or variable resistance training (Comyns et al., 2006). This phenomenon may have a short half-life, but enhancement in voluntary force production detected several minutes after the conditioning activity is also observed (Blazevich and Babault, 2019).

The postactivation performance enhancement (PAPE) is a physiological/neuromuscular phenomenon associated with acute improvement in muscular performance. While the postactivation potentiation has been largely explained by an increased myosin light chain phosphorylation occurring in type II muscle fibers, PAPE is underpinned by changes in muscle temperature, muscle/cellular water content, and muscle

[1] - *Exercise Research Laboratory, School of Physical Education, Physical Therapy and Dance, Federal University of Rio Grande do Sul, Porto Alegre, Brazil.*

Authors submitted their contribution to the article to the editorial board.
Accepted for printing in the Journal of Human Kinetics vol. 82/2022 in April 2022.

activation resulting in voluntary force enhancement detected several minutes after high-intensity muscle contractions (Blazevich and Babault, 2019; Boullosa et al., 2020).

Studies applying PAPE in highly trained volleyball athletes are scarce. McCann and Flanagan (2010) evaluated 16 college-level players and showed that PAPE intervention showed an improvement in the vertical jump at 4 or 5-min after 5 repetitions maximum (RM) of either the back squat or the hang clean. Also, Chen et al. (2017) evaluated the acute effect in college volleyball and basketball athletes showing similar positive effects on vertical jump performance of different conditioning activities to induce the PAPE phenomenon (5RM squat loads and one set of five repetitions using different percentages of optimal drop jump height). Although when considering positive responses arising from PAPE, it should be noted that the dose-response and the manipulation of times and sequences of conditioning activities can interfere with these responses. An important issue for conditioning professionals is the perceptual response during periods after the application of PAPE, for example, during tactical volleyball training. Adequate training loads and recovery have been identified as essential elements to improve performance and well-being in team sports and avoid non-functional overreaching and overtraining. In a recent study, positive adaptation elicited by training stimuli was accompanied by high levels of stress and muscle damage, together with lower perceptions of recovery during the championship preseason (Berriel et al., 2020).

Indeed, performing maximum or submaximal strength sets of exercises for PAPE induction may lead to higher ratings of perceived exertion (RPE) by the effects of fatigue in athletes at the end of the training session, even when these athletes have similar perceived recovery status (PRS). Abbes et al. (2018) showed the RPE values did not differ between the PAPE control conditions showing no significant improvement in performance. Timon et al. (2019) showed no significant differences in the RPE when comparing two protocols of the PAPE, even when the PAPE showed a positive effect on squat jump performance. However, we could not find studies which evaluated perceptions of effort and recovery regarding plyometric training sessions followed by a specific volleyball training session with PAPE intervention in volleyball athletes.

Therefore, we aimed to evaluate the effects of a plyometric training session with and without PAPE followed by a specific volleyball training session on CMJ, PRS, and RPE in high-level volleyball athletes. We hypothesized that PAPE would improve jump performance and, the RPE and PRS would remain similar for PAPE and control conditions.

Methods

Experimental approach

The study sample was randomly divided into two groups: a group with PAPE intervention (GPAPE) and a control group without PAPE intervention (CTRL). Athletes were allocated to the groups before training sessions. The randomization method was performed using the SPSS version 22.0 (IBM, Chicago, EUA).

Plyometric training was performed by both groups. The determination of the load and optimum PAPE time was carried out prior to training. The training session was conducted after 2 days of rest. Before starting the training session, PRS and CMJ heights were assessed. Plyometric training was then performed with or without PAPE intervention, followed by technical and tactical volleyball training. At the end of the volleyball training session, CMJ height and the RPE were evaluated (Figure 1). This study was carried out during the pre-season.

Participants

Sixteen professional male athletes participated in the study, with an average age of 26.8±6.1 years, an average body mass of 92.4±9.4kg, an average height of 195.9±6.7cm and average body fat content of 11.3±1.6%. The inclusion criteria were players of a high-performance volleyball team from Brazil, players with at least two years of experience in national and international competitions, players who trained for a minimum of 4 hours per day, and subjects that did not use supplementation. We did not collect the data of athletes, who, under the guidance of the team's medical department, were unable to perform the proposed tests.

Before participating in the study, athletes read and signed a free and informed consent form containing all the information relevant to the study. This study was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (opinion number: 1,464,312).

Procedures

Determination of the load and optimum PAPE time: The hack squat RM protocol was developed based on the work of Jo et al. (2010) and involved the players completing a standardized warm-up of 5-min cycling (60W, 1-kg resistance) on a cycle ergometer (Cibex, EUA). Following a 2-min recovery period, they performed 10 unloaded hack squats, 8 repetitions at 40% estimated 1RM, 6 repetitions at 60% estimated 1RM, and 4 repetitions at 70% estimated 1RM with a 3-min rest interval between each load. After resting for 3-min, 3RM were determined by trial and error using the Lombardi (1989) table to estimate the load at each attempt. An interval of 5-min was allowed between each attempt (Reynolds et al., 2006). The largest weight with which the participant was able to perform the exercise was adopted as the load for the 3RM (Kilduff et al., 2007).

The test determined the maximum load squat in three maximum repetitions (3RM) of the Hack-Squat exercise (Hack-Squat, Athletics, Santa Catarina, Brazil). The test consisted of the athlete performing a lift from a 90° flexion position of the knee and hip to the 180° extension of the same joints and the positioning of the feet in the anatomical position. The control of knee and hip flexion was done by a goniometer (Goniometer Shahe, Chengdu Sanhe, China), with a limiter to guarantee execution at the correct angle and 3RM was performed at selected auto speed. Players regularly performed the hack squat during their weight training sessions, thus they were familiar with the exercise.

Thirty minutes after the 3RM load determination test, a 5-min warm-up run at $8 km \cdot h^{-1}$ was performed on a treadmill, followed by passive stretching of the lower limbs for 30s for each muscle group. After a 5-min rest interval athletes performed a CMJ to obtain the reference value. After another 10-min interval, participants performed the squat with a load relative to the 3RM, followed by one CMJ. The execution of the CMJ occurred after 15s and 4, 8, 12, 16, 20, and 24-min in a row after the 3RM of the squat were performed, as suggested by Kilduff et al. (2007). The most optimal rest interval for the emergence of PAPE was considered to be the one in which the participant achieved the highest vertical jump height after performing the 3RM of the squat (Kilduff et al., 2007; Mola et al., 2014).

Vertical Jump Height Assessment: The CMJ was executed on a valid force plate (Hidrofit Ltda, Brasil) connected to software Multisprint (Multisprint, Belo Horizonte, Brazil) which estimates the height of the vertical jump according to flight time, using the following equation: $h=g \cdot t^2 \cdot 8^{-1}$ where h is the height, g is the acceleration value of gravity and t is the flight time (Bosco et al., 1983). The intraclass correlation coefficient (ICC) of measurements between familiarization and the test for prescription of training loads and optimal rest intervals for PAPE was 0.97 for 15s, 0.96, 0.87, 0.91, 0.91, and 0.91 for 4, 8, 12, 16, and 20-min, respectively.

PRS and RPE: The athletes' perceived recovery status was evaluated using the PRS scale applied by Laurent et al. (2011). Athletes were asked to answer the following question: What is your perception of recovery at the moment? Participants provided their responses by pointing on the scale. The scale scores ranged from 0 to 10, where 0 was equivalent to no recovery and 10 was equivalent to full recovery.

The RPE was assessed using the CR-10 scale (Borg, 1982). Athletes were asked to answer the following question: What was your perception of effort in the today's match or training? They pointed their responses on the scale. The scale indexes varied from 0 to 10, where 0 was equivalent to no effort and 10 was equivalent to maximal effort. Athletes were familiarized with the scales.

Training session: Participants performed a 5-min warm-up run at $8 km \cdot h^{-1}$ on a treadmill, followed by passive stretching of the lower limbs for 30s for each muscle group. Then, all participants performed a pre-training test to determine the maximum CMJ height on the force plate. From here, the GPAPE athletes underwent three sets of exercises to induce the PAPE phenomenon, based on the work of Kilduff et al. (2007) in which each set consisted of 3RM for the squat exercise, followed by an individual optimal rest interval, pre-established in a test previously mentioned for the implementation of PAPE. At the end of the rest interval, a plyometric training session was performed consisting of a sequence of

CMJs in a target zone corresponding to the maximum height of the pre-training CMJ until jump performance dropped to 5% of the maximum height; training was performed on the force plate to control the height of the jumps during the exercise. When the athlete showed a 5% drop in CMJ performance for three consecutive jumps, it was characterized as a state of fatigue, at which point the exercise was interrupted (Pereira et al., 2009). There was a rest interval of 5 min between each set. For the CTRL, only three sets with the CMJ sequence protocol were performed, with a rest interval of 5-min between each set, identical to the GPAPE.

After training, athletes from both groups underwent a technical tactical volleyball training session for a period of approximately 60-min, and at the end of training, they performed a post-maximal CMJ test on the force plate, as mentioned previously.

Statistical analysis

All data are presented as mean and standard error. For the jump height variable, the analysis of generalized estimation equations (GEE) was used, adopting the time and group factors, with a complementary Bonferroni test. For the PRS and RPE variables, the Shapiro-Wilk test was performed to test normality and, as the data were parametric, the Student's t-test was used for independent samples. Differences were considered significant at $p \leq 0.05$ and all calculations were performed using SPSS software (version 22.0; IBM Corp., Armonk, NY, USA). Hedges' *g* was used to determine the effect size (ES) with the 95% confidence interval (IC) of the difference between pre- and post-training in jump height, PRS, and RPE in the two groups (Rosenthal, 1996). The interpretation of ES's magnitude was based on Hopkins (2002) criteria: <0.2 was trivial, 0.2–0.5 small, 0.6–1.1 moderate, 1.2–1.9 large, and 2.0–4.0 very large.

Results

The height of the CMJ was significantly different between the groups ($p<0.001$; g=.97; 95% CI=-.06; 2.01; moderate) after the training session. The GPAPE showed a significant increase in CMJ performance between the baseline values (38.26±4.44cm) and those obtained after the training session (44.81±2.69cm), while for the CTRL the height did not differ significantly between pre (37.03±4.40cm) and post training sessions (35.38±3.60cm), as shown in Figure 2.

Athletes presented different PAPE induction times. Four athletes had an optimal time of 4-min, 8 athletes had an optimum time of 8 min, 3 athletes had an optimal time of 12-min, and only 1 athlete had an optimum time of 20-min. The mean time with standard error was 8.5±1.12-min.

Both the groups did not show significant differences in the means of PRS and RPE, as shown in Figure 3. The GPAPE had an average of 7.30±0.70 and the CTRL 7.10±0.61 for the PRS in the pre-training session ($p>0.05$; g=.10; 95%CI=-.88; 1.08; trivial). Immediately after the training session, there were no significant differences for the RPE between the groups, with the GPAPE showing an average of 4.30±0.44 and the CTRL showing the value of 4.50±0.37 ($p>0.05$; g=.16 95%CI=-.82; 1.14; trivial) (Figure 3).

Discussion

The aim of this study was to evaluate the effects of a training session with and without PAPE intervention, followed by specific volleyball training, on the height of the CMJ, PRS, and RPE in volleyball players. Athletes increased the average height of the CMJ by 16.3% from the baseline values to after the training session in the GPAPE. The CTRL showed no difference in the height of the jump between the two conditions. This difference between the groups suggests a positive effect of PAPE intervention on CMJ performance after about 20-min of plyometric training followed by 60-min of tactical and technical training in volleyball players. Furthermore, the perceptual responses after the session (RPE) and at the beginning of the following training session were not modified when comparing the two conditions. To the best of our knowledge this is the first study to observe positive acute responses in jump performance while showing no perceptual impairment when applying PAPE in high-level volleyball players.

The literature shows that PAPE enhances voluntary muscle function (Blazevich and Babault, 2019). Studies which have assessed PAPE mechanisms are usually acute-effect evaluations. The findings of the present study show similar results after the training session to those of McCann and Flanagan (2010), but with greater magnitude. McCann and Flanagan (2010) assessed university level volleyball players; after performing five RMs of the squat exercise; players showed a 5.7% improvement in vertical jump performance at the 4th or 5thmin after the conditioning activity which was lower than the value found in the present study.

Time

Group	Pre training session	Training session				After training session
		Warm-up	PAPE	Plyometric training	Training volleyball	
GPAPE	Maximal CMJ height PRS	5-min warm-up running at 8 km·h-1 (treadmill) passive stretching of the lower limbs	3 sets of 3RM hack-squat	3 sets of CMJs sequence in 95% a target zone of height to the maximum CMJ	Technical and tactical training	Maximal CMJ height RPE
CTRL	Maximal CMJ height PRS	5-min warm-up running at 8 km·h-1 (treadmill) passive stretching of the lower		3 sets of CMJs sequence in 95% a target zone of height to the maximum CMJ	Technical and tactical training	Maximal CMJ height RPE

Figure 1

Experimental design and procedures.

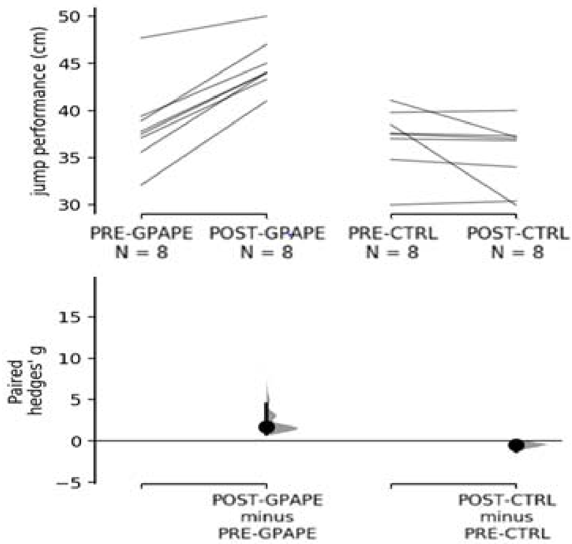

Figure 2

The paired Hedges' g for two comparisons are shown in the above cumming estimation plot. The raw data are plotted on the upper axes; each paired set of observations is connected by a line. On the lower axes, each paired mean difference is plotted as a bootstrap sampling distribution. Mean differences are depicted as dots; 95% confidence intervals are indicated by the ends of the vertical error bars.

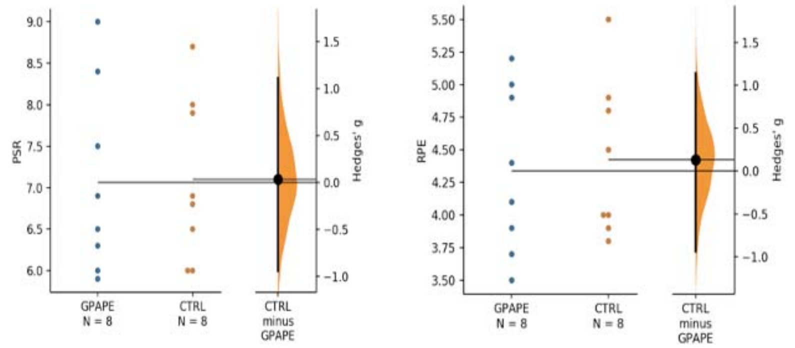

Figure 3

The Hedges' g between group with PAPE induction (GPAPE) and group without PAPE induction (CONTROL) is shown in the above Gardner-Altman estimation plot to perceived recovery status (PRS) and ratings of perceived exertion (RPEs). Both groups are plotted on the left axes; the mean difference is plotted on floating axes on the right as a bootstrap sampling distribution. The mean difference is depicted as a dot; the 95% confidence interval is indicated by the ends of the vertical error bar.

This can be attributed to the difference in the performance level of athletes and difference to access responses (around 80-min after the conditioning activity). Chiu et al. (2003) compared the acute effects of PAPE in athletes who used explosive strength, compared to recreationally trained subjects, and showed significantly higher results in strength and power for athletes ($p<0.05$), suggesting that they achieved greater activation of the involved musculature; thereby, generating more effective responses in mechanisms that induced the PAPE phenomenon. This could explain the possible percentage differences between the findings of the present study and of McCann and Flanagan (2010) since both evaluated volleyball athletes.

A study by French et al. (2003) evaluating athletes who used power in their sporting movements showed an increase in drop jump height of 5.0% after performing three maximum voluntary contractions (MVCs) of three seconds, but without differences in the CMJ. According to the authors, it is important for the induction of PAPE, to have knowledge of the nature of the exercise, and the volume capable of generating the response of the phenomenon. Our findings show positive effects of 3 sets of 3RM hack-squat exercise, with significant results for the CMJ and its height, which are widely used as performance indicators of volleyball athletes (Sheppard and Newton, 2012).

Kilduff et al. (2007) evaluated professional rugby players and although did not evaluate CMJ height, they observed improvement in peak power through CMJ performance after the squat exercise with a load of 3RMs. Petisco et al. (2019) showed positive results of 3.7% for the squat jump and 2.2% for the CMJ after warming up with squats performed at 80% of 1RM in soccer athletes. These results corroborate the findings of the present study in lower magnitude, however, the strategy used in the present study differed from that in the study by Petisco et al. (2019) who used five repetitions at 80% 1RM to induce PAPE, which may have resulted in less stimulus.

Conversely, various studies showed

similar effects of resistance training inducing the PAPE phenomenon and plyometric training on the jumping performance responses. Chen et al. (2017) evaluated college volleyball and basketball athletes and showed similar effects of resistance training inducing the PAPE phenomenon and plyometric training on the jumping performance responses. Furthermore, Mola et al. (2014) found no significant differences in height and jumping power between the groups that performed a plyometric warm-up and the group with PAPE intervention. Till and Cooke (2009) showed that PAPE intervention was not effective in improving performance of sprints and jumps when compared to the control group, who performed only a warm-up protocol.

This study showed positive effects of plyometric training combined with PAPE intervention on the ability to jump after 60-min of tactical-technical training in volleyball players, what seems important to athletes for the maintenance of jump performance during the entire training session and match. The increase in muscle temperature and the blood flow, and, subsequently, in the amount of water in muscles may explain the effects of PAPE for this period, as they are associated with an increase in muscle activation, the rate of strength development, and speed of contraction in muscles involving fast contraction and slow contraction (Blazevich and Babault, 2019).

Regarding PRS and the RPE, the present study found no significant difference between the two groups for these variables, indicating that athletes in both groups showed a similar recovery result before training started. At the end of the training session, athletes in both groups reported a similar level of perceived exertion, which indicates that although the PAPE group had a higher training load than the plyometric group, it did not cause greater physical exhaustion. Similar results have been shown by Abbes et al. (2018) and Timon et al. (2019) without significant differences when comparing different protocols with post-activation performance enhancement.

The literature shows that the ideal recovery time between the condition activity and explosive activity seems to be a decisive factor in inducng PAPE (Jo et al., 2010; Kilduff et al., 2007; Mola et al., 2014). In our study, athletes presented different optimal times for PAPE induction, varying between 4 and 20-min. This result corroborates with the literature that suggests that the optimal application time of PAPE does not exceed 20 min (O'Leary et al., 1997; Vandervoort et al., 1983). Kilduff et al. (2007) in a study with rugby athletes, using a voluntary contraction protocol that consisted of performing 3 repetitions of the squat exercise with 90% of 1RM and performing vertical jumps, 15-s, 4, 8, 12, 16, 20, and 24-min after the squat execution, found that PAPE was the most efficient in the period from the 8th to the 12thmin post-stimulus. In another study by Comyns et al. (2006) anaerobic sports athletes (sprinters, jumpers, and rugby players) used the squat with 5 maximum repetitions and performed a vertical CMJ after 30-s, 2, 4, and 6-min; those authors observed a significant improvement in the jump height after 4 min of the conditioning activity. In the present study, the optimal time for the application of PAPE was similar to that found in the literature and also justifies the postactivation potentiation (PAP) evaluation model proposed by Kilduff et al. (2007) which suggests that an individual assessment is required to be made to determine the optimal time for PAPE, since there seems to be no standard time for its best use.

Among the possible limitations of the present study is the vertical jump height assessment only after the training session. This study was carried out during the basic training period of athletes when the training window might be larger than that during competitive periods. We did not find other studies which observed the effects of PAPE intervention after plyometric training followed by tactical-technical training and its effects. All previous studies have evaluated performance of jumps immediately after the induction of PAPE. Moreover, this study shows important results regarding PAPE effects in high-level athletes after 20-min plyometric training followed by 60-min tactical-technical training on volleyball performance, of significant variables for volleyball performance, such as jump height.

Conclusions

Therefore, it could be concluded that there was superiority of the GPAPE in relation to the CTRL, with a significant increase in the height of the CMJ and no differences between the groups in the perception of effort after training.

This study showed a positive effect on the ability to jump after the induction of PAPE (20-min intervention + 60-min tactical-technical training in volleyball), and without significant difference between the CTRL to the RPE after the training session.

Acknowledgements

We acknowledge financial support from CAPES-Brazil and CNPq-Brazil. We are grateful to the Group Locomotion and Aquatic and Terrestrial Activities Group (GPAT) of the Federal University of Rio Grande do Sul for the discussions and comments. The authors of this manuscript clarify that there were no conflicts of interest.

References

Abbes, Z., Chamari, K., Mujika, I., Tabben, M., Bibi, K. W., Hussein, A. M., Martin, C. & Haddad, M. (2018). 50-m freestyle sprint performance in adolescent swimmers? *Frontiers in Physiology*, *9*(OCT). https://doi.org/10.3389/fphys.2018.01464

Berriel, G. P., Costa, R. R., da Silva, E. S., Schons, P., de Vargas, G. D., Peyré-Tartaruga, L. A. & Kruel, L. F. M. (2020). Stress and recovery perception, creatine kinase levels, and performance parameters of male volleyball athletes in a preseason for a championship. *Sports Medicine - Open*, *6*(1), 1–12. https://doi.org/10.1186/s40798-020-00255-w

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*. https://doi.org/10.3389/fphys.2019.01359

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, *14*(5), 377–381.

Bosco, C., Luhtanen, P. & Komi, P. V. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology and Occupational Physiology*, *50*(2), 273–282. https://doi.org/10.1007/BF00422166

Boullosa, D., Beato, M., Iacono, A. Dello, Cuenca-Fernández, F., Doma, K., Schumann, M., Zagatto, A. M., Loturco, I. & Behm, D. G. (2020). A new taxonomy for postactivation potentiation in sport. *International Journal of Sports Physiology and Performance*, *15*(8), 1197–1200. https://doi.org/10.1123/IJSPP.2020-0350

Chen, Z. R., Lo, S. L., Wang, M. H., Yu, C. F. & Peng, H. Te. (2017). Can different complex training improve the individual phenomenon of post-activation potentiation? *Journal of Human Kinetics*, *56*(1), 167–175. https://doi.org/10.1515/hukin-2017-0034

Chiu, L. Z. F., Fry, A. C., Weiss, L. W., Schilling, B. K., Brown, L. E. & Smith, S. L. (2003). Postactivation potentiation response in athletic and recreationally trained individuals. *Journal of Strength and Conditioning Research*, *17*(4), 671–677. https://doi.org/10.1519/1533-4287(2003)017<0671:PPRIAA>2.0.CO;2

Comyns, T. M., Harrison, A. J., Hennessy, L. K. & Jensen, R. L. (2006). The optimal complex training rest interval for athletes from anaerobic sports. *Journal of Strength and Conditioning Research*, *20*(3), 471–476. https://doi.org/10.1519/18445.1

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. https://doi.org/10.1519/1533-4287(2003)017<0678:CIDEPF>2.0.CO;2

Hopkins, W. G. (2002). *New View of Statistics: Effect Magnitudes*. https://www.sportsci.org/resource/stats/effectmag.html

Jo, E., Judelson, D. A., Brown, L. E., Coburn, J. W. & Dabbs, N. C. (2010). Influence of recovery duration after a potentiating stimulus on muscular power in recreationally trained individuals. *Journal of Strength and Conditioning Research*, *24*(2), 343–347. https://doi.org/10.1519/JSC.0b013e3181cc22a4

Kilduff, L. P., Bevan, H. R., Kingsley, M. I. C., Owen, N. J., Bennett, M. A., Bunce, P. J., Hore, A. M., Maw, J. R. & Cunningham, D. J. (2007). Postactivation potentiation in professional rugby players: Optimal recovery. *Journal of Strength and Conditioning Research*, *21*(4), 1134–1138. https://doi.org/10.1519/R-20996.1

Krzysztofik, M. & Wilk, M. (2020). The effects of plyometric conditioning on post-activation bench press performance. *Journal of Human Kinetics*, *74*(1), 99–108. https://doi.org/10.2478/hukin-2020-0017

Laurent, C. M., Green, J. M., Bishop, P. A., Sjökvist, J., Schumacker, R. E., Richardson, M. T. & Curtner-Smith, M. (2011). A practical approach to monitoring recovery: Development of a perceived recovery status scale. *Journal of Strength and Conditioning Research*, *25*(3), 620–628. https://doi.org/10.1519/JSC.0b013e3181c69ec6

Lombardi, V. P. (1989). *Beginning weight training : the safe and effective way.* (and S. Borrow (ed.)).

McCann, M. R. & Flanagan, S. P. (2010). The effects of exercise selection and rest interval on postactivation potentiation of vertical jump performance. *Journal of Strength and Conditioning Research*, *24*(5), 1285–1291. https://doi.org/10.1519/JSC.0b013e3181d6867c

Mola, J. N., Bruce-Low, S. S. & Burnet, S. J. (2014). Optimal recovery time for postactivation potentiation in professional soccer players. *Journal of Strength and Conditioning Research*, *28*(6), 1529–1537. https://doi.org/10.1519/JSC.0000000000000313

O'Leary, D. D., Hope, K. & Sale, D. G. (1997). Posttetanic potentiation of human dorsiflexors. *Journal of Applied Physiology*, *83*(6), 2131–2138. https://doi.org/10.1152/jappl.1997.83.6.2131

Pereira, G., Morse, C., Ugrinowitsch, C., Rodacki, A., Kokubun, E. & Fowler, N. (2009). Manipulation of rest period length induces different causes of fatigue in vertical jumping. *International Journal of Sports Medicine*, *30*(5), 325–330. https://doi.org/10.1055/s-0029-1202260

Petisco, C., Ramirez-Campillo, R., Hernández, D., Gonzalo-Skok, O., Nakamura, F. Y. & Sanchez-Sanchez, J. (2019). Post-activation potentiation: Effects of different conditioning intensities on measures of physical fitness in male young professional soccer players. *Frontiers in Psychology*, *10*(JUN), 1167. https://doi.org/10.3389/fpsyg.2019.01167

Reynolds, J. M., Gordon, T. J. & Robergs, R. A. (2006). Prediction of one repetition maximum strength from multiple repetition maximum testing and anthropometry. *Journal of Strength and Conditioning Research*, *20*(3), 584–592. https://doi.org/10.1519/R-15304.1

Rosenthal, J. A. (1996). Qualitative descriptors of strength of association and effect size. *Journal of Social Service Research*, *21*(4), 37–59. https://doi.org/10.1300/J079v21n04_02

Sattler, T., Sekulic, D., Hadzic, V., Uljevic, O. & Dervisevic, E. (2012). Vertical jumping tests in volleyball: Reliability, validity, and playing-position specifics. *Journal of Strength and Conditioning Research*, *26*(6), 1532–1538. https://doi.org/10.1519/JSC.0b013e318234e838

Sheppard, J. M. & Newton, R. U. (2012). Long-term training adaptations in elite male volleyball players. *Journal of Strength and Conditioning Research*, *26*(8), 2180–2184. https://doi.org/10.1519/JSC.0b013e31823c429a

Till, K. A. & Cooke, C. (2009). The effects of postactivation potentiation on sprint and jump performance of male academy soccer players. *Journal of Strength and Conditioning Research*, *23*(7), 1960–1967. https://doi.org/10.1519/JSC.0b013e3181b8666e

Timon, R., Allemano, S., Camacho-Cardeñosa, M., Camacho-Cardeñosa, A., Martinez-Guardado, I. & Olcina, G. (2019). Post-activation potentiation on squat jump following two different protocols: Traditional vs. inertial flywheel. *Journal of Human Kinetics*, *69*(1), 271–281. https://doi.org/10.2478/hukin-2019-0017

Vandervoort, A. A., Quinlan, J. & McComas, A. J. (1983). Twitch potentiation after voluntary contraction. *Experimental Neurology*, *81*(1), 141–152. https://doi.org/10.1016/0014-4886(83)90163-2

Zimmermann, H. B., Macintosh, B. R. & Dal Pupo, J. (2020). Does postactivation potentiation (PAP) increase voluntary performance? In *Applied Physiology, Nutrition and Metabolism* (Vol. 45, Issue 4, pp. 349–356). Canadian Science Publishing. https://doi.org/10.1139/apnm-2019-0406

Corresponding author:

Guilherme P. Berriel
Exercise Research Laboratory, School of Physical Education,
Physical Therapy and Dance, Federal University of Rio Grande do Sul, Porto Alegre, Brazil, Felizardo Street, 750, 90690-200. Telephone: 55 51981517215
E-mail: guilhermeberriel@hotmail.com