MLS – SPORT RESEARCH (MLSSR)
https://www.mlsjournals.com/Sport-Research
ISSN: 2792-7156

(2024) MLS-Sport Research, 4(1), 7-18. doi.org/10.54716/mlssr.v4i1.1861.

SYSTEMATIC REVIEW: STRENGTH TRAINING BEFORE A FOOTBALL MATCH

REVISIÓN SISTEMÁTICA: ENTRENAMIENTO DE FUERZA PREVIO A UN PARTIDO DE FÚTBOL

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Manuscript information:

Received/Recibido: 22/02/2023
Reviewed/Revisado: 13/04/2023
Accepted/Aceptado: 23/05/2023

Keywords:
performance, PAP, strength, activation, neuromuscular, priming.

ABSTRACT

Football is a sport of cooperation-opposition, with high uncertainty and in which there are constantly high intensity actions such as jumps, changes of direction or contact with the opponent that demand a high level of physical performance from the player. In recent years, gym training has become an essential tool and it has been demonstrated that strength training before the start of a match offers improvements in the physical performance of the players thanks to the effect of post-activation potentiation (PAP). The aim of the present review was to test which strength training protocols maximize the effect of PAP. A search for articles was carried out in the PubMed database, finding 144 articles which, once filtered according to the inclusion criteria, were reduced to 13. The guidelines for the design of reviews established by PRISMA were maintained. The results show that for most authors strength training, with protocols with concentric, eccentric or plyometric exercises, in all planes of movement, with low volume and at high intensities (±85%1RM) in conventional training or maximum in the case of plyometric exercises, with a test rest of between 5 to 10 minutes, could be beneficial for subsequent performance in a soccer match. It was concluded that there are differential aspects such as that not all people will respond in the same way to the same PAP protocol, being determinant the age or previous experience in strength training.

RESUMEN

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Palabras clave:
rendimiento, PAP, fuerza, activación neuromuscular.

El fútbol es un deporte de cooperación-oposición, con elevada incertidumbre y en el que se dan constantemente acciones de alta intensidad que demandan al futbolista un elevado nivel de rendimiento físico. El trabajo en el gimnasio se ha convertido en los últimos años en una herramienta imprescindible y se ha demostrado que un entrenamiento de fuerza antes del inicio de un partido ofrece mejoras en el rendimiento condicional del futbolista gracias al efecto de potenciación post-activación (PAP). El objetivo del presente trabajo de revisión fue comprobar qué protocolos de entrenamientos de fuerza maximizan el efecto de la PAP. Se realizó una búsqueda de artículos en PubMed, encontrando 144 artículos que, una vez filtrados en base a los criterios de inclusión, se redujeron a 13. Fueron mantenidas las directrices para el diseño de revisiones establecidas por PRISMA. Los resultados muestran que para la mayoría de los autores el entrenamiento de fuerza, con protocolos con ejercicios tanto concéntricos, como excéntricos o pliométricos, en todos los planos del movimiento, con un volumen bajo y a altas intensidades (±85%1RM) en el entrenamiento convencional o máximas si se trata de ejercicios pliométricos, con un descanso a la prueba de entre 5 y 10 minutos, podría ser beneficioso para el rendimiento posterior en un partido de fútbol. Se concluyó que existen aspectos diferenciales como que no todas las personas responderán igual ante un mismo protocolo de PAP, siendo determinantes la edad o la experiencia previa en el entrenamiento de fuerza.

Introduction

Soccer is a socio-motor sport of cooperation-opposition, with high uncertainty that takes place in a space standardized by the international soccer federation (FIFA) of 90-120 meters long by 45-90 meters wide, and must have rectangular geometry (The International Football Association Board, 2021). It is an acyclic sport in which the participation of both teams is simultaneous, which requires open skills and high intensity intermittent actions (Poch, 2008). During the development of the match, players, without a pre-established order, run at different intensities, jump, dribble, dive to the ground and receive contact from opposing players (Castellano & Casamichana, 2016). All of this means that the player must constantly adapt to new situations, changing realities and a diversity of stimuli.

The demands of competition require players to perform actions of high intensity and very short durations. Beyond the total distance covered, the physical performance that a player can give in a soccer match is determined through efforts at high intensity (Stølen et al., 2005). To do so, players must have high levels of speed, endurance, the ability to repeat high intensity efforts, strength and power. (Turner et al, 2011). In terms of external loading, during a soccer match, players travel a total distance of about 10-11 km (Dellal et al., 2011) (Taylor et al., 2017) (Reynolds et al., 2021), of which between 225 m and 335 m are sprinting (> 24km/h) (Dellal et al., 2011) (Barnes et al., 2020), reaching about 500 accelerations and decelerations (≥1.5 $\frac{m}{s^2}$) (Altmann et al., 2021).

Regarding the internal load, due to the characteristics of soccer, the aerobic and anaerobic energy systems are requested together (Bangsbo et al., 2006). To assess such load, physiological parameters can be considered such as heart rate, which ranges between 150 and 190 bpm or 80-90% of the maximum heart rate of athletes (Suarez-Arrones et al., 2015) (Stølen et al., 2005), blood lactate concentration, with values ranging from 3 Mmol/l to more than 10 Mmol/l in the different phases of the match (Stølen et al., 2005) or the percentage of maximal oxygen consumption (VO2Max), which can vary from 50-55 ml/kg/min to 60-65 ml/kg/min in professional soccer players (Hoff, 2005).

With the objective of achieving to prepare the soccer player for the demands of competition, one of the training models currently used in soccer is the structured microcycle (Seirulo Vargas, 2017), in which a microcycle organization methodology is used that allows optimizing the player's training loads (Martín-García et al., 2018). This microcycle bases the periodization of the training contents on the "macth day" (MD), i.e., on when the last game was played and when the next game will be played. In this way, it allows to include simultaneously the work of the conditional aspect as well as the technical, tactical and psychological aspects. Based on a standard 7-day microcycle, the training schedule will be as follows: the day after the match (MD+1), the group will be divided in two, differentiating between players who played more than 60 minutes, who will do regenerative work to eliminate fatigue, and players who played less than 60 minutes, who will do compensatory work to simulate the load of the match. Day MD+2 will be the rest day. From here, the acquisition block begins, which will comprise the MD-4 and MD-3 days (4 and 3 days before the next game respectively) and will be the two most demanding sessions of the week that will aim to provoke new adaptations in the player. Finally, days MD-2 and MD-1 (2 and 1 days before the next match) will belong to the tapering block in which the aim will be to eliminate fatigue in order to arrive at the match in an optimal state (Seirulo Vargas, 2017) (Martín-García et al., 2018).

The implementation of a well-planned and programmed strength training program can improve the performance of players during the match, since it has been

shown that benefits are obtained in several of the conditional actions that are most important in achieving optimal performance in a match: jumps, changes of direction, accelerations or sprints (Loturco et al., 2020) (Fiorilli et al., 2020) (Styles et al., 2016) (Thapa et al., 2021), as well as helping in injury prevention (Biz et al., 2021) (Beato et al., 2021). Thus, strength training should be oriented to the physical abilities and motor patterns that the sport itself will demand from the soccer player, there being a term called "adjuvant training" that refers to training tasks that are further away from the reality of competition but that prepare the soccer player to be able to assimilate the training loads in the best possible way (Gómez et al., 2019). On the other hand, it should be taken into account that the fatigue produced by this type of training in the days prior to the competition can affect the player both mentally, worsening the speed and quality of decision-making and positioning on the field, and physically, reducing the player's ability to make high-intensity efforts (Coutinho et al., 2018), so it is necessary to place this type of work far enough away from the competition to allow eliminating the fatigue it brings completely.

Furthermore, in relation to strength work, in recent years the concept of post-activation potentiation (PAP) has emerged, which is defined as a transient increase in muscle strength after previous contractile activity (Biz et al., 2021), i.e., improvements in sports performance can be obtained after performing strength work. The supposed improvement in performance after performing strength training seems to be given by the contractile history, but as discussed above, fatigue must be taken into account, which can be counterproductive and not allow PAP to be achieved (Picón-Martínez et al., 2019).

Because the physiological mechanisms are still partly unknown, how to obtain such an ideal or optimal contraction is a matter of debate and requires further research. Despite this, two possible responsible mechanisms have been highlighted (Picón-Martínez et al., 2019):

a) Phosphorylation of myosin light chains, because they make the actin-myosin interaction more sensitive to calcium release from the sarcoplasmic reticulum.

b) Increased motor neuron excitability, as evidenced by the amplitude of the H reflex.

Previous studies expose that the effect of PAP varies depending on the characteristics of each individual (Sánchez-Sánchez et al., 2018). There are also articles that support delayed PAP, taking effect even more than 24h after training (González-García et al., 2020). Since enhancing the physical performance of soccer players during competition is desirable for any coaching staff, the aim of the present study was to test which strength training protocols maximize the effect of PAP before playing a soccer match.

Method

An exhaustive search was carried out in the search engines "Pubmed" and "Google Scholar" using keywords such as "PAP", "Soccer", "Neuromuscular", "professional" or "resistance training", combining them with the Boolean operators "AND", "OR" and "NOT".

To perform this search, the following combinations were entered into the search engine: "PAP" AND "soccer", "post-activation potentiation" AND "soccer", "neuromuscular" AND "PAP" AND "soccer", "activation" AND "PAP" AND "soccer", "resistence training" AND "PAP" AND "soccer", "training" AND "PAP" AND "soccer", "PAP"

AND "performance" AND "soccer", "resistance training" AND "PAP" AND "performance" AND "soccer", "PAP" AND "recovery" AND "performance" AND "soccer", "Post-Activation Potentiation" AND "resistence training" y "Post-Activation Performance Enhancement" AND "soccer". Inclusion criteria were that the strength training was performed the day before the match. During the selection process, articles written in both English and Spanish were selected.

Original research articles were accepted. In addition, several articles found through other secondary methods were also useful.

Results

Figure 1 shows the articles selected for review:

Figure 1
Flow chart of the literature review.

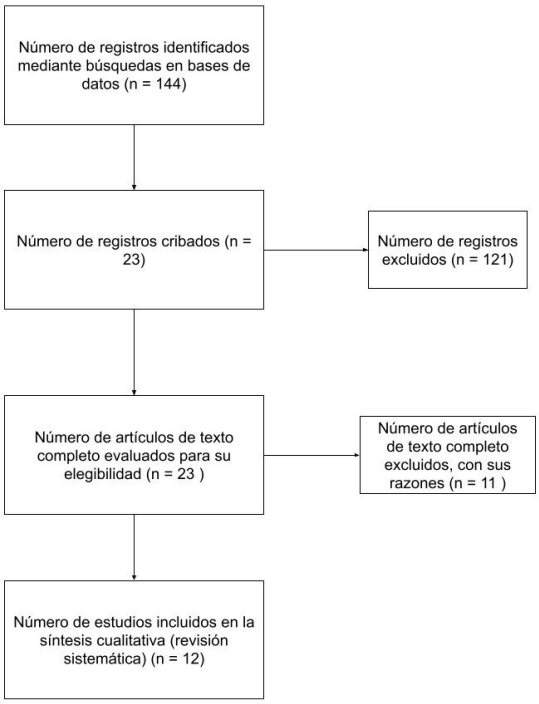

Table 1 shows a summary of the results of the selected articles:

Table 1
Summary of results

Article	Population	Exercise	Volume	Intensity	Rest to the test	Results
Beato et al. (2021)	31 male amateur soccer players	Inertial-Conic Cross-Cutting Step/ Flywheel Leg Extension/Squat Exercise	4x6 each leg/4x6 each leg/4x6 each leg	Maximum	No data	Significant improvements in COD with the dominant and non-dominant leg 4 minutes after INC, EXT and Squat
Cioca et al (2021)	18 college men's soccer players	Plyometry	3x10	Maxima	15 s, 2, 4, 8, 8, 12 and 16 min	Improvements at 2min in PAPE protocol, but no significant differences with control group
Guerra et al (2020)	24 professional soccer players	Ankle hops/hurdle hops/20m ballasted sprint	2x15/3x5/3 series	Max/Max/15% BW	1, 3 and 5 min	Plyometrics in combination with resisted sprinting improves vertical jump performance in professional soccer players
Iacono & Seitz (2018)	18 elite male players	Barbell Hip Thrust	3 x 6	85% 1RM	15s, 4 min and 8 min	Significant differences in the 3 distances
Keijzer at al (2020)	13 college men's soccer players	EOL Half Squat	1, 2 or 3 series x 6 reps	Incertia: 0.0011 kg-m2	3 and 6 min	1º: The effects are only seen in the PAP with more than one series. 2º: More effective with 6 minutes rest
Köklü et al (2022)	12 young players (17 years old)	Squat	3 reps	90%1RM	1, 2, 3 and 4 min	The study concludes that the improvement in both CMJ and sprinting was greater when the rest was 4 minutes. It is also observed that with the 4 different rest times, the marks of the no-load protocol were improved.
Mola et al. (2014)	22 professional male soccer players	Squat	3 reps	3RM	4, 8, 12, 16 and 20 min	First, a series of 3RM squats did not acutely improve the CMJ performance of all experimental

						participants through PAP, although there are both responders and non-responders to PAP. Second, the time constant of PAP elicited by responders differed among these individuals
Nealer (2017)	11 recreational girls soccer players, 13 collegiate girls soccer players	Assisted Sprint	20 m	30% BW	30s, 1min, 2min or 4min	Improvements in all distances, both trained and untrained
Nickerson et al (2018)	12 NCAA Division II men's players	Back Squat	1x3	85%1RM	1, 4, 7, and 10 min	Improved times in 20m. The fastest sprint was 10m later using the Cluster-30s.
Petisco et al (2019)	10 professional male soccer players	Back Squat	1x10, 1x5, 1x1	60%1RM, 80%1RM, 100%1RM	5min, 6min, 8min	Better performance at 80%1RM
Sanchez-Sanchez et al (2018)	8 national category players, 8 regional category players	Multipower Squat	Loss of speed 10%	60% 1RM/90 % 1RM	5 min	No improvement in the sprint with either PAP protocol. Better performance at the national level than at the regional level.
Till & Cooke (2009)	12 professional college soccer players	DeadLift/Double-legged tuck jump/MVC knee extensions	5 rep/5 rep/3 reps of 3s	5RM/Max/Maximum/Maximum	4, 5 and 6 min/7, 8 and 9 min	It finds no differences between the different PAP methods. Sprint performance and CMJ performance improved 7 minutes after the deadlift and Double-legged tuck jump, showing a positive effect on subsequent performance.
Willims et al (2021)	9 male and 6 female high school soccer players (16-18 years old)	Ballasted sprint	3 reps	40-50%Vdec	2 min	Weighted sprints with a weight that causes the loss of speed to be between 40 and 50% cause the time in a 15m sprint to drop. Only 2 athletes increased their time, both of them girls.

Note: BW: Body Weight; RM: Maximum repetition; Vdec: Loss of speed; MVC: Maximum Voluntary Contraction; EOL: Eccentric overload; INC: Inertial Conic Cross; EXT: Leg Extension; Min: Minutes; Reps: Repetitions; s: Seconds

Discussion and conclusions

Throughout the present work, an investigation focused on strength training before a soccer match as a means to achieve Post-Activation Potentation has been carried out, using the 13 articles shown in Table 1 as a theoretical framework.

Sánchez-Sánchez et. al. (2020), Petisco et. al. (2019), Nickerson et al (2018), Mola et. al. (2014), Köklü et. al. (2022), & Beato et. al. (2019) did the PAP protocol with both front and back squat on multipower and free weights. While Petisco et. al. (2019), Nickerson et. al. (2018) and Köklü et. al. (2022) found improvements in all subjects after performing this protocol, it was found that Mola et. al. (2014) does not find benefits in all participants. On the other hand, we can observe how the protocol proposed by Sánchez-Sánchez et. al. (2021) concluded that there was no improvement in any of the subjects. None of the investigations using Squat as an exercise to achieve PAP show changes in the application of the protocol, beyond the age and level of the soccer players, but there is no relationship between this level or age and the improvement of the results after strength training. This is in contrast to Petrella (1989) and Vandervoort & McComas (2002), who argue that age does determine the level of PAP, with younger athletes responding better than older athletes.

Regarding the force vectors, all the authors who worked on the horizontal vector (Hip Thrust or ballasted Sprint) agree that they obtained positive results in their respective tests. On the other hand, the studies that performed work on the vertical vector (Squat or DeadLift) also obtained the same positive result, with the exception of Mola et. al. (2014), where not all subjects improved after the PAP protocol and Sánchez-Sánchez et. al. (2018), where the marks were not improved. These results may be due to the fact that, during running, jumps or changes of direction, both horizontal and vertical forces are exerted, so the introduction of work in both vectors, benefits performance in the 3 types of tests (González-García et. al., 2019).

In terms of intensity, we must differentiate between protocols that were based on concentric strength exercises, those based on drags or those that involved eccentric or plyometric work. In the former, working at submaximal intensities positive results were found, but the greatest improvements were at 1RM percentages between 80%1RM and 85%1RM (Iacono & Seita, 2018; Petisco et. al., 2017). In this regard, we can see how Sánchez-Sánchez et. al. (2018), performed the PAP protocol with Squat, using as indicative to determine the volume, the loss of 10% speed in the series. According to González-García et. al. (2019), a 10% loss of speed is considered light work. This may result in not reaching sufficient activation level to find the PAP. However, if the work to be performed is plyometric or eccentric, all agree that the intensity should be maximum. (Beato et. al, 2021; Till & Cooke, 2009). Drag-based protocols differentiate between two ways of expressing work intensity: % body weight (Nealer, 2017) and % speed loss (Williams et. al., 2021). In both cases, the result was positive. The coincidence of all these authors is based on Picón-Martínez et. al. (2019): the work to be done to achieve PAP has to be at or very close to maximum intensities.

In reference to plyometric training, Till & Cooke (2009) and Guerra et. al. (2020) agree that their PAP protocols were able to improve the performance of soccer players if performed in conjunction with traditional methods, while the authors who based the PAP protocol on concentric strength training, Petisco et. al. (2020) and Beato et. al. (2021), did

not have to incorporate plyometric work to obtain the performance improvements. This may be due to the fact that, by using the method of contrasts or concentric training with loads in which power is worked, we will be in an optimal zone of the strength-velocity curve for the achievement of PAP than if only plyometric work is done, which is more oriented to speed.

One of the limitations found in the studies analyzed is that soccer is a multicomponent sport, where players' performance cannot be reflected by isolated and linear tests such as the CMJ (Guerra et. al., 2020) or Linear Sprint (Nickerson et. al., 2018). In addition to the above, the non-homogeneity of protocols, tests and the different participants selected for study, make the results obtained not easily comparable, and if this were corrected, more significant and binding results could be achieved. For this reason, the scientific community is encouraged to continue along this line of research, matching and improving the different protocols and tests in the following research proposals.

The objective of the present review was to test which loads maximize the effect of PAP before playing a soccer match. After analysis and comparison of the articles included in the study, the authors found the following conclusions:

1. Within the protocols that use concentric exercises, loads of 80-85% of 1RM are those that show the greatest post-activation potentiation effects.
2. Both eccentric and plyometric exercises require maximum intensities to achieve the greatest possible post-activation potentiation effects.
3. The volume with which the authors who find improvements in performance after a strength protocol work is 2 to 4 sets of 6 repetitions for eccentric exercises and 1 to 3 sets of 3 to 10 repetitions with concentric exercises.
4. Times between 4 and 7 minutes from the end of the strength protocol and the start of the test are shown to be the most effective in maximizing PAP, provided concentric or eccentric exercises are used.

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