NEUROMUSCULAR CONDITIONING TECHNIQUES FOR ENHANCING EXPLOSIVE PERFORMANCE IN FOOTBALL PLAYERS: A SYSTEMATIC REVIEW

TÉCNICAS DE ACONDICIONAMIENTO NEUROMUSCULAR PARA MEJORAR EL RENDIMIENTO EXPLOSIVO EN JUGADORES DE FÚTBOL: UNA REVISIÓN SISTEMÁTICA

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Abstract

There is increasing evidence that strength strategies before competition improve performance in explosive actions in football. A time delay between strength strategies and competition could nullify or favor the positive metabolic effects of the Post-Activation Potentiation. The purpose of this review article is to systematic search for published articles that investigated the effect of Post-Activation Potentiation (PAP) in football players. A comprehensive literature, electronic search was conducted using the Preferred Reporting Items for Systematic and Meta-Analyses (PRISMA) guidelines on the following databases: PubMed and Web of Science. Keywords such as "PAP" or "Post-Activation Potentiation" and "Football" or "soccer" and "Strength Training" or "priming" were use in the primary search. The search applied to articles published between January 2003 to March 2023 and restricted to English language. The comprehensive search identified 13 eligible articles that met the criteria for the review. Players performing maximal strength, plyometric, eccentric or maximal isometric exercises improve performance in explosive actions such as sprinting, jumping, agility and deceleration. The use of different potentiation techniques, with optimal rest times, could increases jump height and length, and decreases sprint, agility, and deceleration time. These strategies could be interesting to improve the athlete's performance.

Keywords: Football, PAP, primingpost-activation-potentiation, soccer, strength-training.

Resumen

Hay una evidencia creciente de que las estrategias de fuerza antes de la competición mejoran el rendimiento en acciones explosivas en el fútbol. El timing y el momento de aplicación de estímulos o ejercicios físicos podrían provocar un fenómeno llamado potenciación post-activación (PAP), que incrementa la fuerza y la producción de energía en acciones de potencia y fuerza. El propósito de este artículo es realizar una revisión sistemática sobre el efecto de la PAP en jugadores de fútbol para valorar su rendimiento deportivo. Se realizó una búsqueda exhaustiva de la literatura científica utilizando las guías de Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) en las siguientes bases de datos: PubMed y Web of Science. En la búsqueda primaria se utilizaron palabras clave como "PAP" o "Post-Activation Potentiation" y "Football" o "Soccer" y "Strength Training" o "Priming". La búsqueda se aplicó a artículos publicados entre enero de 2003 y marzo de 2023 y se restringió al idioma inglés. La búsqueda exhaustiva identificó 13 artículos elegibles que cumplieron con los criterios de revisión. Los jugadores que realizan ejercicios de fuerza máxima, pliométricos, excéntricos o isométricos máximos mejoran el rendimiento en acciones explosivas como correr, saltar, agilidad y desaceleración. El uso de diferentes técnicas de potenciación, con tiempos de descanso óptimos, podría aumentar la altura y la longitud del salto, y disminuir el tiempo de carrera, agilidad y desaceleración. Estas estrategias podrían ser interesantes para mejorar el rendimiento del deportista, concretamente en jugadores de fútbol.

Palabras clave: Activación previa, entrenamiento de fuerza, fútbol, PAP, potenciación post-activación.

Introduction

Recent literature has shown increasing interest in ergogenic aids to improve soccer performance (Mielgo-Ayuso et al., 2019; Belkhir et al., 2019). In this sense, sports organizations and scientists have delineated various testing and training recommendations to improve the physical attributes associated with soccer performance (Mola et al., 2014; Bedoya et al., 2015; Styles et al., 2016). The ability to develop high levels of muscular force and power has been extensively considered as an essential neuromuscular component of key tasks (Dello Iacono & Seitz, 2018). The central goal of strength/power training in a highly competitive sport is to improve the players specific and relevant athletic activities inherent in their sport (Silva et al., 2015). Although, the total distance covered in an elite soccer match can total as much as 8-12 km, it is the short high-intensity sprints that represent the crucial game changing moments (Styles et al., 2016). Improvement of these explosive performances (e.g., sprinting speed) have been chronically reported after muscular strength training programs (Styles et al., 2016), although acute improvements may also be obtained under specific conditions (Sanchez-Sanchez et al., 2018). It has been proposed that the use of resistance exercises with moderate or high loads during athlete's warm-up routines, might work as a type of conditioning activity (CA), possibly inducing meaningful enhancements in subsequent motor-tasks (Kobal et al., 2019). This phenomenon is known as post-activation potentiation (PAP), and it seems to be attributed to specific physiological and neuromuscular responses, mainly due to an increased phosphorylation of the regulatory light-chains of myosin and increased recruitment rates of motor units (Blazevich & Babault, 2019).

PAP can acutely increase muscular power and, consequently, performance (Beato et al., 2019). PAP is induced by a voluntary conditioning contraction (CC), performed typically at maximal or near-maximal intensity, and has consistently been shown to increase peak force (Hodgson et al., 2005) and, especially, the rate of force development (RFD) during subsequent twitch contractions (Tillin & Bishop, 2009), enhancing the mechanical power and then the sport performances largely determined by it (Ciocca et al., 2021).

Traditional weightlifting (TW) is one of the modalities used by coaches to elicit a PAP response for subsequent competitive activities. The majority of research investigating TW and its PAP response has reported a positive effect on reducing short distances sprint time and improving countermovement jump (CMJ) performance (Beato et al., 2019). Various methods have been used to induce PAP in athletes and untrained populations. These protocols implemented either maximal isometric actions (Spieszny et al., 2022) or dynamic heavy resistance exercise loads (Mola et al., 2014) to induce an acute effect on performance. Among other methodologies, how eccentric overload (EOL) exercises has consistently proven to be effective for acutely improving horizontal and vertical jumping performance (De Keizer et al., 2020). However, EOL and TW squat exercises acutely increase standing long jump distance and CMJ height with no differences both interventions (Beato et a., 2019).

Recent studies indicate that the requirements for exercise similarity may be greater than it seems, and such variables as a range of motion, force vector, muscle contraction type, or utilization of the stretch and shortening cycle (SSC) may have a significant impact on the magnitude of the PAP effect (Spieszny et al., 2022).

Therefore, the purpose of this systematic review is to synthesize and analyze research findings on the effects of post-activation potentiation strategies on different explosive efforts in soccer.

Material and methods

Search Strategy

A systematic review was conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2015). Relevant published between January 1st, 2003 and March 11th, 2023 in two Databases (Web of Science and PubMed) were identified. The search war performed using the Boolean search method, which limited the search results with operators including OR/AND only in those documents containing relevant key terms (Table 1) in the scope of this review.

Eligibility Criteria

Research articles were included or excluded using criteria defined with the PICOS (Population, Intervention, Comparison and Outcome) criteria, and the literature searches were limited to studies only involving soccer or football players, English language. Theses and systematic reviews were also excluded. The search strategy and eligibility criteria are shown in Table 1.

Table 1

Search Strategy and Inclusion/Exclusion Criteria Based on PICOS (Population, Intervention, Comparison and Outcome)

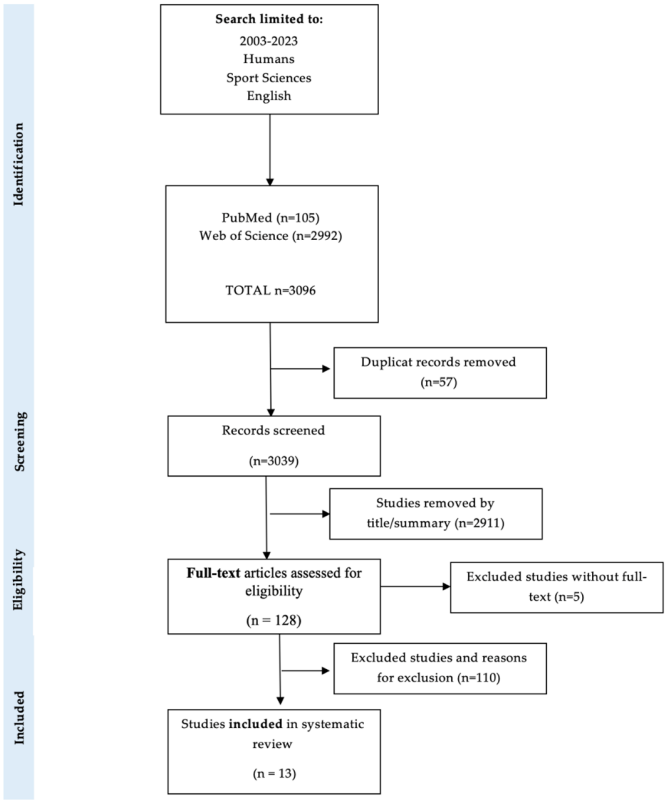
Databases	Search Terms	PICOS	Inclusion Criteria	Exclusion Criteria
PubMed Web of Science	strength training priming pre-activation prior-exercise pre-conditioning warm-up football soccer match pre-match game-day PAP post-activation-potentiation	Population Intervention Comparision Outcome	Football players or soccer players Traditional Warm-Up strategies in football or soccer "PAP" warm-up strategies in football or soccer "PAP" strategies in football or soccer Traditional Warm-up strategies "PAP" effects in Warm-up "PAP" effects Performance in explosive tasks (Sprint, Jump, Agility tasks)	Individual Sports Supplementation Nutrition Massage Vibration Cold/Hot Intervention Stretching Training Hypoxia Only includes strength training

Study Selection

A total of 3096 articles were identified from literature search. Of those, 57 were duplicated and 3039 records were screened by tittle and abstract. Of those, 128 articles were considered for full-text and 13 studies met the inclusion criteria and selected for the final review (Figure 1).

Figure 1

PRISMA (Preferred Reporting Elements for Systematic Review and Meta-Analysis) Study Flow Diagram



Data Extraction

From the includes articles, we extracted sample size, strategies that were compared, transition times between strategies, the criterion tests and the main results (mean and standard deviation) of sprint, jump and/or agility tasks performed. All

outcome data regarding explosive tasks were grouped and analyzed individually using Microsoft Excel 2017 spreadsheet (Microsoft, Redmond, WA, USA).

Data Analysis

Assessment of Risk of Bias. A bias is a systematic error, or deviation from the actual effect, in results or inferences. Assessed the risk of bias of each study against key criteria: Sequences Generation, Allocation concealment, Blinding of participants and personnel, Blinding of outcome assessment, Incomplete outcome data, Selective outcome reporting and Other sources of bias, in accordance with methods recommended by The Cochrane Collaboration. The following classifications were used: low risk, high risk and unclear risk (either lack of information or uncertainly regarding the potential for bias).

Risk of Bias in The Included Articles. In most investigations were randomized and used a crossover design (69%). For practical reasons, most studies didn´t adopt blinding design, but all made a between group comparison.

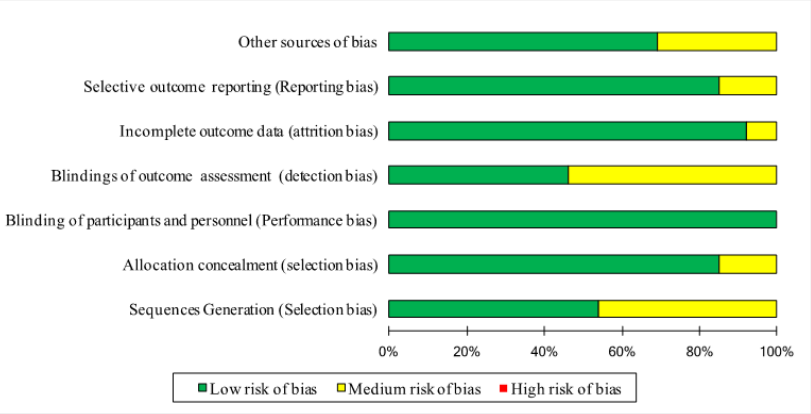
Table 2

Risk of Bias. Study Quality Assessment

Studies	Sequences Generation (Selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (Performance bias)	Blindings of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective outcome reporting (Reporting bias)	Other sources of bias
Beato, et al. (2019)	?	+	+	+	+	+	?
Bridgeman, et al. (2017)	+	+	+	?	+	+	+
Brink, et al. (2022)	+	+	+	+	+	+	+
Ciocca, et al. (2021)	+	+	+	+	+	+	?
de Keijzer, et al. (2020)	?	+	+	+	+	+	+
Dello Iacono & Seitz, (2018)	+	+	+	?	+	+	+
Godwin, et al. (2021)	+	+	+	+	?	+	+
Haris, et al. (2021)	?	+	+	?	+	+	?
Kobal, et al. (2019)	?	?	+	+	+	?	?
Mola, et al. (2014)	+	?	+	?	+	+	+
Sanchez-Sanchez, et al. (2018)	+	+	+	?	+	+	+
Spieszny, et al. (2022)	?	+	+	?	+	?	+
Zois, et al. (2011)	?	+	+	?	+	+	+

Figure 2

Risk-of-Bias Item Presented as Percentages Across all Included Studies



Results

Outcome Results

The results of the Post-Activation Potentiation on explosive tasks are shown in Table 3. Significant improvements had observed in CMJ, when the experimental groups perform a standard warm-up, which includes 5 min of running or cycling, dynamic mobility or dynamic stretching, and they also complement it with strength exercises, either concentric, eccentric or isometric strength.

When we talk about these exercises, we mainly focus on actions like CMJ or Long Jump (LJ). Also, we found little or no evidence for performance enhancement in CMJ or LJ.

However, the results that make up the actions such as Sprint, Agility or Deceleration (DCC), the groups that performed a standardized warm-up with strength exercises and actions similar to the main one, obtained significant differences in Sprint, Agility and DCC time. We also found that there are no significant differences between some PAP protocols or even that performance decreases over time for Sprint, Agility and DCC.

The present review aimed to analyze, from a qualitative and quantitative point of view, the findings provided in the literature regarding warm-up and strength training strategies for football players. The included articles identified substantial improvements in explosive activities (i.e., sprint, deceleration, jump...) using different warm up and strength strategies.

Although many studies have conducted, to date, no consensus has reached regarding an optimal strategy or protocol to apply in football. Of the 13 included articles, 8 showed an improvement in CMJ performance. Of the remaining articles, 4 didn´t study jumping performance, and a single study reduced performance.

Regarding the performance in the sprint, only 4 articles spoke of an improvement in performance, 2 of them reduced it and 5 articles studied other actions. To discuss performance in agility, only 2 articles found an increase in performance in these actions. The rest of the articles studied the performance of other different explosive actions, so there is no more data.

When we talking about the long jump, 2 articles showed an increase in performance when using a PAP strategy. The rest of the articles didn´t study the long jump. Only one article was found that presented a study on deceleration, showing that using the PAP strategy increases the performance of this factor.

Table 3

Results of Post-Activation Potentiation (PAP) on Explosive Performance in Football Players

Reference	Subjects	PAP Strategy	Rest	Main Outcome				
				CMJ	Sprint	Agility	Long Jump	DCC
Beato et al. (2019)	10 male amateur athletes Age: 22±2 years Height: 1.79±0.05 m BM: 73.2±8.0 kg	PAP (EOL): 10 min cycling + DM 3 min + 3 set x 6 reps HS Flywheel + CMJ-LJ-5m sprint PAP (TW): 10 min cycling + DM 3 min + 3 set x 6 reps HS Olympic Bar + CMJ-LJ-5m sprint	1 min 3 min 7 min	#EOL #TW at 3 and 7 min EOL = TW	#EOL #TW		#EOL #TW at 3 and 7 min EOL = TW	
Bridgeman et al. (2017)	12 strength trained athletes Age: 25.4#63.5 years Height: 177.2#64.5 cm BM: 84.0#10.1 kg	PAP1: SWU 5-min Cycling + 10 BW SQ + 3 CMJ + BM DJ + 3 CMJ´s PAP2: SWU + 10% BM DJ + 3 CMJ´s PAP3: SWU + 20% BM DJ + 3 CMJ´s PAP4: SWU + 30% BM DJ + 3 CMJ´s	2 min 6 min 12 min	PAP3 > PAP1 PAP3 > PAP2 PAP3 > PAP4 2 and 6 min > 12 min				
Brink et al. (2022)	69 professional soccer players Age: 24±5 years Height: 1.74±0.06 m BM: 69.2±9.8 kg	CG: 20 min WU + 6 vs 2 x 5 min + 2 x 20m sprint + 20 min AR + ~90s walking + 2 x 20m sprint PAP1: 20 min WU + 6 vs 2 x 5 min + 2 x 20m sprint + 20 min AR + 2 x >20m sprint + 2 x 20m sprint PAP2: 20 min WU + 6 vs 2 x 5 min + 2 x 20m sprint + 20 min AR + 3 set x 10 rep ALB 10% BM + 2 x 20m sprint	2 min 6 min		#PAP1#PAP2 #2 min#6 min			

Table 3 (cont.)

Results of Post-Activation Potentiation (PAP) on Explosive Performance in Football Players

Reference	Subjects	PAP Strategy	Rest	Main Outcome				
				CMJ	Sprint	Agility	Long Jump	DCC
Ciocca et al. (2021)	18 soccer players Age: 22±2 years	CG: 3 min jogging + 10 min DS + Sprint/ Deceleration 5 min + DT + Walking ~75s + DT PAP: 3 min jogging + 10 min DS + Sprint/ Deceleration 5 min + DT + 3 set x 10 rep ALB + DT	15s 2 min 4 min 8 min 12 min 16 min					#PAP 2 min
de Keijzer et al. (2020)	13 university soccer players Age: 20±1 years Height: 1.79±0.06 m BM: 72.1±7.8 kg	PAP1: 10 min cycling + 3 min DM + CMJ/LJ + 1 set x 6 rep EOL HS + CMJ/ LJ PAP2: 10 min cycling + 3 min DM + CMJ/LJ + 2 set x 6 rep EOL HS + CMJ/ LJ PAP3: 10 min cycling + 3 min DM + CMJ/LJ + 3 set x 6 rep EOL HS + CMJ/LJ	3 min 6 min	#PAP2 #PAP3 #6 min			#PAP2 #PAP3 #6 min	
Dello Iacono & Seitz (2018)	18 elite male soccer players Age: 19.3±0.2 years Height: 178.3±3.2 cm BM: 76.2±3.1 kg	85PAP: 4x20m sprint + 3 sets x 6 rep BHT (136 kg) + 20m Sprint PAP: 4x20m sprint + 3 sets x 8 rep BHT (100 kg) + 20m Sprint	15s 4 min 8 min		PAP > 85PAP 4 min >15s 8 min > 15s			

Table 3 (cont.)

Results of Post-Activation Potentiation (PAP) on Explosive Performance in Football Players

Reference	Subjects	PAP Strategy	Rest	Main Outcome				
				CMJ	Sprint	Agility	Long Jump	DCC
Godwin et al. (2021)	23 professional football players Age: 24±4.5 years Height: 178.26±7.62 cm BM: 80.21±8.4 kg	CG: 5 min cycling + 3 set DM + 3xCMJ + 2 min rest + 3xCMJ PAP1: 5 min cycling + 3 set DM + 3xCMJ + 3 set x EOL 20%BM + 3xCMJ PAP2: 5 min cycling + 3 set DM + 3xCMJ + 3 set x EOL 40%BM + 3xCMJ		#PAP1 #PAP2				
Haris et al. (2021)	20 university soccer players Age: 21.3±1.5 years Height: 169.8±6.4 m BM: 63.3±9.5 kg	PAP: 10 Body Weight Squat + 10 forward lunges + 3 min DS + 3xCMJ + 3x20m sprint + 3xAgility Test + 2 set x 10 ankle hops + 3 set x 5 hurdle hops + 5 DJ + 3xCMJ + 3x20m sprint + 3xAgility Test	1 min 5 min	#PAP 1 min and 5 min	#PAP 1 min and 5 min	#PAP 1 min and 5 min		
Kobal et al. (2019)	18 college athletes Age: 5.42±3.58 years Height: 75.17±7.35 cm BM: 8.84±10.63 kg	PAP1: 5 min running + 3 min DS + CMJ + 5 rep 50% CA + 3 set x 1RM + CMJ PAP2: 5 min running + 3 min DS + CMJ + 5 rep 50% CA + 3 set x 3RM + CMJ PAP3: 5 min running + 3 min DS + CMJ + 5 rep 50% CA + 3 set x 5RM + CMJ PAP4: 5 min running + 3 min DS + CMJ 5 rep 50% CA + 3 set x 6 rep 60% 1RM + CMJ	4 min	#PAP1 #PAP2 #PAP3 #PAP4				

Table 3 (cont.)

Results of Post-Activation Potentiation (PAP) on Explosive Performance in Football Players

Reference	Subjects	PAP Strategy	Rest	Main Outcome				
				CMJ	Sprint	Agility	Long Jump	DCC
Mola et al. (2014)	22 Professional football players Age: 23#4.5 years Height: 1.83#6.6 m BM: 80.9#7.8 kg	CG: SWU 5-min Cycling + 2-min DS + CMJ + 10-min + CMJ. PAP: SWU + CMJ + 3 sets 3RM SQ (3x75%, 2x90%, and 1x100%) + CMJ	15 s 4 min 8 min 12 min 16 min 20 min	CG > PAP CG > PAP 4, 8, 12, 16, 20 min. CG > PAP 15s. PAP 16 min > PAP 15s and 4, 8, 12, 20 min >				
Sanchez-Sanchez et al. (2018)	16 soccer players (8 National League and 8 Regional League) Age: NL 20.7±1.4 years RL 20.8±1.0 years Height: NL 177.4±5.2 cm RL 176.6±5.6 cm BM: NL 68.5±7.0 kg RL 68.7±4.0 kg	CG: 10 min 60% HR + DS PAP1: 10 min 60% HR + DS + 1 set #60% 1RM until PCV reduced #10% PAP2: 10 min 60% HR + DS + 1 set #90% 1 RM until PCV reduced #10%	5 min post PAP 20s between sprints		No Differences in PAP1 or PAP2 #PAP1 #PAP2 (NL/RL) PAP1 (NL) > PAP2 (RL)			
Spieszny et al. (2022)	31 handball and soccer players Age: 19±2 years Height: 179±5 cm BM: 76.6±11.5 kg	CG: 5 min cycling + 2 circuits x 10 rep + CMJ-SJ + ~6 min walking + CMJ-SJ PAP: 5 min cycling + 2 circuits x 10 rep + CMJ-SJ + 3 set x 3 rep IBS + CMJ-SJ + CMJ-SJ	4 min 8 min	#PAP#4 min#8 min				
Zois et al. (2011)	10 Amateur Football players Age: 23.3±2.5 years Height: 1.78±0.04 m BM: 69.1±4.1 kg	WU1: 5 min jogging + Performance Tests WU2: 5 min jogging + 3 sets 3vs3 SSG 2 min WU3: 5 min jogging + 5RM leg press 15s WU4: Team Sport WU 23 min (TS)	SSG: 2 min TS: 60s + 2x30s 4 min	#WU2 and WU3 > WU1 and WU4#WU3 #WU2	WU3 > WU1 WU3 > WU2 WU3 > WU4 #WU3 #WU2 #WU4	WU2 and WU3 > WU1 and WU4		

Increased value; # decreased value; = unchanged value. >indicates better performance. < indicates worst performance.
Abbreviations: BW, Body Mass; SQ, Squat; BW SQ, Body Weight Squat; SJ, Squat Jump; CMJ, Countermovement Jump; DS, Dynamic Stretching; SWU, Standardized Warm Up; CG, Control Group; SJH, Squat Jump Height; CMJH, Countermovement Jump Height; HJ, Hop Test; RL, Repeated Lunge; EMD, Electromechanical Delay; DL, Drop Landing; Ecc, Eccentric; CA, Conditioning Activity; DT, Deceleration test; ALB, Alternative Leg Bounds; AR, Active Recovery; IBS, Isometric Back Squat; LJ, Long Jump; TW, Traditional Weightlifting.

Discussion

The aim of this study was a systematic review to synthesize and analyze research findings on the effects of post-activation potentiation strategies on different explosive efforts in soccer. Athletes performing maximal strength, plyometric, eccentric, or isometric exercises enhance performance in explosive actions like sprinting, jumping, agility, and deceleration. Potentiation techniques with optimal rest times can improve jump height and length, and reduce sprint, agility, and deceleration times, thus enhancing athletic performance.

For sprint, agility, and deceleration, standardized warm-ups with strength exercises showed significant improvements. Some post-activation potentiation (PAP) protocols showed no significant differences, and performance may decrease over time.

Significant improvements in countermovement jump (CMJ) were observed with standard warm-ups including running or cycling, dynamic mobility, and strength exercises. However, evidence for performance enhancement in CMJ or long jump (LJ) is limited. Mola et al. (2014) in their research with 22 professional football players showed an increase in jump height after the PAP strategy in which the soccer players perform 3 sets of several repetitions of a 3RM squat, although it also shows an increase in performance in the control group. In the same way, it has also been shown that multisets (1-3) with a heavy weight are effective in inducing a PAP effect in college soccer players (Kobal et al., 2019). Performing other strength exercises such as the 5RM single leg press in amateur football players, increases vertical jump performance as long as we perform multisets (Zois et al., 2011). When we are talking about strength exercises, also talk about traditional weightlifting, which according to the literature increases performance in both the vertical jump and the long jump in amateur athletes (Beato et al., 2019).

Not only traditional weightlifting, according to the literature, increase the performance of explosive actions. Eccentric exercises also have been shown to get an influence on increasing performance in vertical and horizontal jump actions. However, the eccentric exercises reduce sprint performance, probably due to inadequate rest times or accumulated fatigue (Beato et al., 2019). Only Godwin et al. (2021) speaks of a decrease in performance in the vertical jump action, explaining as the main reason that the force-velocity profile for each football player wasn`t considered, this is individualized and important step for professional football players. Furthermore, another important reason is the relationship between peak power and the use of Type II muscle fibers, assuming that professional football players are highly trained and will have more of them. Both articles reported reductions of performance in some explosive action when using the PAP. With traditional exercises, EOL exercises have shown that performing more than 1 sets (1-3) increases jump performance in university soccer players (De Keijzer et al., 2020). As in traditional weightlifting exercises in which several sets are performed (Mola et al., 2014; Kobal et al., 2019; Zois et al., 2011), in the same way, eccentric exercises the performance is also increased.

There are other methods, including plyometric exercises, which indicate an increase in performance. In the case of the drop jump, depending on the optimal load used, it has great benefits when it comes to increasing the height in the jump, with 20% of the body weight being when the greatest increase occurs (Bridgeman et al., 2017). Performing sets of different weighted plyometric exercises also increases performance in jumping actions (Haris et al., 2021).

The use of isometric exercises, specifically doing 3 sets of 3 repetitions of back squats, increases performance in the vertical jump (Spieszny et al., 2022).

In order to increase the performance of actions related to running, as sprinting, agility or deceleration, the literature shows different methods that induce post-activation potentiation. Performing one set of 5RM leg press decreases sprint and agility time (Zois et al., 2011), just as performing different sets of BHT from 100 to 136 kg increases 20 m sprint performance (Dello Iacono & Seitz, 2018). However, performing several sets of traditional weightlifting exercises in amateur athletes increases the time to perform sprint and agility actions, reducing performance (Beato et al., 2019), which could be possibly explained by fatigue. Note that both peripheral fatigue (i.e., fatigue attributed to processes at or distal to the neuromuscular junction) and central fatigue (i.e., fatigue due to processes within the central nervous system) are significantly affected by training volume (Alix-Fages et al., 2022). Using a set of between 60% and 90% of the RM in the squat increases performance in sprints, but there aren´t enough differences between one load or another. However, it doesn´t increase performance much, as it may not have enough neuromuscular load to induce PAP, thus limiting the ability of the neuromuscular system to achieve a higher physiological functional state (Sanchez-Sanchez et al., 2018). In accordance with previous articles, performing 3 sets

between 6 to 8 repetitions of exercises such as the BHT with an optimal weight for each athlete, with loads between 100 to 136 kg and adding rest times between 4 and 8 min, increases sprint and agility performance (Dello Iacono & Seitz, 2018).

Plyometric exercises also have a great impact on increasing sprint and agility, especially by performing 2 sets of multi jumps (Haris et al., 2021). Only 1 study talks about the improvement in deceleration, through the use of plyometric exercises, specifically using 3 sets of 10 alternative single leg bounds (Ciocca et al., 2021). This can be a great study object for future research.

It is suggested that maximal sprint acceleration, specifically 2 sets of 20 m maximal intensity runs, may induce a PAP response in a subsequent maximal 10 m and 20 m sprint at 2 min and 6 min (Brink et al., 2022).

When talking about the rest time to increase performance after a PAP strategy, which we have previously seen in most studies increases the performance of these actions, there is a certain disparity with these times.

Normally, certain studies speak of different rest times, between 1 min and 20 min. Focusing on concentric or traditional strength exercises, rest times that increase performance in vertical and horizontal jump are 15s (Mola et al., 2014), but there is also scientific evidence that performance increases with rest times that exceed 2 min (Beato et al., 2019). Although, it isn´t stipulated, the maximal rest time where there is an improvement in jumping actions is usually around 6 min (Bridgeman et al., 2017; de Keijzer et al., 2020; Brink et al., 2022) or 8 min (Mola et al., 2014; Dello Iacono & Seitz, 2018; Spieszny et al., 2022).

Where the greatest improvement in jumping performance is found when recovery times range from 3 min to 8 min after strength exercises. Normally it is because the accumulated fatigue of the sets of maximum strength or sprints is regulated (Beato et al., 2019). This evidence also speaks of increases in the performance of actions such as sprinting, agility and deceleration, when rest times are 2 min (Haris et al., 2021), up to 7 min (Dello Iacono & Seitz, 2018).

Times below 2 min and above 8 min up to 20, have little evidence on increased performance. Rest time of approximately 15s don´t induce any improvement in this actions (Dello Iacono & Seitz, 2018). On the other hand, some studies with this rest times did induce improvements in explosive actions, with times between 15s and 1 min (Mola et al., 2014; Haris et al., 2021). Many authors indicate that this is due to excessive fatigue, when speaking of low rest times, or deactivation after the corresponding strength exercises, when referring to high rest times up to 8 to 20 min.

Conclusion

The results of the analysis of the scientific literature performed in this systematic review could translate into positive effects on short-term explosive performance. In Football, which require football players to sprint intermittently throughout the match, it is imperative that the “PAP” improves acute explosive performance.

So, to conclude, performing maximum strength exercises, optimal load and plyometric exercises during warm-up and before competitions, produce positive effects on jump, both vertical and horizontal, sprint, agility and deceleration. This effect could be very effective between 2 and 8 min after performing the exercises

Ethics Committee Statement

Not applicable as this is a systematic review.

Conflict of Interest Statement

There are no conflicts of interest.

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Authors' Contribution

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Data Availability Statement

Data availability is not applicable to this article as it is based on a systematic review of previously published studies.

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