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ORIGINAL ARTICLE

The Mediating Effects of Caffeine Ingestion and Post-Activation Performance Enhancement on Reactive Dive Times in Goalkeepers

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ABSTRACT

Background. The reactive abilities of goalkeepers are crucial and may directly impact match results. Therefore, research on factors that may enhance goalkeeper performances during diving tasks (DT) and how these factors are mediated would provide valuable information for coaches and goalkeepers. **Objectives.** The purpose of this investigation was to: (i) assess the impact of caffeine consumption and post-activation performance enhancement (PAPE) on the DT ability of goalkeepers and (ii) investigate the potential mechanisms responsible for changes in DT performance. **Methods.** Purposive sampling was utilized, coupled with a double-blinded cross-over study design. 25 soccer goalkeepers volunteered for the study (age: 22.50 ± 4.32 years; height: 1.67 ± 0.78 m; mass: 66.58 ± 11.30 kg). Players were evaluated for simple reaction time (SRT), dynamic reaction time (RT), jump height (JH), and reactive DT under three treatment conditions: control, caffeine, and PAPE. **Results.** Improvements in DT are mediated by improvements in RT rather than changes in JH (i.e. explosiveness) when consuming caffeine (β = -0.09, t (48) = -3.17, P =0.002) or performing plyometric drills (β = -0.14, t (48) = -4.47, P <0.001). Both treatments were similarly effective (Mdiff = 0.00 sec, P < 0.994). **Conclusion.** Caffeine consumption or PAPE is similarly effective in improving goalkeeper DT performances. These improvements may likely be related to changes in dynamic RT, thereby implying that faster information processing by the CNS is the likely source for improvements.

KEYWORDS: ***Ergogenic, Performance Enhancement, Plyometrics, Reaction Time, Soccer.***

INTRODUCTION

Goalkeepers perform a highly specialized role in field sports such as soccer and hockey. Although goalkeepers are the last line of defense, evidence-based tools for goalkeeper-specific performance improvements are lacking (1, 2). Most research on goalkeepers tends to be limited to anthropometric and physiological characteristics (3, 4), or time-motion analyses (5, 6), with research on perceptual cues and anticipatory skills being much more limited (7, 8). New laws regarding penalties, such as goalkeepers being sanctioned for moving off the goal line too early, mean that goalkeepers are required to enhance their reactive ability (9). Goalkeepers, therefore, need to ensure that the timing of their movement coincides with ball contact while also selecting the correct direction within a restricted timeframe (10). Reactive ability is arguably one of the most critical skills required by goalkeepers.

Data from European top division soccer leagues showed that the teams that won the 2018/2019 seasons tended to average seven shots on target per game (11). Such data would imply that, on average, a goalkeeper from the opposition would need to make game-changing

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decisions/reactions once every 13 minutes and would therefore need to be primed to maximize the likelihood of a successful outcome. Approximately 85-90% of a goalkeepers' sensory information is obtained visually, with hearing being the second most used sense (12). The time it takes a goalkeeper to respond to the sensory information is termed total response time (TRT), which is composed of simple reaction time (SRT) and movement time (MT) (13). The SRT represents the time interval between a sensory stimulus and the appropriate voluntary response to that stimulus and is thought to represent the individual's processing speed (14). The mean reaction time for college-aged individuals is approximately 190 msecs and tends to average around 293.2 ± 76.45 msec across studies (14, 15). SRT performance may be affected by factors such as type of reaction test, sex, age, constitution, motivation, emotion, the intensity of the stimulus, fitness, time of day, fatigue, amount of sleep, and muscles involved (15). Since effective goalkeeping is complex, evaluating factors that may acutely enhance dynamic RT and SRT, such as the use of ergogenic aids and muscle potentiation, is imperative (10, 16, 17).

Ergogenic aids are substances (e.g., recovery aids, cellular metabolites, drugs etc.) that may enhance endurance, power, strength, and speed (16). A known ergogenic aid that functions as a central nervous system (CNS) stimulant is caffeine (15-19) which tends to increase alertness and arousal as exhibited by significant reductions in SRT (15, 19, 20), as well as heightening muscle strength and power responses (21, 22). Caffeine acts as an adenosine A_1 and A_{2A} receptor agonist, thereby blunting the fatiguing effects of adenosine (22), and may also act on intramuscular calcium release to increase motor unit activation and maximal contractile force (23); although evidence for the latter is more varied. Evidence has shown that the effectiveness of caffeine exhibits a clear dose-response relationship whereby dosages < 2 mg/kg typically show no significant improvements in performance, whereas dosages of 3 – 6 mg/kg do (18). Similarly, post-activation performance enhancement (PAPE), also considered an ergogenic aid, is known to increase muscle force production through increased (i) calcium sensitivity (especially in type-II muscle fibers), (ii) muscle temperature, (iii) muscle blood flow, and (iv) neuronal activation (24–26). PAPE also exhibits a dose-response relationship with performance in that (i) PAPE activities that preceded performance measures by 7-10 minutes usually showed superior results, and (ii) multiple PAPE sets of moderate-intensity are superior to single sets of high intensity (19). However, the extent to which the aforementioned mechanisms alter reactive diving ability within soccer goalkeepers is unknown.

Given the importance of RT for goalkeeping performances, the purpose of this study was two-fold: (i) to assess the impact of neuromuscular perturbations, in the form of caffeine and PAPE, on the reaction diving ability of goalkeepers using a double-blinded cross-over study design and (ii) to determine the latent mechanisms responsible for potential changes in reactive diving performance.

MATERIALS AND METHODS

Study Design. A randomized, double-blinded repeated-measures cross-over design was used. Participants completed six sessions under different treatment conditions: familiarisation and baseline assessments, followed by plyometric, passive, placebo, and caffeine trials completed in a randomized sequence to avoid an order effect. Each session was separated by 48-72 hours. All testing was completed at the same time of day (± 0.30 h) to minimize the potential effect of circadian rhythms on physical performance.

Participants. Purposive sampling was utilized to recruit goalkeepers for the study from the Eastern Cape province of South Africa. Following the recruitment process, 25 soccer goalkeepers across ten soccer teams volunteered for this study (age: 22.50 ± 4.32 years; height: 1.67 ± 0.78 m; body mass: 66.58 ± 11.30 kg). The *a-priory* sample size was calculated to be 55 participants (assuming: f^2 = 0.15 [moderate], alpha = 0.05, power = 0.80, and 2 predictors) (G*Power, version 3.1.9.4). For eligibility into the study, participants had to: (i) be collegiate-level soccer goalkeepers, (ii) have at least two years of playing experience, (iii) be free of injury prior to and during testing, and (iv) sign the informed consent form. The following eligibility into the study, participants were then informed: (i) of any potential risks and discomforts associated

with testing, (ii) to avoid strenuous exercise and caffeine 24 hours prior to testing, and (iii) to arrive for testing in a well hydrated and post-prandial state. The study was approved by the university research ethics committee and complied with the declaration of Helsinki (ethics code: H18-HEA-HMS-008).

Experimental Protocol. During the first visit, participants completed the (i) informed consent forms, (ii) baseline anthropometric data such as height (measured to the nearest 0.01 m) and weight (measured to the nearest 0.01 kg), and (iii) familiarisation bouts of the testing protocols and procedures. The second visit was utilized to determine baseline values for all tests (simple auditory and visual RT, fitlights RT using hands and feet, squat jump (SJ) height, and reactive dive times). Sessions3-6, completed in a randomized order, comprised plyometric, passive, placebo, caffeine modifications of the same baseline tests.

Caffeine vs. Placebo Trials. Caffeine doses of 4-6 mg/kg BW were administered in a capsule (Caffeine Anhydrous BP, Medicolab, Amalgam, Johannesburg, South Africa) (18). Placebo capsules were filled with corn flour similar in texture and appearance to powdered caffeine to ensure adequate blinding (Maizena, Bokomo Foods, Atlantis, Cape Town, South Africa). Both caffeine and the placebo were placed in non-transparent blue-red capsules to ensure that visibility of the contents was shielded from participants. To ensure a double-blinded approach, an independent researcher randomized the dissemination of capsules to the participants for each session.

Post-Activation Performance Enhancement vs. Passive Trials. Participants performed a short plyometric drill during the PAPE session consisting of 40 jumps (10 squat jumps, ten ski jumps, ten tuck jumps, and ten lunge jumps). The drill was followed by 3 minutes of rest before completing the SJ. The 40 jumps were based on previous research, which suggested a volume of 40 jumps is enough to induce potentiation (19, 20). The 3 minutes rest was based on previous research, which found the greatest PAPE obtained from a plyometrics bout is after 3-7 minutes (21-23). Each participant served as their control for the PAPE session by utilizing a passive session, where the participants stood still for 8 minutes prior to each test. The 8 minutes was selected for three reasons: (i) the ATP-PC system is required for a short duration exercise bout (ii) previous research shows that the ATP-PC system recovers quickly, approximately after 4-5 minutes (24), and (iii) to minimize any arousal after having arrived at the testing station.

Adequate, dynamic warm-up protocols preceded all testing and were followed by a 30-minute cool-down session.

Data Collection. Reaction Time. Simple visual RT (VRT) was used to estimate visual processing speed. Participants were required to place one foot on a pressure-sensitive mat linked to a light-emitting device (Whole Body Reaction Type II, Takei Kiki Kogyo Co., LTD., Japan) (25). When a light stimulus was presented, participants were required to remove the foot from the mat as fast as possible to stop the timing system. A total of 10 successful trials were recorded, with the average being retained for analysis. For the dynamic RT tests, 8 fitlights (FITLIGHT Sports Corp, Aurora, Ontario, Canada) were programmed to be activated in a random sequence for a total of 32 individual activations. The fitlights were placed in a grid formation on a wall, with each light being separated by 0.80-m. Participants were positioned 0.50-m from the wall and were required to deactivate the lights as fast as possible using their hands and feet. Following the familiarisation, the average of all 32 activations was retained for analysis.

Squat Jump. Jump height was measured using a jumping mat (SmartJump; FusionSport, Coopers Plains, Queensland, Australia) and measuring the flight time (26). Participants were positioned on the jump mat with arms akimbo and instructed to squat as low as possible. The bottom position was held for 1-second before exploding up as fast as possible while keeping the arms on the hips throughout the movement. Participants were directed to land with straight legs and cushioned the landing by flexing the hips, knees, and ankles. A total of 3 trials were recorded for each athlete, with the highest jump being retained for analysis.

Reactive Diving. Participants were positioned 0.50-m behind a set of timing gates that, once triggered, would set off a second pair of timing gates positioned 1.0-m to the front, and 1.50-m on either side, of the participant. The bilateral timing gates would be set off randomly, and participants were required to complete ten reactive dives (5

left, five right). The heights of the timing gates were set at 0.75-m (first set) and 0.30-m (bilateral) to simulate diving to the corners of a goal. The average reactive dive time was retained for analysis.

Statistical Analysis. All data are presented as mean ± SD unless otherwise stated. Data were assessed for normality using the Shapiro-Wilk test. The mediation analysis was completed by evaluating, through regression analysis, whether the mediator (e.g., reaction time or jumping height) could predict the performance of the dependent variable to a greater extent than in the absence of the mediator (27, 28). Differences in the model's predictive capacity between mediator inclusion and exclusion were evaluated using the Sobel Test. Equivalence testing was utilized to evaluate the practical significance of changes in DT as a function of the treatment, with confidence bounds set at 0 ± 0.05 sec (29). Treatment effects (caffeine vs. PAPE), evaluated as differences from baseline (M_{diff}), were evaluated using the paired t-test with a Tukey correction. Statistical significance was accepted at the alpha level of 0.05 (30). All statistics were conducted using Jamovi (The Jamovi Project, v1.1, Computer Software; retrieved from http://www.jamovi.org) and Microsoft Excel™ (29).

RESULTS

The mediating roles of RT and JH were evaluated on the relationships between treatment (T1: caffeine vs. control; T2: PAPE vs. control) and DT. In terms of T1, the results revealed that the total effects of treatment on DT (c pathway, panel A Figure 1) were significant (β = -0.14 sec, t(48) = -4.75, P <0.001, pr^2 = 0.32) (Table 1). With the inclusion of the mediating variable (RT), the impact of the T1 on DT (c' pathway) was no longer significant (β = -0.04 sec, t(47) = -1.12, P = 0.271, pr^2 = 0.03). The indirect effects of T1 on DT through RT (ab pathway) were statistically significant (β = -0.09, t(48) = -3.17, P =0.002), thereby implying that changes in RT fully mediate the relationship between T1 and DT. The Sobel test determined that the ab effect was significantly greater than zero, Z = 3.08, p = .002. Similarly, the mediating role of explosiveness (i.e., JH) was evaluated on the same relationship between T1 and DT (panel B, Figure 1 and Table 1). With the inclusion of the mediating variable (JH), the impact of the T1 on DT was still significant (β = -0.12 sec, t(47) = -4.46, P <0.001, pr^2 = 0.30), suggesting that changes in JH did not mediate the relationship between T1 and DT. The Sobel test verified that the c- and c'-pathways were not significantly different, Z = 1.22, P = 0.221.

With regards to T2, the results showed that the total effects of the treatment on DT (c pathway, panel C Figure 1) were significant (β = -0.14 sec, t(48) = -4.53, P <0.001, pr^2 = 0.30) (Table 1). When the mediating variable (RT) was included in the relationship between T2 and DT, the association was no longer significant (β = -0.01 sec, t(47) = 0.25, P = .803, pr^2 < 0.00) (c' pathway, panel C Figure 1). The indirect effects of T2 on DT, mediated through RT (ab pathway), were found to be significant (β = -0.14, t(48) = -4.47, P <0.001), thereby implying that the relationship between T2 and DT is fully mediated by changes in RT. The Sobel test verified that the ab effect was significantly greater than zero, Z = 4.35, P < 0.001. Finally, the mediating role of lower extremity explosiveness was evaluated on the relationship between T2 and DT (c pathway), which was significant (β = -0.14 sec, t(48) = -4.53, P < .001, pr^2 < 0.30) (panel D, Figure 1). Although inclusion of the mediator reduced the magnitude of the relationship between variables, the association was still significant (β = -0.11 sec, t(47) = -3.65, P <.001, pr^2 = 0.22) (c' pathway). Given that the indirect effects of T2 on DT (ab pathway) were not statistically significant (β = -0.03, t(48) = -1.87, P =0.067), the implication is that the relationship between T2 and DT was likely only partially mediated by JH, but not to an appreciable extent since the c- and c' pathways were not significantly different (Sobel: Z = 1.83, P = 0.067).

Caffeine trials yielded faster RT compared to baseline (M_{diff} = -0.14 sec, 95% CI [-0.18, -0.09], P < 0.001) as did PAPE trials (M_{diff} = -0.14 sec, 95% CI [-0.17, -0.10], P < 0.001) (Figure 2). Improvements in RT between caffeine and PAPE trials were not significantly different (M_{diff} = 0.00 sec, 95% CI [-0.04, 0.04], p = 0.994) (Figure 2), and both fell outside the equivalence bounds (P = 0.999). Improvements in RT/DT of 0.05-0.19 sec are considered practically meaningful on the basis that this represents the discrepancy between average penalty kick velocity and goalkeeper movement time (31).

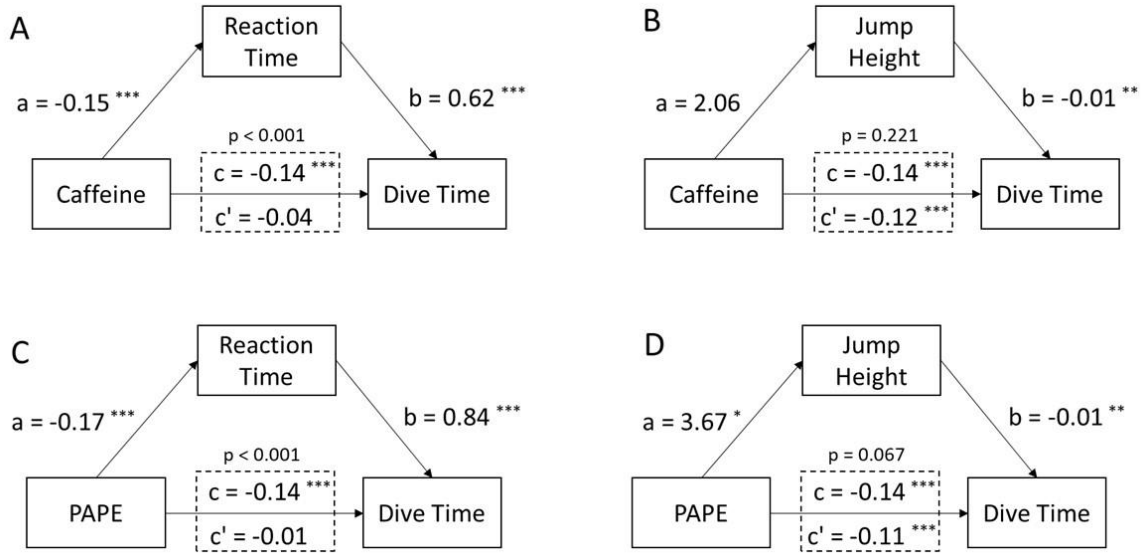

Figure 1. Mediated relationship between treatment condition (i.e. caffeine; PAPE) and reactive diving times with either RT or jump height as the mediator

Table 1. Model Summaries for Mediation Analyses

Model: Caffeine → RT → DT	**F**	**P**	**R^2**
Treatment Condition predicting Diving Times	(1, 48) = 22.56	<0.001	0.32
Treatment Condition predicting RT	(1, 48) = 54.52	<0.001	0.53
Treatment Condition and RT predicting Diving Times	(2, 47) = 19.50	<0.001	0.45
Model: Caffeine → JH → DT	**F**	**P**	**R^2**
Treatment Condition predicting Diving Times	(1, 48) = 22.56	<0.001	0.32
Treatment Condition predicting JH	(1, 48) = 1.82	0.184	0.04
Treatment Condition and JH predicting Diving Times	(2, 47) = 17.23	<0.001	0.42
Model: PAPE → RT → DT	**F**	**P**	**R^2**
Treatment Condition predicting Diving Times	(1, 48) = 20.51	<.001	0.30
Treatment Condition predicting RT	(1, 48) = 64.56	<.001	0.57
Treatment Condition and RT predicting Diving Times	(2, 47) = 29.14	<0.001	0.55
Model: PAPE → JH → DT	**F**	**P**	**R^2**
Treatment Condition predicting Diving Times	(1, 48) = 20.51	<0.001	0.30
Treatment Condition predicting JH	(1, 48) = 5.87	0.019	0.11
Treatment Condition and JH predicting Diving Times	(2, 47) = 15.51	<0.001	0.40

Where: RT, reaction time; DT, dive time; JH, jumping height; PAPE, post-activation performance enhancement

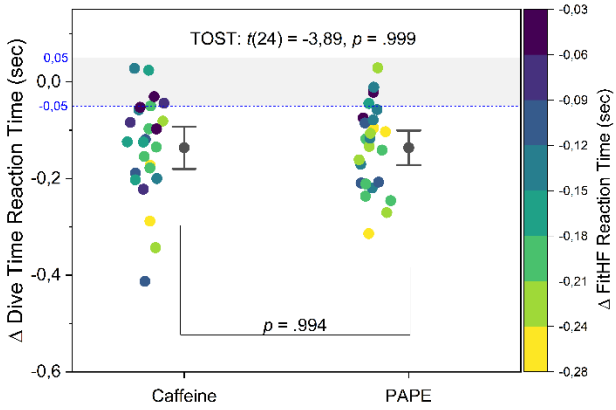

Figure 2. Data for paired t-test of the mean difference between treatment (caffeine and PAPE) and baseline, and equivalence bounds for the two one-sided t-test (TOST). Data points are color-mapped based on the dynamic RT results (FitHF))

DISCUSSION

The novel findings of the present study showed that: (i) both caffeine and PAPE, when compared to control conditions, can improve reactive diving in goalkeepers, and (ii) the potential mechanisms of the improvement in diving performance are likely mediated by changes in dynamic reaction time, which may be considered a proxy for central nervous system processing, rather than changes in explosiveness, which may be considered a proxy for muscular force output.

Caffeine appears to be an effective ergogenic aid for achieving acute increases in muscle power expressed as a single vertical jump height (32). While several different mechanisms have been proposed to underlie the performance-enhancing effects of

caffeine, the main pathway appears to be the stimulation of the central nervous system (CNS) (33). The caffeine-mediated antagonism of adenosine receptors tends to induce higher catecholamine concentrations in the brain, which reduce the downregulation of adenosine, thereby increasing arousal and nervous system activity (34). Although the present study showed that caffeine consumption was associated with greater jumping height, this was not significantly different from the control condition. Therefore, at least within the present study, the most likely mechanism by which caffeine appears to attenuate DT improvements is enhanced dynamic RT.

On the other hand, PAPE tends to enhance performance via increased force or power output following some form of high-intensity voluntary contractions (35, 36). Interestingly, compared to the control condition, the PAPE treatment was associated with a significantly greater jumping height; however, this did not appear to be the mediating mechanism by which DT was improved. Instead, it seems as though PAPE also enhanced the CNS stimulation by similarly improving the dynamic RT to that achieved by the caffeine treatment. Like caffeine, exercise can induce a neurotransmitter-receptor interaction. PAPE and caffeine treatments were similarly effective in improving reactive DT. To be practically meaningful, the DT would need to improve by at least 0.05-0.19 sec to increase the probability of initiating a save (31). Therefore, the 0.14-sec improvements in either treatment fell well within these bounds.

Based on the potential limitations of successfully initiating PAPE during soccer match-play, caffeine may trump PAPE as the favored mechanism by which performance could be enhanced. The half-life of caffeine is approximately five hours (range 1.5 – 9.5 hours), implying is that caffeine concentration will only decrease by half every five hours (37). Although not assessed within the present study, the acute performance-enhancing effects from caffeine are likely sustained for a whole soccer match, including extra time. The acute effects of PAPE, on the other hand, are tapered within several minutes of its initiation (38, 39) and would likely need to be repeated sporadically throughout discreet periods of match-play. Combining the two ergogenic aids could also be an effective alternative as caffeine may facilitate the release of Ca^{2+} from the sarcoplasmic reticulum, the primary mechanism known to enhance excitation-contraction coupling following a conditioning activity (40). Guerra et al. (22) reported a 5.75% increase in vertical JH following caffeine ingestion and plyometrics in professional male soccer players. However, based on the present study results, it is unlikely that improvements in JH lead to improvements in goalkeeper-specific performances. The potential synergistic effects of caffeine and PAPE could offer a practical method for optimizing goalkeeper performance which should be considered for future research to gain insight into its application in practical settings.

Although there are numerous strengths to the present study, several limitations were also present. Firstly, the interindividual caffeine metabolism kinetics were unknown, and it is unclear how quickly caffeine could be absorbed and metabolized across individuals. Secondly, no objective measures of gastric emptying of caffeine or caffeine tolerance, nor consideration of familiarity with plyometrics or fitness levels were assessed during this study. These might have impacted the magnitude of the intervention response. Thirdly, only male participants were included in the sample; therefore, the generalisability to female goalkeepers is unknown.

CONCLUSION

It was consuming 4-6 mg/kg BW of caffeine or completing a short plyometric drill to induce a PAPE effect to appear to be similarly effective in enhancing the reactive diving ability of goalkeepers. In both instances, the likely mechanism for the improvement appears to be mediated through changes in dynamic RT, thereby implying that faster CNS processing is the likely source for improvement.

APPLICABLE REMARKS

- Goalkeeper reactive diving performances (DT) are enhanced by similar mechanisms when ingesting caffeine or completing a PAPE drill. The ergogenic improvements are likely to be transferred to on-field performances because DT was enhanced within practically meaningful ranges.

REFRENCES

1. Otte FW, Millar S, Klatt S. Ready to perform? A qualitative-analytic investigation into professional football goalkeepers' match warm-ups. *Int J Sports Sci Coach*. 2020;**0**(0):1-13. **doi:** 10.1177/1747954120909956

2. Schwab S, Memmert D. The impact of a sports vision training program in youth field hockey players. *J Sport Sci Med*. 2012;**11**:624-631.
3. Rebelo-Gonçalves R, Figueiredo AJ, Coelho-e-silva MJ, Tessitore A. Assessment of Technical Skills in Young Soccer Goalkeepers: Reliability and Validity of Two Goalkeeper - Specific Tests. *J Sport Sci Med*. 2016(15):516-523.
4. Sørensen H, Thomassen M, Zacho M. Biomechanical Profile of Danish Elite and Sub-elite Soccer Goalkeepers. *Footb Sci*. 2008;**5**:37-44.
5. Di Salvo V, Benito PJ, Calderón FJ, Di Salvo M, Pigozzi F. Activity profile of elite goalkeepers during football match-play. *J Sports Med Phys Fitness*. 2008;**48**(4):443-446.
6. Sainz de Baranda P, Adan L, Garcia-Angulo A, Gomez-Lopez M, Nikolic B, Ortega-Toro E. Differences in the Offensive and Defensive Actions of the Goalkeepers at Women's FIFA World Cup 2011. *Front Psychol*. 2019;**10**:223. **doi:** 10.3389/fpsyg.2019.00223 **pmid:** 30804856
7. Knoop M, Fernandez-Fernandez J, Ferrauti A. Evaluation of a specific reaction and action speed test for the soccer goalkeeper. *J Strength Cond Res*. 2013;**27**(8):2141-2148. **doi:** 10.1519/JSC.0b013e31827942fa **pmid:** 23168375
8. Rodríguez-arce J, Flores-núñez LI, Portillo-rodríguez O, Flores-núñez LI, Portillo-rodríguez O. Assessing the performance of soccer goalkeepers based on their cognitive and motor skills. *Int J Perform Anal Sport [Internet]*. 2019;**19**(5):655-671. **doi:** 10.1080/24748668.2019.1647042
9. IFAB. FIFA: Laws of the Game.2020.
10. Ibrahim R, Kingma I, de Boode VA, Faber GS, van Dieen JH. Kinematic and kinetic analysis of the goalkeeper's diving save in football. *J Sports Sci*. 2019;**37**(3):313-321. **doi:** 10.1080/02640414.2018.1499413 **pmid:** 30036138
11. Holienka M, Nagy N, Baša R, Babic M. Relationship between the shooting success rate and match result in soccer at the FIFA world cup 2018. *J Phys Educ Sport*. 2020;**20**(3):1513-1521.
12. Wimshurst ZL, Sowden PT, Cardinale M. Visual skills and playing positions of Olympic field hockey players. *Percept Mot Skills*. 2012;**114**(1):204-216. **doi:** 10.2466/05.22.24.PMS.114.1.204-216 **pmid:** 22582689
13. Devi S, Madhuri K. Comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical students. *MedPulse Int J Physiol*. 2017;**4**(1):4-6.
14. Jain A, Bansal R, Kumar A, Singh KD. A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students. *Int J Appl Basic Med Res*. 2015;**5**(2):124-127. **doi:** 10.4103/2229-516X.157168 **pmid:** 26097821
15. Woods DL, Wyma JM, Yund EW, Herron TJ, Reed B. Factors influencing the latency of simple reaction time. *Front Hum Neurosci*. 2015;**9**:131. **doi:** 10.3389/fnhum.2015.00131 **pmid:** 25859198
16. Durlac PJ, Edmunds R, Howard L, Tipper SP. A rapid effect of caffeinated beverages on two choice reaction time tasks. *Nutr Neurosci*. 2002;**5**(6):433-442. **doi:** 10.1080/1028415021000039211 **pmid:** 12509073
17. Saville CWN, de Morree HM, Dundon NM, Marcora SM, Klein C. Effects of caffeine on reaction time are mediated by attentional rather than motor processes. *Psychopharmacology (Berl)*. 2018;**235**(3):749-759. **doi:** 10.1007/s00213-017-4790-7 **pmid:** 29273820
18. Salinero JJ, Lara B, Del Coso J. Effects of acute ingestion of caffeine on team sports performance: a systematic review and meta-analysis. *Res Sports Med*. 2019;**27**(2):238-256. **doi:** 10.1080/15438627.2018.1552146 **pmid:** 30518253
19. Wilson JM, Duncan NM, Marin PJ, Brown LE, Loenneke JP, Wilson SM, et al. Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. *J Strength Cond Res*. 2013;**27**(3):854-859. **doi:** 10.1519/JSC.0b013e31825c2bdb **pmid:** 22580978
20. Sharma SK, Raza S, Moiz JA, Verma S, Naqvi IH, Anwer S, et al. Postactivation Potentiation Following Acute Bouts of Plyometric versus Heavy-Resistance Exercise in Collegiate Soccer Players. *Biomed Res Int*. 2018;**2018**:3719039. **doi:** 10.1155/2018/3719039 **pmid:** 29568749
21. Seitz LB, Haff GG. Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. *Sports Med*. 2016;**46**(2):231-240. **doi:** 10.1007/s40279-015-0415-7 **pmid:** 26508319

22. Guerra MA, Jr., Caldas LC, De Souza HL, Vitzel KF, Cholewa JM, Duncan MJ, et al. The acute effects of plyometric and sled towing stimuli with and without caffeine ingestion on vertical jump performance in professional soccer players. *J Int Soc Sports Nutr*. 2018;**15**(1):51. **doi:** 10.1186/s12970-018-0258-3 **pmid:** 30348178
23. Tobin DP, Delahunt E. The acute effect of a plyometric stimulus on jump performance in professional rugby players. *J Strength Cond Res*. 2014;**28**(2):367-372. **doi:** 10.1519/JSC.0b013e318299a214 **pmid:** 23689338
24. McArdle WD, Katch FI, Catch VL. Exercsie physiology: nutrition, energy, and human performance. 7th ed. Lippincott Williams &Wilkins2010.
25. Dykiert D, Der G, Starr JM, Deary IJ. Age differences in intra-individual variability in simple and choice reaction time: systematic review and meta-analysis. *PLoS One*. 2012;**7**(10):e45759. **doi:** 10.1371/journal.pone.0045759 **pmid:** 23071524
26. Moir GL. Three Different Methods of Calculating Vertical Jump Height from Force Platform Data in Men and Women. *Meas Phys Educ Exerc Sci*. 2008;**12**:207-218. **doi:** 10.1080/10913670802349766
27. Warner RM. From Bivariate Through Multivariate Techniques. In: Applied Statistics: From Bivariate Through Multivariate Techniques. 2nd ed. London, UK: Sage Publications2013.
28. Fairchild AJ, Mackinnon DP, Taborga MP, Taylor AB. R2 effect-size measures for mediation analysis. *Behav Res Methods*. 2009;**41**(2):486-498. **doi:** 10.3758/BRM.41.2.486 **pmid:** 19363189
29. akens D, Scheel AM, Isager PM. Equivalence Testing for Psychological Research: A Tutorial. *Adv Methods Pract Psychol Sci*. 2018;**1**(2):259-269. **doi:** 10.1177/2515245918770963
30. Cumming G. Calin-Jageman R. Introduction to the new statistics. New York: Routledge2017.
31. van der Kamp J, Dicks M, Navia JA, Noël B. Goalkeeping in the soccer penalty kick: It is time we take affordance-based control. *Ger J Exerc Sport Res*. 2018;**48**:169-175. **doi:** 10.1007/s12662-018-0506-3
32. Grgic J, Trexler ET, Lazinica B, Pedisic Z. Effects of caffeine intake on muscle strength and power: a systematic review and meta-analysis. *J Int Soc Sports Nutr*. 2018;**15**:11. **doi:** 10.1186/s12970-018-0216-0 **pmid:** 29527137
33. Heckman MA, Weil J, Gonzalez de Mejia E. Caffeine (1, 3, 7-trimethylxanthine) in foods: a comprehensive review on consumption, functionality, safety, and regulatory matters. *J Food Sci*. 2010;**75**(3):R77-87. **doi:** 10.1111/j.1750-3841.2010.01561.x **pmid:** 20492310
34. Brunye TT, Mahoney CR, Lieberman HR, Taylor HA. Caffeine modulates attention network function. *Brain Cogn*. 2010;**72**(2):181-188. **doi:** 10.1016/j.bandc.2009.07.013 **pmid:** 19733954
35. Blazevich AJ, Babault N. Post-activation Potentiation Versus Post-activation Performance Enhancement in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. *Front Physiol*. 2019;**10**:1359. **doi:** 10.3389/fphys.2019.01359 **pmid:** 31736781
36. Cuenca-Fernandez F, Smith IC, Jordan MJ, MacIntosh BR, Lopez-Contreras G, Arellano R, et al. Nonlocalized postactivation performance enhancement (PAPE) effects in trained athletes: a pilot study. *Appl Physiol Nutr Metab*. 2017;**42**(10):1122-1125. **doi:** 10.1139/apnm-2017-0217 **pmid:** 28675792
37. In Summary: Caffeine for the Sustainment of Mental Task Performance: Formulations for Military Operations. *Nutr Today*. 2002;**37**(1):26-27. **doi:** 10.1097/00017285-200201000-00009 **pmid:** 11984428
38. Hespel P, Maughan RJ, Greenhaff PL. Dietary supplements for football. *J Sports Sci*. 2006;**24**(7):749-761. **doi:** 10.1080/02640410500482974 **pmid:** 16766503
39. Bishop D. Dietary supplements and team-sport performance. *Sports Med*. 2010;**40**(12):995-1017. **doi:** 10.2165/11536870-000000000-00000 **pmid:** 21058748
40. Apostolidis A, Mougios V, Smilios I, Frangous M, Hadjicharalambous M. Caffeine supplementation is ergogenic in soccer players independent of cardiorespiratory or neuromuscular fitness levels. *J Int Soc Sports Nutr*. 2020;**17**(1):31. **doi:** 10.1186/s12970-020-00360-x **pmid:** 32513182